Oil Prices and Stock Prices of Alternative Energy Companies: Time Varying Relationship with Recent Evidence

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Abstract

This paper examines the recent interactive relationships between crude oil prices and stock performances of alternative energy companies. The examination was conducted from 2001 to mid 2010, and the sample period is divided into three sub-periods according to two Middle East wars. Different dynamics of oil prices across these sub-periods are significantly documented for the first time. By method of vector autoregression model, oil prices and stock indices of alternative energy sector were found independent from each other only before late 2006. In the recent years, oil prices become significantly responsible for the stock performances of alternative energy companies. This finding suggests that the stock market investors of alternative energy sector incorporate oil price shocks into their trading decisions only recently. The oil prices and stock index of oil companies also found to be interdependent with each other during recent years.

Keywords: Crude oil price; Alternative energy; Oil stock index; VAR

JEL Classifications: Q43; P28; G10

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1. Introduction

Oil is the primary energy source in modern economies. For example, the average daily global consumption of crude oil in 2008 was 8.5 billion in US dollar, which was higher than any other type of energy.[1] However, recently, the development of alternative energy has gained immense popularity because of the recognition of environmental protection and political instability of oil export countries (e.g., Bleischwitz and Fuhrmann, 2006; McDowall and Eames, 2006). Therefore, the relationship between oil price and alternative energy industry in recent years requires close examination.

Henriques and Sadorsky (2008) found that oil prices and stock prices of alternative energy companies do not interact with each other, where the trend of alternative energy stock index is significantly linked with that of technology stock prices. Choi and Hammoudeh (2009) showed that oil prices are better modeled with the nonlinear ARFIMA and structural breaks have partially reduced the persistence of oil price returns. Chiou and Lee (2009) documented significant structural change in recent oil price and showed that the impacts from oil to stock prices are dynamical and asymmetrical. This study extends this line of research and focuses on the recent interaction between oil prices and financial performances of alternative energy companies in recent years. The stock performances of oil industry are also considered to interact with the two variables, where prior studies suggested their significant relations (Osmundsen, et al. 2006). In addition, since oil prices have fluctuated significantly in recent years and have been affected by the two Middle East wars (i.e., the Iraq and Lebanon Wars), the empirical examination of this research is applied with three different time segments according to the period of said wars.[2] Our findings show that oil prices apparently behaved differently across these sub-periods, as well as the inter-relationships between oil prices, stock prices of alternative energy companies, and stock prices of oil industry. This paper also finds that owing to the recent developments and attentions of green energy, and oil price had its most volatile state in history;[3] the stock prices of alternative energy companies become depending on crude oil price dynamics.

This study differs with previous studies in several aspects. One, it provides the first

[1] Statistical Review of World Energy (June 2009), the British Petroleum Corporation

[2] Detailed description of time period segmentation is provided in Section 3. The trend of oil price and summary statistics of oil price for the entire sample period, as well as for the three sub-periods, can be found in Figure 1 and Table 2.

[3] During this period, the oil price of West Texas Intermediate (WTI) reached its highest in history at $143.74 in July 2, 2008 and dropped to $32.94 in December 24, 2008. In September 30, 2009, the WTI bounced back to $66.56. Data are extracted from the Thomson Datastream database.

empirical examination on the interactive relationships between oil prices, stock performance of alternative energy firms, and stock performances of oil companies covering the recent period of economic recession. Two, this study shows apparent different dynamics of oil prices before and after the two Middle East wars. Three, consistent with previous studies, this paper shows that the interactions between oil prices and stock prices of alternative energy firms are insignificant prior to the Lebanon War in 2006; however, they become significant after 2006. These findings, the first in literature, should be of use to investors and policy makers.

The rest of the paper is organized as follows: Section 2 reviews literatures; Section 3 discusses the methodology and data; Section 4 presents the empirical outcomes; and the last section concludes the research.

2. Literature Review

Since the Industrial Revolution, the impacts of crude oil production on global economy have been highly significant. Hamilton (1983) and Gisser and Goodwin (1986) showed significant negative effects of oil shock on macroeconomic conditions. Sadorsky (1999) found significant impacts on economic activities from oil price shock and concluded that oil price movement is an important explanatory factor to stock return. Balke et al. (2002) studied asymmetric effects of oil shocks on US economic activities. Jones et al. (2004) examined empirical relationships between oil price shocks and macroeconomic variables. Nandha and Faff (2008) further documented the complexities of crude oil price, and their results showed that oil derivatives generated wider effects on economic conditions than expected.

In particular, many prior studies have confirmed the significant and direct relationship between oil price and stock performance of oil companies. Huang et al. (1996) found significant interactions between oil price and stock returns of major US oil companies during 1980s under the framework of vector autoregressive (VAR) model, as well as insignificant relationships between oil price and the S&P500 index return. Sadorsky (2001) documented oil price as a major risk factor in stock returns of Canadian oil and natural gas companies using a multifactor market model. In addition to oil price, Boyer and Filion (2007) further showed that reserves of oil, volume of oil production, and drilling success rate also serve as key factors in explaining the stock prices of Canadian energy companies. Cong et al. (2008)

provided evidence of the significant impacts of oil shocks on the stock returns of oil companies, and they also found that higher oil price volatility contributed to positive returns of mining and petrochemical stock indices.

The economic development triggered by oil production has generated intense impacts on the global environment. Glick (2004) showed a significant increase of the atmospheric CO_2 concentration from 275 to 375 ppm during the past 140 years, where CO_2 concentration had remained unchanged for the previous 1,000 years. Duncan (2006) argued that higher atmospheric CO_2 concentration is one major cause of global warming, and discussed the possibility of reducing carbon emission by excising carbon tax. In addition to recent oil price jumps, the understanding of environmental protection significantly contributes to the development of alternative energy in recent years. In 1980, the global consumption of alternative energy was 1,753 billion kWh; in 2007, such consumption reached 3,472 billion kWh, a 98% increase.[4] The US Economic Report of the President in 2006 concluded,

"*In the long run, households and businesses respond to higher fuel prices by cutting consumption, purchasing products that are more efficient, and switching to alternative energy sources. Higher energy prices also encourage entrepreneurs to invest in the research and development of new energy-conserving technologies and alternative fuels, further expanding the opportunities available to households and businesses to reduce energy use and switch to low-cost sources*…"

While high oil price has allowed the use of alternative energy to receive great deal of attention, larger oil price volatility creates greater challenges for oil-related analyses. Basher and Sadorsky (2006) showed that different levels of oil price volatility would result in various impacts on economic activities and stock markets, and Kilian (2009) argued that the global demand shocks contribute to higher oil price volatility. Aguilera et al. (2009) provided evidences showing that petroleum resources are likely to last longer than oil market expectation, where the idea of depletion needed not drive the oil prices at their high levels during 2007-2008. Moreover, since many major oil-exporting countries are Middle East sovereign states, the instabilities or conflicts in the region have created significant impacts on oil prices.[5] For instance, the WTI jumped by 86% from $16.10 to approximately $30 immediately after the occupation of Kuwait by Iraq in 1990.

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[4] Data source: Energy Information Administration (EIA).

[5] The Middle East region holds 60% of global oil reserve and 32% of current oil production. Data source: Energy Information Administration (EIA), http://www.eia.doe.gov/. See the article, "As the price of oil soars, so does its power to shape politics from Washington to Beijing," (*New York Times*, July 25, 2006), http://www.nytimes.com/2006/07/25/world/middleeast/25oil.html.

Figure 1 illustrates the oil price of West Texas Intermediate (WTI) between January 2001 and May 2010. The two shaded areas indicate the periods of Iraq and Lebanon Wars. The figure shows that the WTI oil price before the 2002 Iraq War was generally stable between $20 and $40. However, after the Iraq War, the change in oil price showed a significantly upward and stable trend, reaching nearly $80. After the Lebanon War of 2006, a small drop of oil price was first observed, followed by a dramatic jump up to more than $140 within two years. The price then crashed below $40 in late 2008; such severely volatile oil price confirmed the recent structural changes in oil price dynamics (Chiou and Lee, 2009). The summary statistics of oil price between these three periods are provided in Table 1. These statistics are discussed in detail in the next section, confirming the observations in Figure 1.

3. Methodology and Data

3.1 Vector Error Correction Model

This study adopts the VAR or vector error correction model (VECM) by Johansen (1991) in order to examine the interdependencies between crude oil prices, stock index of alternative energy companies, and stock index of oil industry. Kilian (2010) applied VAR to investigate the relationship between gasoline price in the US and crude oil prices. VAR or VECM are maximum likelihood estimation model allowing full information to be diagnosed in a single stage of regression. Maysami and Koh (2000) documented the reliability of the VECM, and many prior studies have commonly adopted the method in analyzing the dynamics of economic and financial time series (Enders, 2004). VECM can be shown as

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_j \Delta X_{t-j} + \alpha\beta' X_{t-k} + \mu + \varepsilon_t \,, \tag{1}$$

where variable X_t is an n vector of endogenous variables with same order of integration; Δ represents the first difference; k shows the lag length; Γ_j is an $n \times n$ matrix of coefficients to be estimated; and μ and ε_t are the intercept vector and *i.i.d.* error term, respectively. In addition, α is an $n \times r$ matrix showing the speed of correction and β is the cointegrated matrix.

VECM can be seen as a first-difference version of VAR model and is applied when each variable of regression is integrated with an order of 1. Therefore, prior to the application of VAR or VECM, proper tests of stationarity and cointegration must be conducted. In this

study, both Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests are used for test of stationarity, and the Johansen cointegration test is applied to investigate if the target I(1) variables exhibited long-term relationships. Under the Johansen test, both trace and maximum eigenvalue statistics are composed.[6] In addition, under the framework of VAR/VECM, the Granger Causality test is also conducted to evaluate the empirical outcomes.[7]

3.2 Data

Three oil price series are used in this study: the spot prices of West Texas Intermediate (WTI), spot prices of Brent (Brent), and NYMEX Crude Futures (Futures). The first two spot prices of oil have been widely applied in literature (e.g., Hammoudeh et al., 2004; El-Sharif et al., 2005; Scholtens and Wang, 2008; and Cong et al., 2008). Sadorsky (2001) and Scholtens and Wang (2008) argued that futures price of oil better reflects the value of crude oil because spot prices can easily be driven by short-term supply-demand shocks. Following Huang et al. (1996) and Hammoudeh and Li (2005), the NYMEX futures price of oil is adopted in this study.

Following Henriques and Sadorsky (2008), the WilderHill Clean Energy Index (ECO) is applied to represent the stock performance of alternative energy companies. The ECO index is the first stock index to focus on clean energy-related firms. All the components of the index must have at least one business concentration that produces or develops environmentally friendly energy.[8] Following Sadorsky (2008), the crude oil stock index of American Stock Exchange is used to proxy the financial performance of oil companies, where the index is comprised of the stock prices of 12 global oil companies.

The data period spans January 3, 2001 to May 31, 2010, and all data are extracted from the Thomson Datastream database. Weekly data are comprised from original daily frequencies, using the Wednesday price to avoid holidays. In case of holiday falling on a Wednesday, Thursday data are used. The two wars that separate the sample period are the Iraq War (a.k.a. the Second Gulf War) in March 2003 and the Lebanon War (a.k.a. the Israel-Hezbollah War) in July 2006. In order to avoid extreme volatile movements of oil

[6] See Johansen (1988) and Johansen and Juselins (1990) for detailed descriptions.
[7] See Granger (1969) for details.
[8] There are currently 40 components covered in ECO index, composed according to US dollar. Detailed descriptions of the index are shown at www.wilderhill.com.

prices during the two Middle East wars, a four-month period during the war is omitted from the empirical application.

Table 1 provides summary statistics for the variables of both spot prices of oil, WTI and Brent, futures price of oil (Futures), ECO index, and the stock index of oil industry (Oil index). The statistics are shown for the entire sample period, as well as the three sub-periods. The statistics for the spot prices and futures price of crude oil are close, with similar mean, median, standard deviation, skewness, and kurtosis across periods. When the statistics of oil prices across time periods are compared, using WTI as an example, the standard deviations are 4.01, 13.54, and 23.41 for Periods I, II, and III, respectively, with coefficients of variation (CVs) of 0.15, 0.28, and 0.30 respectively for the three sub-periods. Moreover, the differences between maximum and minimum of WTI are 19.58, 46.02, and 110.80 for Periods I, II, and III, respectively. Such statistics show the volatilities and ranges of oil prices increase from Periods I to III. In addition, the skewness of WTI is -0.04, 0.14, and 0.77 for Period I, II, and III, respectively, implying that the price structures of oil are different across the three periods. In sum, we can see that the oil prices are relatively stable in Period I (lowest CV), grows gradually in Period II (skewed to the right), and fluctuates most strongly in Period III (highest CV and range). This observation is consistent with Figure 1.

The ECO index also exhibits different dynamics across the sub-periods. For example, the CVs of the index are 0.30, 0.19, and 0.38 with skewness of 0.16, 0.79, and 0.05 for Periods I, II, and III, respectively. Such trend shows that the alternative energy stock index is least volatile in Period II but yet most skewed. In addition to observation where the kurtosis of the ECO index also apparently differs across the three sub-periods, these statistics imply that price behaviors for alternative energy stocks vary through time. The Oil index seems to have an inverse trend of CVs compared to ECO index with the CVs of 0.09, 0.29, and 0.18 for Periods I, II, and III, respectively. Contrary to the oil price, the volatility of Oil index is at its highest in Period II, rather than Period III.

4. Empirical Results

We first investigate the levels of correlation between the oil prices, alternative energy stock, and oil stock to understand their simple linear relationships. We then conduct unit root and cointegration tests for these time series and provide key results based on VAR/VECM applications.

Table 2 presents the correlation analysis between three variables: oil prices, stock index of alternative energy companies, and stock index of oil industry. During the full sample period from January 2001 to May 2010, the correlations between stock index of alternative energy companies (ECO) and the three oil prices, WTI, Brent, and Futures, are 0.3470, 0.3529, and 0.3464, respectively, and the correlation between the ECO index and Oil index is 0.4848. At the same time, the correlations between Oil index and the three oil prices, WTI, Brent, and Futures, are 0.9025, 0.9172, and 0.9036, respectively.

When exploring the correlations in further detail according to sub-periods, for Period I (pre-Iraq War), the correlations between ECO index and the three oil prices, WTI, Brent, and Futures, are -0.2240, -0.1748, and -0.2242, respectively. Likewise, for Period I, the correlations between Oil index and the three oil prices, WTI, Brent, and Futures, are -0.2623, -0.1698, and -0.2591, respectively. These correlation coefficients are significantly different from the ones in Periods II and III where the correlations turn positive. The coefficients between stock indices of oil and ECO indices for Periods I, II, and III are 0.8141, 0.8212, and 0.9236, respectively, showing a closer relation between the two variables over time. Oil index and the three oil prices, WTI, Brent, and Futures, are highly correlated in Period II, with the correlations as 0.9759, 0.9776, and 0.9769, respectively. In general, based on Table 2, the correlations between oil prices and ECO index are smallest in Period I and strongest in Period II; this is also true for the relationships between oil prices and Oil index. In contrast, the relationship between Oil index and ECO index becomes tighter from Period I to III.

Table 3 presents the unit root test result for all data series by both ADF and PP statistics. None of the tests is able to reject the null hypothesis of unit root process for all series in level, while all tests confirm stationarity for the first differences of the sample series. The results show that all variables are integrated to an order of 1 during the entire sample period and the sub-periods. Table 4 presents the cointegration test result based on Johansen statistics. Between ECO index and oil prices, regardless which sample periods being examined, the results are not able to reject the null hypothesis of no cointegrarted vector. Therefore, these two series do not have statistically significant long-term relations. However, between Oil index and the oil prices, only for Periods II and III, the trace statistics exceed the 5% significance threshold implying that they are cointegrated during these time periods. The results of Table 4 suggest that long-term relationships between the targeted variables differ across periods, requiring different processes of investigation on their interdependencies.

Table 5 presents the VAR/VECM and Granger Causality results. Since oil prices and the ECO index are both I(1) and not statistically cointegrated, VAR is applied on their first

differences to determine their interactive relationships. The cointegrated series (between oil prices and Oil index in Periods II and III) are applied with VECM. Granger Causality test is used for robustness check. The optimal lag length is one, which is selected based on SBC for all pair of tests, which is consistent to prior empirical studies using weekly data. The first and second columns of the table are the left-hand-side and right-hand-side variables, with every two rows estimated under bivariate VAR/VECM framework.

In Panel A of Table 5, the first two rows for the entire sample period show the VAR outcome between WTI and ECO index. Here, the coefficient estimates are 0.1310 and 0.0482 for vectors of WTI-ECO index, respectively, with only one-way causality from oil prices to ECO index found positive and statistically significant at 1%. The result shows that the ECO index has no effects on WTI price, which is confirmed by Granger Causality test with χ^2 as 1.16 (insignificant). This result is consistent with the results of ECO index against the other two oil prices. In contrast, between WTI and Oil index, interdependence is significant in two-way causality. For example, the estimated coefficients are -0.3649 and 0.0037, respectively, for the third and fourth rows of Panel A; both are significant at 1%. The relationships between the other oil two prices (i.e., Brent and Futures) and Oil index are similar to WTI-Oil index relations with significant negative impacts from Oil index to oil price and significant positive impacts from oil prices to the Oil index. The last two rows of Panel A show only mild one-way dependence from ECO index to Oil index during the entire examination period.

Panel B of Table 5 presents the results for Period I, the pre-Iraq War period, from January 3, 2001 to February 26, 2003; this is also the period when oil prices are least volatile. Using the same structure as Panel A, the first two rows show relations between WTI and ECO index where both coefficients are positive and insignificant. All estimated coefficients for the oil prices-ECO index vector are statistically insignificant. This finding implies that the oil prices and alternative energy stock performance did not interact with each other between 2001 and early 2003. This relationship is also true between oil prices and the Oil index, where none of the vectors have significant VAR outcomes. The results of Granger Causality suggest the same observations.

Compared to the results for the entire period, the outcomes of Panel B of Period I suggest that when oil prices are relatively stable, their impacts on other variables are rather limited. Boyer and Filion (2007) and Park and Ratti (2008) showed that oil price volatility is a key factor in stock market operation. Higher uncertainties of oil price movements generate

greater impacts on stock returns.[9] Therefore, when oil prices are rather stable and inexpensive, the stock performances for both green energy firms and oil companies do not interact with oil prices. This finding implies that at this low and less volatile oil prices era, market participants of green energy and oil stocks generally did not need to incorporate shocks of oil prices into their trading behaviors.

Panel C of Table 5 provides the outcomes for Period II (May 2003 to June 2006), the time between the Iraq and Lebanon wars. Between oil prices and ECO index, all estimated coefficients are statistically insignificant. For instance, the first two rows show that the estimates are -0.0093 and -0.0186 for vectors of WTI-ECO index with *p*-values as 0.9705 and 0.4724, respectively. Between oil prices and Oil index, however, there is one-way causality from oil prices to stock index of oil industry, where the significant estimates are 0.0097, 0.0077, and 0.0081 for WTI, Brent, and Futures, respectively. The result is confirmed by Granger Causality test, and this outcome is different from one in previous period. In addition, there is also a one-way causality significant at 10% from ECO index to Oil index during this period. Therefore, not only do the sample series exhibit different dynamics across the three sub-periods constructed from this study, but their relationships also change from one period to another.

The outcomes of Panel C suggest that when oil prices gradually rise, they generate stronger impacts on stock performances of oil industry. Hammoudeh and Li (2005) found that the increase of oil prices affects the levels of oil export and performances of oil companies. The stock market investors of oil firms now more closely relate their trading decisions to the price movements of crude oil, which have higher prices and greater impacts on the general economic conditions. The stock investors of alternative energy companies, on the other hand, have not yet response to oil price behaviors. In addition, the investors of oil stocks also now mildly consider shocks of green energy stocks into their investment behaviors.

Panel D of Table 5 presents the outcomes for Period III (June 2006 to May 2010; post-Lebanon War). Between oil prices and the ECO index, there is now a significant one-way dependence for ECO index on oil prices, found for the first time compared to previous periods. For instance, the first two rows have the estimated coefficients of 0.1050 and 0.1066 for vector of WTI-ECO index with only second row significant at 1%. Such result can also be seen in both vectors of Brent-ECO index and Futures-ECO index

[9] The total consumption of alternative energy increased by 37% from 2001 to 2008. Data source: Energy Information Administration (EIA) at http://www.eia.doe.gov/.

suggesting that ECO index significantly depends on oil price movements during this period. Between oil prices and Oil index, highly significant interactive relations with negative impacts from oil stock to oil prices and positive ones in reverse directions are obtained, also newly found in this period. Between Oil and ECO indices, one-way significant causality (at 10% level) is found from Oil index to ECO index; this result is contrary to Period II.

The time-varying relations from Panel B to Panel D are consistent with prior studies. Miller and Ratti (2009) documented significant changes in the relationships between oil prices and stock market after 1999, and Hamilton (1983) pointed out that changes in the dynamics of oil prices can have different impacts on key macroeconomic variables. Therefore, when examining the relations between oil prices and other key variables, using a period in which oil price dynamics structurally change (such as the results of Panel A for the entire period) may mislead true relationships.

Only in Period III, after the Lebanon War in 2006, ECO index is found depending on oil prices. As shown in Figure 1 and Table 1, this is the period when oil prices exhibits highly drastic movements. This is also the time when financial crisis emerges (thus, the ECO and Oil indices also become more volatile). This finding implies that investors of alternative energy companies now pay closer attention on oil price shocks when making their investment decisions. When oil prices jump and fluctuate, higher demand of green energy emerges and leads to a better performance of ECO index. In addition, only in this period, the two-way causality between oil prices and Oil index is observed. This finding suggests not only must the investors of oil firms closely observe oil price behaviors when conducting stock trading, but crude oil market participants also start to determine their levels of oil trading according to the stock performances of oil companies.

5. Conclusions

This study explores the recent interdependent relationship between oil prices and stock performances of alternative energy companies using the method of VAR/VECM and Granger Causality test. The examination is conducted separately for three sub-periods, constructed according to two Middle East wars. The oil price movements significantly differ from one sub-period to another: oil prices are relatively stable in Period I, grow gradually in Period II, and fluctuate strongest in Period III. The empirical results show no interdependence between the oil prices and stock index of green energy companies during Period I. No interactive relation is found between oil prices and stock index of oil industry neither in the same period.

During Period II, oil prices begin to significantly affect the stock index of oil companies, and in Period III, the oil prices generate significant impacts on the stock index of green energy companies, and an interdependent relationship between oil prices and Oil index is documented.

In sum, while price uncertainty of crude oil rises and green energy gains greater deal of attention in recent years, the interrelationships between oil prices and stock performances of alternative energy companies become more significant. For Periods I and II, time before the Lebanon War from 2001 to late 2006, no causality is shown from oil prices to ECO index or vice verse, implying that the movements of crude oil prices do not affect how the investors trade with the stocks of alternative energy industry. In the most recent period, when oil prices reach historical high and crash back with volatile dynamics, oil price behavior becomes responsible for stock performances of alternative energy companies. Also only recently, the dynamics in oil trading also depend on how stocks of oil companies perform. These results add to literature showing that investors of alternative energy companies conduct their trading decisions upon observation of crude oil price shocks. The two markets, i.e. crude oil market and stock market for green energy sector, seem to be more closely interactive with each other. The full picture of how the crude oil markets react to the development of green energy, however, requires additional examinations and is certainly an area worthy of future exploration.

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Table 1. Descriptive Statistics of Weekly Close Price and Index

	WTI	Brent	Futures	ECO index	Oil index
Panel A. Full Period (2001/01/03~2010/05/31, N=491)					
Mean	54.49	53.15	54.54	158.98	868.92
Median	52.51	51.09	52.77	160.02	875.37
Maximum	143.74	142.17	143.57	297.05	1625.29
Minimum	18.38	18.46	18.36	63.73	411.09
Std. Dev.	26.22	26.21	26.24	49.01	332.85
C.V.	0.48	0.49	0.48	0.30	0.38
Skewness	0.88	0.82	0.87	0.14	0.30
Kurtosis	3.51	3.33	3.50	2.16	1.88
Panel B. Period I: Pre-Iraq War Period (2001/01/03~2003/02/26, N=112)					
Mean	26.60	25.40	26.57	158.17	508.98
Median	26.94	25.77	26.92	163.49	515.12
Maximum	37.96	33.54	37.70	258.71	590.08
Minimum	18.38	18.46	18.36	78.78	411.09
Std. Dev.	4.01	3.46	3.95	47.07	46.69
C.V.	0.15	0.14	0.15	0.30	0.09
Skewness	-0.04	-0.18	-0.06	0.16	-0.36
Kurtosis	3.28	2.64	3.31	2.06	2.12
Panel C. Period II: Post-Iraq and Pre-Lebanon War Period (2003/05/07~2006/06/28, N=165)					
Mean	47.82	45.74	47.86	160.04	759.92
Median	47.36	44.09	47.27	156.80	713.44
Maximum	72.26	73.42	72.28	253.02	1165.25
Minimum	26.24	24.18	26.23	97.42	449.23
Std. Dev.	13.54	12.15	13.62	30.61	218.72
C.V.	0.28	0.27	0.28	0.19	0.29
Skewness	0.14	0.21	0.14	0.79	0.23
Kurtosis	1.73	1.73	1.71	3.79	1.67
Panel D. Period III: Post-Lebanon War Period (2006/09/06~2010/05/31, N=196)					
Mean	76.54	75.74	76.65	160.39	1175.30
Median	72.23	71.48	72.15	182.54	1143.42
Maximum	143.74	142.17	143.57	297.05	1625.29
Minimum	32.94	35.62	34.62	63.73	802.18
Std. Dev.	23.41	22.38	23.31	61.17	211.76
C.V.	0.30	0.29	0.30	0.38	0.18
Skewness	0.77	0.81	0.79	0.05	0.19
Kurtosis	3.25	3.39	3.27	1.55	1.87

This table presents the summary statistics of crude oil prices, stock index of green energy sector, and stock index of oil companies. Std. Dev. and C.V. stand for standard deviation and coefficient of variation, respectively. WTI is spot price of West Texas Intermediate Oil; Brent is spot price of Brent; Futures is NYMEX Futures Oil price; ECO index is WilderHill Clean Energy index; and Oil index is the American Stock Exchange Oil index. N is numbers of samples. The data were extracted from the Datastream database.

Table 2. Correlation Matrix of Weekly Close Price and Index

	WTI	Brent	Futures	ECO index
Panel A. Full Period (2001/01/03~2010/05/31, N=491)				
Brent	0.9965	-----		
	(0.0001)			
Futures	0.9998	0.9968	-----	
	(0.0001)	(0.0001)		
ECO index	0.3470	0.3529	0.3464	-----
	(0.0001)	(0.0001)	(0.0001)	
Oil index	0.9025	0.9172	0.9036	0.4848
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel B. Period I: Pre-Iraq War Period (2001/01/03~2003/02/26, N=112)				
Brent	0.9609	-----		
	(0.0001)			
Futures	0.9958	0.9643	-----	
	(0.0001)	(0.0001)		
ECO index	-0.2240	-0.1748	-0.2242	-----
	(0.0176)	(0.0651)	(0.0175)	
Oil index	-0.2623	-0.1698	-0.2591	0.8141
	(0.0052)	(0.0734)	(0.0058)	(0.0001)
Panel C. Period II: Post-Iraq and Pre-Lebanon War Period (2003/05/07~2006/06/28, N=165)				
Brent	0.9942	-----		
	(0.0001)			
Futures	0.9994	0.9950	-----	
	(0.0001)	(0.0001)		
ECO index	0.7678	0.7753	0.7690	-----
	(0.0001)	(0.0001)	(0.0001)	
Oil index	0.9759	0.9776	0.9769	0.8212
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel D. Period III: Post-Lebanon War Period (2006/09/06~2010/05/31, N=196)				
Brent	0.9935	-----		
	(0.0001)			
Futures	0.9998	0.9936	-----	
	(0.0001)	(0.0001)		
ECO index	0.5166	0.5326	0.5159	-----
	(0.0001)	(0.0001)	(0.0001)	
Oil index	0.6982	0.7172	0.6977	0.9236
	(0.0001)	(0.0001)	(0.0001)	(0.0001)

This table presents the correlation statistics between crude oil prices, stock index of green energy sector, and stock index of oil companies. Descriptions of variables and data please see Table 1. The numbers shown in parentheses are *p*-values.

Table 3. Unit Root Test

	Levels		First differences	
	ADF	PP	ADF	PP
Panel A. Full Period (2001/01/03~2010/05/31, N=491)				
WTI	-1.43	-1.71	-22.80***	-23.20***
Brent	-1.40	-1.74	-21.93***	-22.66***
Futures	-1.40	-1.73	-22.20***	-22.83***
ECO index	-1.75	-1.89	-21.39***	-21.42***
Oil index	-1.33	-1.31	-20.18***	-20.09***
Panel B. Period I: Pre-Iraq War Period (2001/01/03~2003/02/26, N=112)				
WTI	-0.44	-0.49	-11.04***	-11. 03***
Brent	-0.97	-1.25	-10.63***	-10.63***
Futures	-0.30	-0.42	-11.17***	-11.18***
ECO index	-1.49	-0.74	-5.73***	-10.60***
Oil index	-1.36	-1.04	-11.17***	-11.91***
Panel C. Period II: Post-Iraq and Pre-Lebanon War Period (2003/05/07~2006/06/28, N=165)				
WTI	-0.82	-0.70	-14.01***	-14.07***
Brent	-0.55	-0.51	-12.50***	-12.51***
Futures	-0.75	-0.70	-13.38***	-13.39***
ECO index	-1.92	-1.95	-13.07***	-13.06***
Oil index	-0.40	-0.31	-12.86***	-12.86***
Panel D. Period III: Post-Lebanon War Period (2006/09/06~2010/05/31, N=196)				
WTI	-1.32	-1.53	-14.24***	-14.30***
Brent	-1.32	-1.62	-13.99***	-14.19***
Futures	-1.30	-1.53	-13.92***	-14.01***
ECO index	-0.83	-0.90	-12.48***	-12.42***
Oil index	-1.30	-1.36	-12.35***	-12.26***

This table presents the results of unit root test for crude oil prices, stock index of green energy sector, and stock index of oil companies. Descriptions of variables and data please see Table 1. All tests use an intercept with no trend, and the null hypothesis is that the series has a unit root. Each Augmented Dickey-Fuller (ADF) statistic is reported for the shortest lag length which has been chosen based on the AIC. The Phillips–Perron (PP) test uses the same models as the ADF tests, but uses a nonparametric correction, due to Newey and West (1987), to address the potential serial correlation. The lag truncation for the nonparametric correction is conducted with an automated bandwidth estimator of the Bartlett kernel (Andrews, 1991). *,**,*** Significant at the 10%, 5% and 1% critical level.

Table 4. Johansen Cointegration Test

	Oil Price						ECO index	
	WTI		Brent		Futures			
H_1	λ_{max}	Trace	λ_{max}	Trace	λ_{max}	Trace	λ_{max}	Trace
Panel A. Full Period (2001/01/03~2010/05/31, N=491)								
ECO index	0.0137	10.0677	0.0140	9.8985	0.0139	10.0713	-----	-----
Oil index	0.0331	20.2221†	0.0382	22.5482†	0.0323	19.9407†	0.0083	5.8430
Panel B. Period I: Pre-Iraq War Period (2001/01/03~2003/02/26, N=112)								
ECO index	0.0910	11.4250	0.0561	6.2802	0.0568	6.2795	-----	-----
Oil index	0.0491	5.9417	0.0505	5.7605	0.0501	6.5477	0.0910	11.4250
Panel C. Period II: Post-Iraq and Pre-Lebanon War Period (2003/05/07~2006/06/28, N=165)								
ECO index	0.0364	6.8852	0.0387	6.8375	0.0360	6.6437	-----	-----
Oil index	0.0949	16.5118†	0.0846	20.5375†	0.0839	19.9948†	0.0402	6.7453
Panel D. Period III: Post-Lebanon War Period (2006/09/06~2010/05/31, N=196)								
ECO index	0.0375	9.9974	0.0340	8.9597	0.0371	10.0255	-----	-----
Oil index	0.0495	16.2607†	0.0551	16.6399†	0.0505	16.4083†	0.0551	11.7615

This table presents the results of cointegration test between crude oil prices, stock index of green energy sector, and stock index of oil companies. Descriptions of variables and data please see Table 1. The null hypothesis of no cointegrated vector is concerned, and the lag length of cointegrated test is applied based on the SBC. The Significant value of Trace is 15.34 at 5% level with † indicating the significance. We can derive the value of λ_{max} from the following formula:

$$-T\log(1-\hat{\lambda}_{r+1}),$$

The value of Trace can be calculated by the subsequent formula:

$$-T\sum_{i=r+1}^{n}\log(1-\hat{\lambda}_i)$$

where $\hat{\lambda}_i$ is the eigenvalue.

Table 5. VAR/VECM and Granger Causality

Left-hand side	Right-hand side	VAR/VECM		Causality	
		Coefficient	*p*-value	χ^2	*p*-value
Panel A. Full Period (2001/01/03~2010/05/31, N=491)					
WTI	ECO index	0.1310	0.2825	1.16	0.2820
ECO index	WTI	0.0482	0.0061***	7.60	0.0059***
WTI	Oil index	-0.3649	0.0058***	7.66	0.0056***
Oil index	WTI	0.0037	0.0002***	14.42	0.0001***
Brent	ECO index	0.1473	0.2565	1.29	0.2560
ECO index	Brent	0.0480	0.0035***	8.59	0.0034***
Brent	Oil index	-0.3694	0.0100**	6.70	0.0097***
Oil index	Brent	0.0041	0.0001***	17.30	0.0001***
Futures	ECO index	0.1119	0.3741	0.79	0.3736
ECO index	Futures	0.0426	0.0127**	6.26	0.0123**
Futures	Oil index	-0.3604	0.0067***	7.40	0.0065***
Oil index	Futures	0.0035	0.0002***	14.19	0.0002***
Oil index	ECO index	0.0248	0.0603*	3.55	0.0597*
ECO index	Oil index	0.2657	0.2117	1.56	0.2111
Panel B. Period I: Pre-Iraq War Period (2001/01/03~2003/02/26, N=112)					
WTI	ECO index	0.6271	0.3987	0.72	0.3968
ECO index	WTI	0.0088	0.4864	0.49	0.4849
WTI	Oil index	-0.0026	0.9984	0.01	0.9984
Oil index	WTI	0.0068	0.3981	0.72	0.3962
Brent	ECO index	-0.0682	0.9340	0.01	0.9339
ECO index	Brent	0.0108	0.3599	0.85	0.3578
Brent	Oil index	-0.2875	0.8408	0.04	0.8404
Oil index	Brent	0.0093	0.2192	1.53	0.2165
Futures	ECO index	0.3397	0.6702	0.18	0.6694
ECO index	Futures	-0.0005	0.9608	0.01	0.9607
Futures	Oil index	-1.0805	0.4495	0.58	0.4478
Oil index	Futures	0.0012	0.8705	0.03	0.8702
Oil index	ECO index	0.0728	0.2322	1.44	0.2296
ECO index	Oil index	0.0570	0.7299	0.12	0.7292

This table presents the results of VAR or VECM between crude oil prices, stock index of green energy sector, and stock index of oil companies. When two series are cointegrated according to results of Table 4, VECM is applied; otherwise, VAR in differences is applied. Descriptions of variables and data please see Table 1. For Granger Causality, the null hypothesis states no causality relationships between two variables, and the selection of lag length based on the SBC. *,**,*** Significant at the 10%, 5% and 1% critical level.

Table 5. VAR/VECM and Granger Causality (continued)

Left-hand side	Right-hand side	VAR/VECM		Causality	
		Coefficient	*p*-value	χ^2	*p*-value
Panel C. Period II: Post-Iraq and Pre-Lebanon War Period (2003/05/07~2006/06/28, N=165)					
WTI	ECO index	-0.0093	0.9705	0.01	0.9704
ECO index	WTI	-0.0186	0.4724	0.52	0.4713
WTI	Oil index	0.4024	0.5162	0.42	0.5153
Oil index	WTI	0.0097	0.0046***	8.28	0.0040***
Brent	ECO index	0.0471	0.8658	0.03	0.8656
ECO index	Brent	-0.0121	0.6013	0.27	0.6006
Brent	Oil index	0.7281	0.2358	1.42	0.2340
Oil index	Brent	0.0077	0.0164**	5.89	0.0153**
Futures	ECO index	0.0459	0.8645	0.03	0.8643
ECO index	Futures	-0.0319	0.1916	1.72	0.1897
Futures	Oil index	0.4918	0.4337	0.62	0.4326
Oil index	Futures	0.0081	0.0139**	6.18	0.0129**
Oil index	ECO index	0.0509	0.0653*	3.44	0.0635*
ECO index	Oil index	-0.1798	0.5924	0.29	0.5917
Panel D. Period III: Post-Lebanon War Period (2006/09/06~2010/05/31, N=196)					
WTI	ECO index	0.1050	0.4857	0.49	0.4849
ECO index	WTI	0.1066	0.0037***	8.63	0.0033***
WTI	Oil index	-0.4380	0.0261**	5.03	0.0250**
Oil index	WTI	0.0057	0.0061***	7.68	0.0056***
Brent	ECO index	0.1381	0.3862	0.75	0.3851
ECO index	Brent	0.1024	0.0033***	8.87	0.0029***
Brent	Oil index	-0.4458	0.0353**	4.49	0.0340**
Oil index	Brent	0.0059	0.0033***	8.84	0.0030***
Futures	ECO index	0.0771	0.6184	0.25	0.6178
ECO index	Futures	0.1064	0.0031***	8.95	0.0028***
Futures	Oil index	-0.4340	0.0281**	4.90	0.0269**
Oil index	Futures	0.0056	0.0059***	7.75	0.0054***
Oil index	ECO index	0.0065	0.7222	0.13	0.7219
ECO index	Oil index	0.8444	0.0815*	3.07	0.0799*

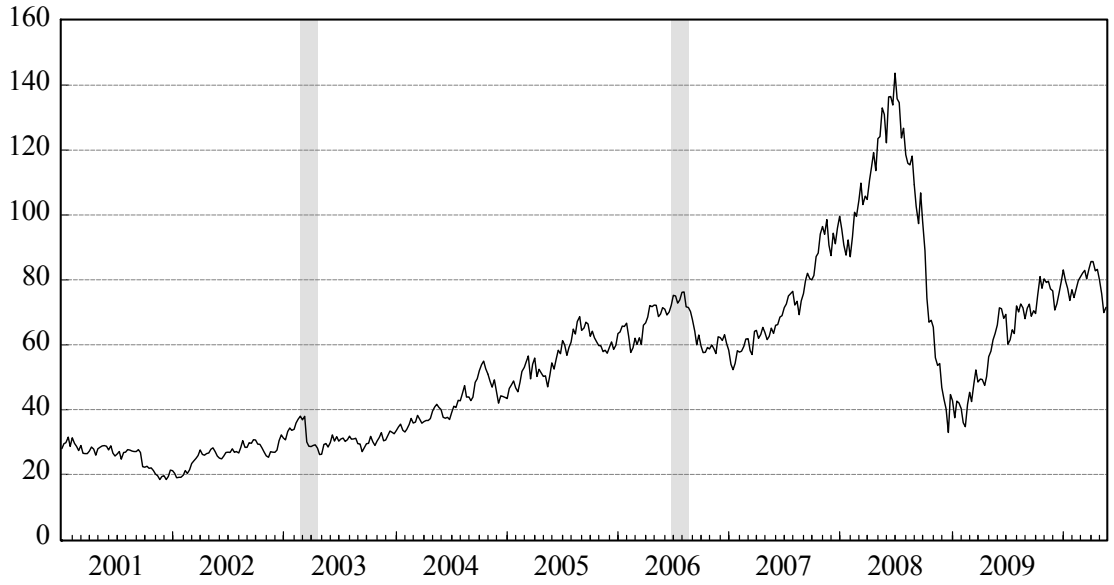

Figure 1. Crude Oil Price of WTI

This figure presnets the trend of West Texas Intermediate Crude Oil Price between January 2001 and May 2010 in US dollar. The first and second shaded areas indicate the periods of Iraq War and Lebanon War, respectively.