Relationship among crude oil prices, share prices and exchange rates

— Do higher share prices and weaker dollar lead to higher crude oil prices? —

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Summary

Share prices and U.S. dollar exchange rates are often referred to as factors of daily changes in crude oil prices. In general, it is said that there is positive correlation between crude oil prices and share prices and negative correlation between crude oil prices and exchange rates, i.e., higher share prices or weaker dollar lead to higher crude oil prices.

However, there is a risk that we may fail to conclude correctly, due to "spurious correlation," as long as we see the relationship among crude oil prices, share prices and exchange rates naively. In this paper, data characteristics of these variables were examined followed by inspection of their relationship: what kind of relationship exists and whether it is constant or variable.

The results show that the causal relationship among crude oil prices, share prices and exchange rates changes over time more than expected. In 2008, bidirectional causality could be found in any combination of them. In 2010, the causality from share prices and exchange rates to crude oil prices as widely believed has been lost. The reasons the causality changes are supposed to be changes in market participants' mix, degree of confidence in price forecast based on fundamentals, momentum covering the markets, etc. The weak causal relationship in 2010 may suggest that other factors are being focused on in crude oil markets.

1. General views on relationship among crude oil prices, share prices and exchange rates and their issues

1.1 Crude oil prices and share prices

Share prices are often referred to as a factor of daily changes in crude oil prices. For instance, Wall Street Journal said on crude oil prices on 20th September 2010 as follows:

"Crude-oil futures settled higher, bouncing back from four-straight sessions of losses as rising U.S. *equities* boosted optimism about the economic outlook."[1]

It said also on crude oil prices on 24th September, Friday in the same week:

"Crude-oil prices rose, spurred by advancing U.S. *stock prices* and a slumping *dollar*."[2]

In both articles, the higher share prices are referred to as one of the factors of the rise in crude oil prices. Actually, in its headline on crude oil markets, share prices are referred explicitly as often as once per two days in some months.

Similarly, "Oil Market Report", July 2010 edition by International Energy Agency said

"Benchmark crude prices traded in a $71-79/bbl range in June, … Financial and *equity* markets remained the focus of attention, …",

followed by its August 2010 edition saying

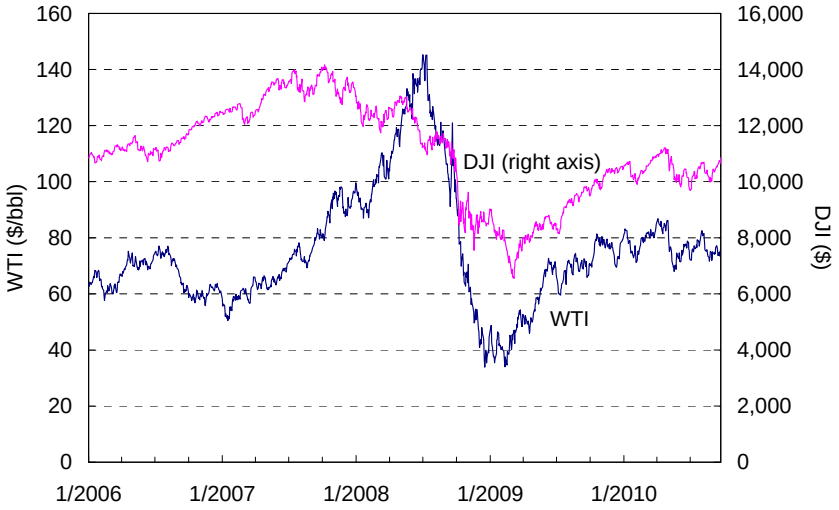
"By early August, oil prices shot up to three-month highs … A strong recovery in *equity* markets on the back of positive second-quarter earnings and a sharp downturn in the US *dollar* were reportedly behind the rebound."

Share prices are regarded as mirrors reflecting economic situation today and/or expectation of future economy. Therefore, expectation for economic expansion may be associated with both rise in share prices and rise in crude oil prices caused by increased oil demand. In general, it is said that there is correlation between crude oil prices and share prices these days, *i.e.,* higher share prices lead to higher crude oil prices and lower share prices lead to lower crude oil prices. When we see a figure plotting crude oil price (WTI) and share price (DJI)[3], we can see that some kind of relationship may exist between them (Figure 1).

[1] "The Wall Street Journal", 21st September 2010, 'Crude Gains, Helped by Equities'.
[2] "The Wall Street Journal", 24th September 2010, 'Oil Prices Punch Through $76'.
[3] In this paper, futures (of front month with exception in case of quoted) price of Light Sweet Crude Oil listed at the New York Mercantile Exchange (so called West Texas Intermediate, or WTI) and Dow Jones Industrial Average, or DJI, of the New York Stock Exchange are used as crude oil price and share price, respectively.

Until around 2008, however, *low* correlation between commodities including crude oil and traditional financial assets including shares, which leads to risk reduction, were mentioned as a factor in the flow of funds to commodity markets.

Figure 1 Change in the crude oil price and the share price



Source: U.S. Energy Information Administration, New York Stock Exchange

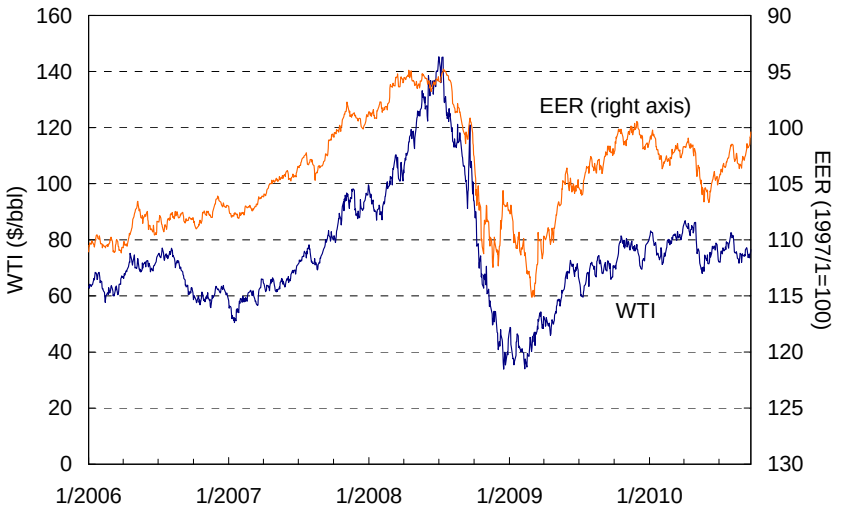
1.2 Crude oil prices and exchange rates

Exchange rates of U.S. dollar are also referred to as a factor of daily changes in crude oil prices. In the article by Wall Street Journal on crude oil prices on 24th September and "Oil Market Report" of August 2010 above, exchange rates are referred to as one of the factors of the rise in crude oil prices and share prices.

In general, it is said that there is negative correlation between crude oil prices and exchange rates, *i.e.*, stronger U.S. dollar leads to lower crude oil prices and weaker dollar leads to higher crude oil prices. When we see a figure plotting the crude oil price (WTI) and dollar exchange rate (EER)[4], we can see that some kind of relationship may exist between them like the crude oil price and the share price (Figure 2).

[4] In this paper, nominal effective exchange rate, or EER, of U.S. dollar is used as exchange rate. EER is a weighted average of the foreign exchange values of the U.S. dollar against the currencies of a large group of major U.S. trading partners.

Figure 2 Change in the crude oil price and the exchange rate



Source: U.S. Energy Information Administration, U.S. Board of Governors of the Federal Reserve System

1.3 No pitfall in the views?

Volatility of daily share prices (and exchange rates) is much larger than changes in surmised real economy and future expectation of the economy. That may come from something else than their nature as mirrors of the economy. Daily crude oil prices are also hard to explain well with fundamentals in oil markets like supply-demand balance.[5] Nonetheless, the trend mentioned above is observed actually. That suggests that there can be sort of covariation among crude oil prices, share prices and exchange rates beyond changes led by common macroeconomic factors.

Meanwhile it is known as "spurious correlation" that non-correlated random walk series sometimes move in similar way and show an aspect that there is a sort of relationship between them. Daily share prices and exchange rates are indeed surmised to be random walk series and often supposed to be random walk series in analyses and modelling. Crude oil prices are not much different. This means there is a risk that we may fail to conclude correctly as long as we see their relationship naively. For example, correlation coefficients obtained by simple calculation may show excessive numbers beyond their real relationship.

In this paper, the data characteristics of the crude oil price, the share price and the exchange rate are examined followed by inspection of their relationship: what kind of relationship exists and whether it is constant or variable.

2. Data characteristics of crude oil price, share price and exchange rate

Daily data of the crude oil price, the share price and the exchange rate for almost five years, between 3rd January 2006 and 24th September 2010, were used for the analysis. All series were

[5] As a concrete issue, daily supply and demand of oil cannot be observed.

transformed in natural log[6]. Although an analysis with short periods might be better considering the speed of markets, it has shortcoming that enough degree of freedom to secure accuracy cannot be obtained from a small sample size. In this paper, the whole period was split simply into five annual periods under comprehensive judgement criteria including easy to understand.

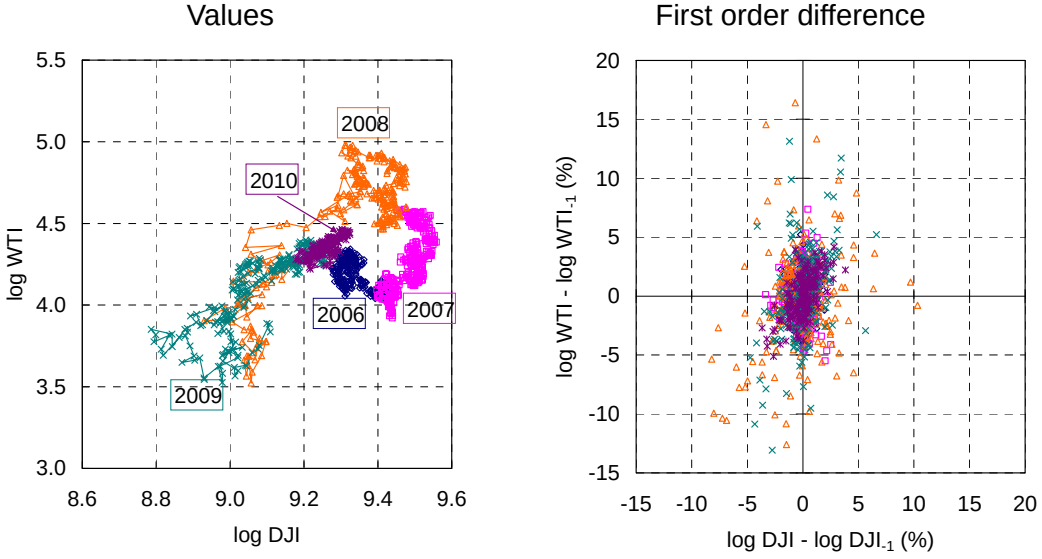
To judge whether each series is a random walk or not, its stationarity was examined. Measured degrees of integration by Augmented Dickey-Fuller test are shown in Table 1.

Table 1 Degrees of integration of the crude oil price, the share price and the exchange rate

	2006	2007	2008	2009	2010
Crude oil price	1	0	1	1	1
Crude oil price (of 4th maturity)	1	0	1	1	1
Share price	1	1	1	1	1
Exchange rate	1	1	1	1	1

The crude oil price, the share price and the exchange rate are non-stationary as level in most cases and their differential series are stationary, *i.e.*, they are surmised to be integrated of order one, or $I(1)$. This means there is a risk that we may fail to conclude correctly the relationship between them as long as we see them naively.[7]. Actually, a figure plotting the share price and the crude oil price levels suggests some kind of relationship may exist between them but the impression is weakened once they are differentiated (Figure 3).

Figure 3 Correlation between the share price and the crude oil price

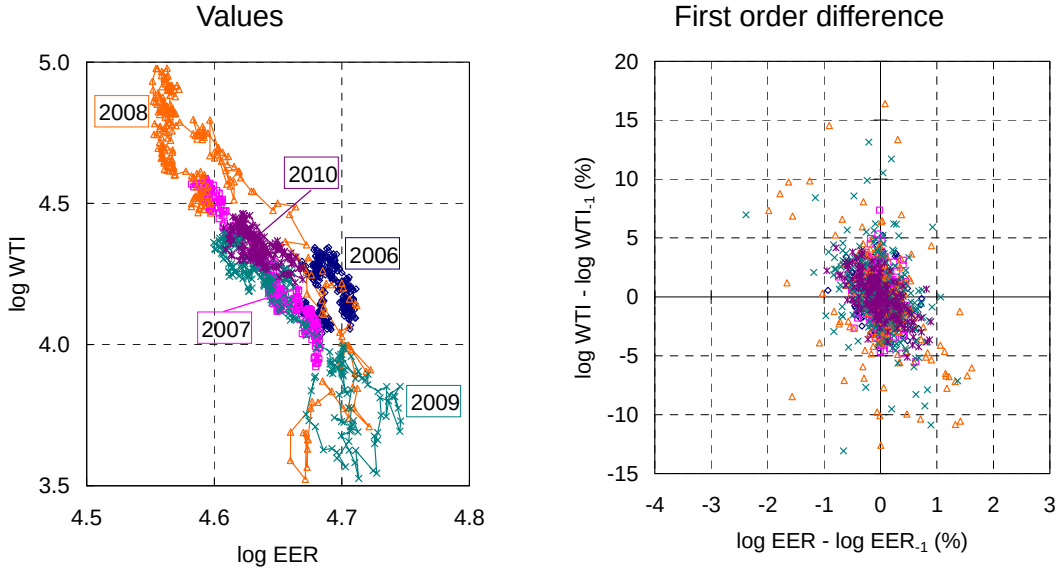


[6] Difference in a natural log is approximately equivalent to rate of change. $\log X_t - \log X_{t-1} \approx X_t / X_{t-1} - 1$.
[7] In case of co-integration, in which a stable relationship exists between two or more series in medium- and long-term, examination in actual values is fine even if they are $I(1)$. Tests, however, did not reject null hypothesis that co-integration does not exist in any combination among the crude oil price, the share price and the exchange rate.

Correlation coefficients between the share price and the crude oil price decline also by the differentiation, *e.g.*, the correlation coefficients in actual values in 2009 are 0.81 but only 0.44 in the difference.

Similar situation can be found between the exchange rate and the crude oil price (Figure 4).

Figure 4 Correlation between the exchange rate and the crude oil price



3. Building a model of crude oil price, share price and exchange rate

Here relationship among the crude oil price, the share price and the exchange rate in a form of Vector Autoregression model, or VAR is examined. Although all variables modelled by VAR have to be stationary, the crude oil price, the share price and the exchange rate are surmised as non-stationary, $I(1)$, in most cases as mentioned above. Usually a model is built with stationary difference (log rate of change) series.

It, however, is easily imagined that actual values is preferred rather than rates of change when relationship among crude oil prices, share prices and exchanges rate is inspected. Additionally, forward curve (crude oil price in back months), which is regarded as average forecast (expectation) in markets, may affect crude oil prices in front month (Yanagisawa, 2009). Modelling the rate of change prevents inspection including the forward curve as actual values information is omitted by differentiation. Then in this paper, a model was built with series of actual values using Lag Augmented Vector Autoregression model, or LA-VAR (Toda and Yamamoto, 1995) not with rates of change using standard VAR.

Meanwhile, crude oil futures price with maturity of three months later than the front month (the fourth maturity) was included in the model as proxy of the forward curve because having multiple crude oil prices in back months in the model led to issues of multi-correlation.

The built model is shown in the annex below.

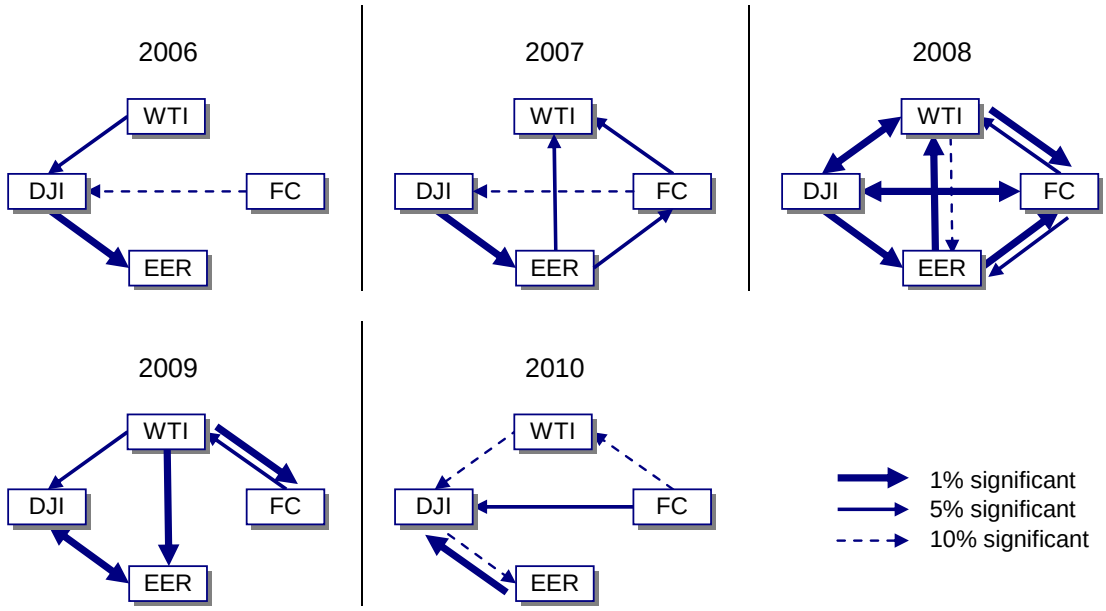
4. Causality among crude oil price, share price and exchange rate

Granger causality among the crude oil price, the share price, the exchange rate and the forward curve was inspected based on the model.

Granger causality from Z to X is judged whether Z is useful to forecast of X on the average, that is, whether past information of Z, or $\{\cdots, z_{t-3}, z_{t-2}, z_{t-1}\}$, reduces prediction mean squared error of x_t. In addition to Granger causality, there is instantaneous Granger causality, looking at relationship between X and Z at the current period (x_t and z_t). This instantaneous Granger causality among the crude oil price, the share price and the exchange rate is mentioned in the next section.

Results of Granger causality tests among the crude oil price, the share price, the exchange rate and the forward curve in the last five years are shown in Figure 5.

Figure 5 Granger causality among crude oil price, share price, exchange rate and forward curve



Note: WTI, DJI, EER and FC imply the crude oil price, the share price, the exchange rate and the forward curve, respectively.

As expected somewhat in advance, the Granger causality among the crude oil price, the share price, the exchange rate and the forward curve changes indeed by time but more than expected.

In 2006, which was the third year of the crude oil price rise, financial indicators – the share price and the exchange rate – do not influence the crude oil price. The crude oil price in 2007 reverted to rising to around $100/bbl from $50/bbl in January almost monotonically after a decline in the second half of 2006. In that period, causality from the exchange rate and the forward curve to the crude oil price occurred. In 2008, a very volatile year when the crude oil price surged to over $140/bbl, the historical highest, and dropped to as much as $30/bbl at the

end of the year, causality could be found in any combination of the crude oil price, the share price, the exchange rate and the forward curve. Additionally, almost all of the causal relationships were bidirectional *i.e.,* feedback. While the crude oil price rose by more than $40/bbl in 2009, the financial indicators lost causality to the crude oil price but causality from the crude oil price to the financial indicators and causality between the crude oil price and the forward curve remained. In 2010, the crude oil price has fluctuated in a range of $70/bbl-$80/bbl so far. The financial indicators do not cause the crude oil price like in the previous year. Additionally, causality from the crude oil price to the financial indicators gets vague. The weak causal relationship in 2010 may suggest that other factors are being focused on in crude oil markets.

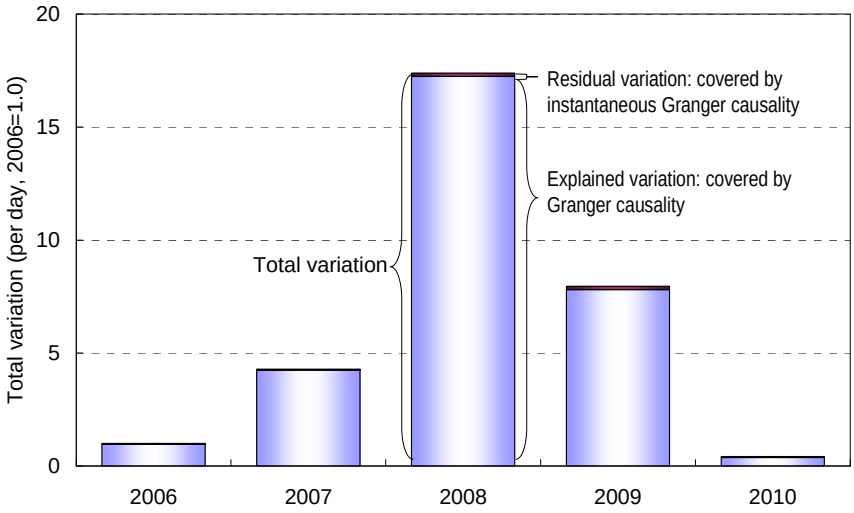
The reasons the causality changes are supposed to be complex ones. Changes in market participant mix can be a background factor of changes in trading backing share prices and exchange rates. Degree of confidence in price forecast based on fundamentals may affect degree of causality, too; the causality from factors outside the fundamentals is vague if markets are highly confident with the forecast, and factors outside the fundamentals are focused on if the markets are not confident enough. Momentum covering the markets – it is also a result of the markets – can be a factor that expands the relationship in a runaway manner when the causal relationship is bidirectional (feedback). Oil stockpile level and others sometimes amplify factors outside the fundamentals, depending on their situation. Furthermore, if the reflection rate of share prices and exchange rates as mirrors of economy fluctuation by time, the causal relationship between these financial indicators and crude oil prices can change.

5. Instantaneous causality among crude oil price, share price and exchange rate

It is known that instantaneous Granger causality is captured by covariance of disturbances (residuals) in the framework of VAR[8]. According to correlation coefficients[9], that is, covariance of the residuals in the model divided by their standard variation, the correlation gets stronger year by year. However, the residual variation which instantaneous Granger causality is related to is much smaller than the total variation of the crude oil price in any period. In other words, it is hard to say that the instantaneous Granger causal relationship play crucial role among the crude oil price, the share price and the exchange rate. Then the instantaneous causality will be mentioned in the next time.

[8] Therefore, direction of causality cannot be examined.
[9] Covariance depends on scale of its original data, but correlation coefficients do not.

Figure 6 Total variation of the crude oil price and coverage by each causality



6. In closing

Granger causality is quite defined mathematically and that gives people an unnatural impression sometimes in comparison with the general understanding of "causality". Nonetheless, the results of the statistical inspection on the current relationship among crude oil prices, share prices and exchange rates, which is surmised as spurious correlation due to the series' nature as random walk, suggest that the causality is vague and other factors are being focused on in the markets.

Annex Summary of the build model

2006

Exogenous variables	Equations (indigenous variables)			
	WTI	DJI	EER	FC
WTI(-1)	1.178	-0.090	-0.018	0.317
	(0.224)	(0.079)	(0.027)	(0.189)
WTI(-2)	-0.215	0.015	0.002	-0.223
	(0.223)	(0.079)	(0.027)	(0.188)
DJI(-1)	0.231	0.989	-0.142	0.229
	(0.182)	(0.065)	(0.022)	(0.154)
DJI(-2)	-0.178	-0.033	0.108	-0.140
	(0.186)	(0.066)	(0.022)	(0.157)
EER(-1)	0.317	-0.093	0.944	0.248
	(0.529)	(0.188)	(0.064)	(0.446)
EER(-2)	-0.001	0.031	-0.057	0.141
	(0.501)	(0.178)	(0.060)	(0.423)
FC(-1)	-0.191	0.053	0.005	0.637
	(0.266)	(0.095)	(0.032)	(0.225)
FC(-2)	0.229	0.011	0.001	0.272
	(0.262)	(0.093)	(0.032)	(0.221)
Constant	-1.991	0.746	0.903	-2.666
	(1.618)	(0.574)	(0.195)	(1.367)
R^2	0.957	0.979	0.969	0.962

True lag: 1, additional lag: 1.
WTI, DJI, EER and FC imply the crude oil price, the stock price, the exchange rate and the forward curve, respectively.
WTI(-1) implies crude oil price in the previous day.
Numbers in parentheses are standard errors.

2007

Exogenous variables	Equations (indigenous variables)			
	WTI	DJI	EER	FC
WTI(-1)	1.498	0.063	0.008	0.261
	(0.244)	(0.116)	(0.024)	(0.215)
WTI(-2)	-0.561	-0.049	-0.020	-0.156
	(0.372)	(0.177)	(0.036)	(0.328)
WTI(-3)	0.048	-0.012	0.005	-0.088
	(0.242)	(0.115)	(0.024)	(0.213)
DJI(-1)	0.112	0.840	-0.078	0.115
	(0.141)	(0.067)	(0.014)	(0.124)
DJI(-2)	0.082	0.177	0.040	0.038
	(0.179)	(0.085)	(0.017)	(0.158)
DJI(-3)	-0.191	-0.059	0.028	-0.160
	(0.146)	(0.069)	(0.014)	(0.129)
EER(-1)	0.605	-0.080	0.900	0.428
	(0.716)	(0.340)	(0.070)	(0.631)
EER(-2)	-1.094	-0.282	0.101	-0.931
	(0.963)	(0.458)	(0.094)	(0.849)
EER(-3)	-0.057	0.291	-0.074	0.091
	(0.652)	(0.310)	(0.063)	(0.575)
FC(-1)	-0.750	-0.149	-0.024	0.568
	(0.276)	(0.131)	(0.027)	(0.244)
FC(-2)	0.944	0.153	0.018	0.425
	(0.426)	(0.202)	(0.041)	(0.375)
FC(-3)	-0.284	-0.016	0.002	-0.093
	(0.284)	(0.135)	(0.028)	(0.250)
Constant	2.958	0.773	0.484	2.321
	(1.686)	(0.801)	(0.164)	(1.486)
R^2	0.989	0.952	0.996	0.987

True lag: 2, additional lag: 1.

2008

Exogenous variables	Equations (indigenous variables)			
	WTI	DJI	EER	FC
WTI(-1)	0.557	-0.042	-0.003	-0.027
	(0.165)	(0.104)	(0.022)	(0.139)
WTI(-2)	-0.050	0.030	0.011	-0.119
	(0.188)	(0.119)	(0.025)	(0.158)
WTI(-3)	0.486	0.042	0.002	0.395
	(0.188)	(0.119)	(0.025)	(0.158)
WTI(-4)	0.209	0.111	-0.024	0.128
	(0.193)	(0.122)	(0.025)	(0.162)
WTI(-5)	-0.544	-0.198	0.033	-0.429
	(0.189)	(0.119)	(0.025)	(0.159)
WTI(-6)	0.414	0.012	0.019	0.313
	(0.190)	(0.120)	(0.025)	(0.160)
WTI(-7)	-0.363	0.054	-0.047	-0.372
	(0.243)	(0.154)	(0.032)	(0.204)
WTI(-8)	0.081	0.025	0.033	-0.054
	(0.289)	(0.182)	(0.038)	(0.243)
DJI(-1)	0.416	0.797	-0.096	0.368
	(0.113)	(0.072)	(0.015)	(0.095)
DJI(-2)	-0.424	0.071	0.098	-0.422
	(0.141)	(0.089)	(0.019)	(0.119)
DJI(-3)	0.171	0.127	0.000	0.321
	(0.152)	(0.096)	(0.020)	(0.127)
DJI(-4)	-0.163	-0.218	0.001	-0.276
	(0.154)	(0.098)	(0.020)	(0.130)
DJI(-5)	0.076	0.105	0.004	0.111
	(0.156)	(0.099)	(0.021)	(0.131)
DJI(-6)	0.031	-0.030	0.000	-0.056
	(0.154)	(0.097)	(0.020)	(0.130)
DJI(-7)	0.086	-0.013	-0.050	0.142
	(0.151)	(0.095)	(0.020)	(0.127)
DJI(-8)	-0.062	0.097	0.025	-0.080
	(0.120)	(0.076)	(0.016)	(0.101)
EER(-1)	1.032	-0.265	0.974	0.131
	(0.603)	(0.381)	(0.079)	(0.507)
EER(-2)	-0.856	0.014	0.067	-0.242
	(0.825)	(0.521)	(0.108)	(0.693)
EER(-3)	-0.467	0.369	-0.199	0.044
	(0.827)	(0.522)	(0.109)	(0.695)
EER(-4)	-0.430	-0.824	0.379	-0.571
	(0.825)	(0.521)	(0.108)	(0.693)
EER(-5)	0.422	0.625	-0.208	0.823
	(0.828)	(0.523)	(0.109)	(0.695)
EER(-6)	0.709	0.169	-0.203	0.291
	(0.833)	(0.526)	(0.109)	(0.700)
EER(-7)	0.421	-0.136	0.191	0.218
	(0.808)	(0.510)	(0.106)	(0.679)
EER(-8)	-0.945	-0.261	-0.044	-0.759
	(0.574)	(0.362)	(0.075)	(0.482)
FC(-1)	0.370	-0.001	0.011	0.874
	(0.202)	(0.128)	(0.027)	(0.170)
FC(-2)	0.091	-0.022	-0.028	0.193
	(0.233)	(0.147)	(0.031)	(0.196)
FC(-3)	-0.438	0.091	-0.031	-0.316
	(0.232)	(0.146)	(0.030)	(0.195)
FC(-4)	-0.407	-0.224	0.071	-0.226
	(0.236)	(0.149)	(0.031)	(0.198)
FC(-5)	0.323	0.089	-0.029	0.245
	(0.233)	(0.147)	(0.031)	(0.196)
FC(-6)	-0.077	0.322	-0.041	-0.002
	(0.229)	(0.144)	(0.030)	(0.192)
FC(-7)	0.328	-0.276	0.067	0.243
	(0.283)	(0.179)	(0.037)	(0.238)
FC(-8)	-0.006	-0.045	-0.045	0.130
	(0.320)	(0.202)	(0.042)	(0.269)
Constant	-0.579	2.166	0.367	-0.584
	(1.401)	(0.885)	(0.184)	(1.177)
R^2	0.991	0.981	0.993	0.992

True lag: 7, additional lag: 1.

2009

Exogenous variables	Equations (indigenous variables)			
	WTI	DJI	EER	FC
WTI(-1)	1.204	-0.029	0.013	-0.020
	(0.136)	(0.060)	(0.017)	(0.103)
WTI(-2)	-0.099	0.113	-0.057	0.241
	(0.209)	(0.092)	(0.027)	(0.159)
WTI(-3)	0.015	-0.028	0.010	-0.018
	(0.140)	(0.062)	(0.018)	(0.107)
DJI(-1)	0.001	0.837	-0.079	-0.025
	(0.177)	(0.078)	(0.023)	(0.135)
DJI(-2)	0.265	0.105	0.045	0.233
	(0.225)	(0.099)	(0.029)	(0.171)
DJI(-3)	-0.371	-0.011	0.023	-0.254
	(0.178)	(0.079)	(0.023)	(0.136)
EER(-1)	0.304	-0.073	0.759	0.189
	(0.587)	(0.259)	(0.075)	(0.446)
EER(-2)	-0.752	-0.573	0.086	-0.788
	(0.730)	(0.321)	(0.093)	(0.555)
EER(-3)	-0.309	0.357	0.114	-0.038
	(0.571)	(0.251)	(0.073)	(0.434)
FC(-1)	-0.390	0.010	-0.008	0.919
	(0.187)	(0.082)	(0.024)	(0.142)
FC(-2)	-0.020	-0.164	0.052	-0.395
	(0.278)	(0.123)	(0.035)	(0.212)
FC(-3)	0.144	0.067	-0.004	0.106
	(0.186)	(0.082)	(0.024)	(0.141)
Constant	5.096	2.109	0.258	4.106
	(2.374)	(1.045)	(0.302)	(1.804)
R^2	0.980	0.984	0.989	0.982

True lag: 2, additional lag: 1.

2010

Exogenous variables	Equations (indigenous variables)			
	WTI	DJI	EER	FC
WTI(-1)	0.989	-0.236	-0.017	-0.052
	(0.265)	(0.161)	(0.052)	(0.244)
WTI(-2)	0.155	0.182	-0.003	0.217
	(0.274)	(0.167)	(0.054)	(0.253)
DJI(-1)	0.095	0.672	-0.038	0.068
	(0.171)	(0.104)	(0.034)	(0.158)
DJI(-2)	0.078	0.164	0.047	0.063
	(0.164)	(0.100)	(0.032)	(0.151)
EER(-1)	-0.303	-0.670	1.018	-0.280
	(0.515)	(0.313)	(0.101)	(0.475)
EER(-2)	0.440	0.490	-0.038	0.402
	(0.527)	(0.321)	(0.103)	(0.485)
FC(-1)	0.000	0.372	0.033	1.119
	(0.289)	(0.176)	(0.057)	(0.266)
FC(-2)	-0.305	-0.278	-0.011	-0.403
	(0.306)	(0.186)	(0.060)	(0.282)
Constant	-1.527	2.173	-0.005	-1.249
	(1.426)	(0.868)	(0.280)	(1.314)
R^2	0.899	0.898	0.940	0.905

True lag: 1, additional lag: 1.

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