Seoul Journal of Business
Volume 2 Number 1

Precedence and Exogeneity of Oil to the Stock Markets

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Abstract

This study investigates whether changes of oil price would have precedence, exogeneity and causal prediction to the stock markets. The result shows that changes of oil price have precedence over the stock returns in the United States, Japan and Korea markets. And the evidence suggests that there be exogeneity of oil to the stock markets because the stock returns can be causally interpreted by the current or past changes of oil price during the past two decades. Thus changes of oil price would contain any information exploitable in forecasting the stock markets and have the predictive value of leading indicators.

I. Introduction

The dependence of the world economy on oil was again reflected in the international reaction to Iraq's occupation of Kuwait. The Maneuvers by Iraq to raise the world price of crude oil late in July 1990 led to a near doubling of oil prices from \$16.10 to \$30.00 per barrel. In fact, this oil price movement is comparable to even the notorious OPEC price hikes of 1973–74 and 1979–80.

There are two distinguishing features of oil in the postwar world economy.

Acknowledgement: I would like to thank Yongkyun Kim and anonymous referees for valuable comments and suggestions. Youngil Kim provided very capable research assistance. All remaining errors and ambiguities are mine.

First, as you know, oil is a major resource that has been extensively used around the world. Second, oil price hikes in the postwar era appear to be dominated by shocks exogenous to the rest of world economy. Hamilton (1983, 1985), Helliwell, Sturm, Jarrett and Salou(1986) and Rasche and Tatom(1981) argue that they must give a causal interpretation to the correlation between oil prices and macroeconomic phenomena.

Given the importance of oil to the world economy, it is surprising that little research has been conducted on the effects of oil on the stock markt except Jones & Kaul(1996)[1]. They find that the relation of United States and Canadian stock prices to oil shocks can be completely accounted for by the impact of these shocks on real cash flows alone. In contrast, in both the United Kingdom and Japan innovations in oil prices appear to cause larger changes in stock prices than can be justified by subsequent changes in real cash flows or by changing expected returns.

This article conducts a detailed investigation to the effects of oil on stock returns during the past two decades. Our main contribution is that we gauge whether changes in oil price have precedence and exogeneity to the stock market returns in the United States, Japan, and Korea. The peculiar characteristics of oil shocks, that is, their precedence and exogeneity provided us a unique opportunity to evaluate the predictive values of the events that exogenously perturb the stock markets.

This paper investigates the reaction of stock returns to changes of oil prices in the United States, Japan and Korea markets. If the cross correlation coefficients at particular lags are inferred to be significantly different from zero, it suggests that changes of oil price proceed to build an appropriate model to describe the stock markets. And if variations of oil price are also exogenous and precedent to stock returns, the one will be useful in the prediction of the other.

The remainder of this article is organized as follows. Section II contains a discussion of the methodological basis about precedence, exogeneity and

1) Notable exceptions are a few recent studies that use oil prices as one of many risk factors that may be priced in the stock markets (see Chen, Roll, and Ross(1986), Ferson and Harvey(1993) and Schwert(1990)). The economic relevance of oil shocks is also reflected in their apparent significant importance in explaining the postwar negative relation between stock returns and inflation (see Fama(1990) and Kaul and Seyhum(1990)).

prediction. Section Ⅲ contains description of data and selection of lag length by Akaike Information Criterion. Section Ⅳ contains an analysis of experience of the United States, Japan, and Korea during the past two decades. Section Ⅴ contains a brief summary and conclusions.

Ⅱ. Methodology

1. Precedence

There have been many studies such as Bulmash & Trivoli(1990), Neftci (1982) and Rogalski & Vinso(1977) providing precedence and exogeneity among the macroeconomic variables in a country. Their studies have used the cross correlation analysis and direction of causality. The cross correlation analysis can provide the evidences about the lead-lag relation of variables. If the cross correlation coefficients at particular lags are inferred to be significantly different from zero, one may proceed to build an appropriate model to describe the relation. And if both variables are independent each other, the cross correlation coefficient will be zero for all lags. The lead-lag relation of variables, in other words, precedence can be pointed out in applying the Ljung−Box Q−statistics test. The fact that future lags of $X_1(t)$ have coefficients significantly different from zero shows precedence of $X_2(t)$ over $X_1(t)$.

Where if $E(x_1)$ and $E(x_2)$ are the sample means for each of the series $X_1(t)$, $X_2(t)$ and estimate of the cross covariance function is the following:

$$c_k[X_1(t);\ X_2(t)] = \begin{cases} \dfrac{1}{N}\sum_{t=1}^{N-k}[X_1(t)-E(x_1)][X_2(t+k)-E(x_2)] \\ \qquad\qquad \text{for} \quad k=0,1,2,3,\cdots \\ \dfrac{1}{N}\sum_{t=1}^{N-k}[X_2(t)-E(x_2)][X_1(t+k)-E(x_1)] \end{cases} \quad \cdots (1)$$

These series may then be cross correlated to obtain the cross correlation coefficient:

$$\hat{r_k} = r_k[X_1(t);\ X_2(t)] = \frac{c_k[X_1(t);\ X_2(t)]}{\sqrt{c_0[X_1(t)]}\ \sqrt{c_0[X_2(t)]}} \quad \cdots (2)$$

Haugh(1976) has shown that if the two series $X_1(t)$ and $X_2(t)$ are white noise series after filtering and the two series are independent, then the sets of cross correlation estimators are asymptotically uncorrelated with one another and would be normally distributed with zero mean and constant variance $1/N$.

Given these asymptotic results under the null hypothesis of series independence, Ljung−Box statistic Q for K lags is the following:

$$Q^{*}=T(T+2)[\sum_{j=1}^{K}\frac{\Pi_j^2}{T-J}] \qquad \cdots (3)$$

where Π_j is the jth lag autocorrelation coefficient of residuals, K is the number of autocorrelation used, and is selected according to the formula $K=\min(T/2, {}^3\sqrt{T})$, with a maximum value for K of 36. T is the number of sample observations. Under a null hypothesis of no serial correlation, Q is asymptotically distributed as a χ^2.

In applying this test, the fact that future lags of the independent variable have coefficients as a whole significantly different from zero only shows that the independent variable has the joint precedence over the dependent variable. And we suggest that this proceed to build an appropriate model to describe the relation. If the estimated correlation coefficients have significantly negative values, one may conclude that the interaction between each variable is reciprocal.

2. Exogeneity

The generally accepted definition of causality is due to Granger(1969) and is based on the time series notion of predictability. That is, given a set of variables, variable X_1 causes variable X_2 if present values of X_2 can be predicted more accurately by using only past values of X_1 than by using all or any combination of other variables in what follows as it is a suitable definition for empirical testing.

We begin by specifying a criterion to evaluate the predictive value of a stochastic process. Thus, let $X_1(t)$ and $X_2(t)$ be two jointly covariance-stationary and linearly regular stochastic processes with zero means.

Let the series $\varepsilon_k(t)$ and $\varepsilon_k^*(t)$ be given by

$$\varepsilon_k(\mathrm{t})=X_1(t)-\sum_{s=1}^{k} b_{k(s)}X_1(t-s),$$

$$\varepsilon_{k^*}(\mathrm{t})=X_1(t)-\{\sum_{s=1}^{k} a_{k1}(s)X_1(t-s)+\sum_{s=1}^{k} a_{k2}(s)X_2(t-s)\}$$

Then we say that $X_2(t)$ is useful in predicting $X_1(t)$, *if*

$$\lim_{k\to\infty} \{ \mathit{inf}\ E\,|\varepsilon_k^{*(t)}|^2\} < \lim_{k\to\infty} \{ \mathit{inf}\ E\,|\varepsilon_{k(t)}|^2\}. \qquad \cdots (4)$$

Otherwise, we say that $X_2(t)$ is not useful in predicting $X_1(t)$.

It is well known that if $X_1(t)$ and $X_2(t)$ are jointly covariance-stationary and linearly regular, then there will exist sequences or lag distributions $\{a_{k1}\}$, $\{a_{k2}\}$ and $\{b_k\}$ which will satisfy the equality or the strict inequality in (4). Thus given any two time series satisfying these conditions, we can in principle determine whether the one is useful in predicting the other in the sense of Granger definition. What makes this definition operational in the present case is the following:

$$\sum_{s=0}^{\infty} a_{11}(\mathrm{s})\mathrm{X}_1(t-s)+\sum_{s=0}^{\infty} a_{12}(\mathrm{s})\mathrm{X}_2(t-s)=e_1(t) \qquad \cdots (5)$$

$$\sum_{s=0}^{\infty} a_{21}(\mathrm{s})\mathrm{X}_1(t-s)+\sum_{s=0}^{\infty} a_{22}(\mathrm{s})\mathrm{X}_2(t-s)=e_2(t) \qquad \cdots (6)$$

where $e_1(t)$ and $e_2(t)$ are serially uncorrelated white noise processes with $a_{11}(0)=1$ and $a_{22}(0)=1$. Then, if $\{a_{21}(s)=0$, all $s\}$, $X_2(t)$ is said to be causally prior with respect *to* $X_1(t)$ in Granger's sense.

If $X_1(t)$ and $X_2(t)$ represent a leading and a coincident indicator respectively, and if $\{a_{21}(\mathrm{s})=0$, all s$\}$, then the coincident indicator will be causally prior with respect to the leading indicator. But the leading indicator will not be useful in predicting the coincident series.[2] Thus, the test to determine whether a series is useful in prediction reduces to a test of the causal priority of coincident series.

In order to overcome these conditions, Sims (1974) shows that one way to proceed is to estimate the two-sided distribution lags:

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2) This also requires that

$$\lim_{k\to\infty} e_k^* = e_1(t),$$
$$\lim_{k\to\infty} e_k^* = e_2(t).$$

But if $\{a_{21}(s)=0$, all $s\}$, then these conditions will be satisfied too.

$$X_1(t)=\sum_{s=-\infty}^{\infty} b_1(s)X_2(t-s)+e_1(t), \quad \cdots (7)$$

$$X_2(t)=\sum_{s=-\infty}^{\infty} b_2(s)X_1(t-s)+e_2(t), \quad \cdots (8)$$

where the first term on the right hand side represents the projection of $X_i(t)$, $i=1, 2$, and $e_1(t)$ and $e_2(t)$ are mutually orthogonal.

Under these conditions, he shows that the hypothesis

$$H_0: \{b_1(s)=0, \ -k_1 \leq s < 0\} \quad \cdots (9)$$

is then equivalent to the causal priority of $X_2(t)$ with respect to $X_1(t)$.

Geweek, Meese and Dent(1982) examined several forms of exogeneity tests and found that the Sims exogeneity test was sensitive to failure to correct for serially correlated residuals. As an alternative they proposed the exogeneity test using a two-sided distrbuted lag augmented with lagged dependent variables. Although the lag distribution on X_1 is changed completely by the addition of the lagged dependent variables, the X_1 coefficients are still one-sided under the null.

$$a_{11}(0)X_1(t)=\alpha_1(t)+\sum_{s=1}^{\infty} a_{12}(s)X_1(t-s)+\sum_{s=-\infty}^{\infty} a_{13}(s)X_2(t-s)+e_1(t) \quad \cdots (10)$$

$$a_{21}(0)X_2(t)=\alpha_2(t)+\sum_{s=-\infty}^{\infty} a_{22}(s)X_1(t-s)+\sum_{s=1}^{\infty} a_{23}(s)X_2(t-s)+e_2(t) \quad \cdots (11)$$

where $e_1(t)$ and $e_2(t)$ are mutually orthogonal. Under these conditions, if the null hypothesis $H_0(1): \{a_{13}(s)=0, \ s<o\}$ is rejected and $H_0(2): \{a_{22}(S)=0, \ s<o\}$ is not rejected, we suggest that X_2(t) have exogeneity to X_1(t). And if the two null hypotheses are not rejected, it is possible to say that X_2(t) has the feedback relationship with X_1(t).

This investigation tests whether the logarithmic differences in crude oil price are exogenous in a bivariate relation with stock market returns for the United States, Japan and Korea. Using their recommendation, we compute a two-sided distribution lag of stock markets on oil, including lagged stock variables.

III. Data Description and Lag Length Selection

This study investigates the experiences of three countries—the United States, Japan and Korea—to gauge precedence, exogeneity and prediction of oil to stock market returns. The effects of oil shocks are likely to vary considerably with each countries depending on their production and consumption of oil reserves. The experiences of the United States, Japan and Korea should provide a wide variety of evidence, with presumably different institutional and regulatory environments. The empirical analysis limits the period to the past two decades of 1975~1995 because of data availability considerations.

In the international crude oil market, there are four typical commodities as Arabian—Light, Dubai, Brent and WTI(West Texas Intermediates). Our footnote shows that their correlation coefficients are more than 98 percent during the recent decade[3]. Price series of international crude oil is transformed as first differences in the logarithms. Then, the monthly logarithmic difference of Arabian—Light crude oil price is chosen as the international oil variable in this study, because it has longer time series than Dubai, Brent and WTI

We measure the stock market returns by the monthly logarithmic difference on each country's stock composite index(i.e., S & P 500 for the United States, Nikkei 225 for Japan, Korea Composite Stock Price Index for Korea). The prewhitening by Hildreth—Lu scanning search is conducted to remove any serial correlation induced by the averaging of nonsynchronously measured components of the overall price index. This procedure has the advantage of removing any spurious statistical significance of lagged variables.

A number of criteria have been proposed for allowing the data to determine the length of a distributed lag. According to Christiano & Ljungquivst

3) Correlation Coefficients of International Crude Oil Prices.

(1985~1995)

	A−L	Brent	Dubai	WTI
A−L	1.0000	0.9908	0.9987	0.9827
Brent	0.9908	1.0000	0.9897	0.9914
Dubai	0.9987	0.9897	1.0000	0.9801
WTI	0.9827	0.9914	0.9801	1.0000

(1988) and Geweek(1984), the consequences of cross correlation analysis and exogeneity test turn out to be very sensitive to the choice of lag length.

We select the lag length by minimizing the function over different choices for the length of lag. There are Likelihood ratio test, Akaike Information Criterion, Schwarz Criterion and Hannan & Quinn as the method of lag length selection.

Since the only real difference among them is the precise functional form, it would be generally conducted by two of them, the Akaike Information Criterion (AIC) and the Shwarz Criterion (SC). AIC will be chosen for this study because the Shwarz Criterion puts a heavier penalty on additional parameters. We will use AIC as the following

$$AIC=T\log(RSS)+2k \qquad \cdots (12)$$

where k is the number of regressors and T is the number of observations.

The results of AIC between crude oil prices and stock market returns for each country are reported in table Ⅲ-1. The evidence shows that the minimum is at lag 6 in Korea, lag 6 in United States and lag 5 in Japan stock market. We make a selection lag 6, that is 6 months, as the criterion of lag length in this precedence and exogeneity test.

Table Ⅲ-1 Akaike Information Criterion between Changes of Crude Oil Price and Stock Market Returns for the United States, Japan and Korea.

This table contains estimates of formulation (12)

$$AIC=T\log(RSS)+2k$$

where k is the number of regressors and T is the number of observations. Estimation period is 1975. 2~1995. 12

Lags	U.S.A	Japan	Korea
0	143.96	144.35	139.30
1	142.04	144.32	140.36
2	144.01	145.88	142.34
3	143.81	144.28	141.41
4	142.21	143.37	140.96
5	141.21	142.75	142.34
6	140.84	145.70	137.81
7	141.34	146.47	139.80

Lags	U.S.A	Japan	Korea
8	143.05	148.28	141.63
9	143.85	149.71	143.07
10	144.34	148.63	142.90
11	145.54	149.19	142.90
12	147.49	151.18	144.08
13	149.46	151.57	145.76
14	151.63	437.45	147.28
15	438.26	439.45	149.05
16	440.45	441.30	147.81
17	439.59	443.07	148.19
18	439.78	444.87	150.32
19	441.79	446.81	152.15
20	441.45	447.59	151.61
21	441.58	447.78	153.52
22	442.09	448.31	155.48
23	442.95	449.52	157.35
24	444.78	451.40	436.96

Ⅳ. The Evidence

In the United States, Japan and Korea stock markets, if changes of crude oil price and stock market returns are independent each other, the cross correlation coefficient will be zero for all lags. Table Ⅳ−1 reports the cross correlation coefficient computed between stock market returns and the logarithmic differences in oil price using the function (2). We can observe negative coefficients of oil price with stock returns at lag 1 to 4 for all invested markets. Therefore crude oil price appears to cause minus changes in stock prices during four months. It suggests that the interaction between crude oil price movements and stock market returns is reciprocal in four months.

Table Ⅳ−1. Cross Correlation Coefficient Between Changes of Oil Price and Stock Market Returns for the United States, Japan and Korea.

This table contains estimates of function (2):

$$\hat{r_k}=r_k[X_1(t);\ X_2(t)]=\frac{c_k[X_1(t);\ X_2(t)]}{\sqrt{c_0[X_1(t)]}\ \sqrt{c_0[X_2(t)]}}$$

where $\hat{r_k}$ is estimate of the cross correlation coefficient. c_k is estimate of the cross co-variance between the logarithmic difference in oil price and each stock market returns at lag K. Estimation period is 1975. 2~1995. 12.

series (239 obs)	Lags	0	1	2	3	4	5	6
U.S.A	0 to 6	−0.08	−0.07	−0.05	−0.00	−0.04	0.10	0.03
	−1 to −6		−0.08	0.03	0.01	0.02	0.06	−0.02
Japan	0 60 6	−0.11	−0.02	−0.04	−0.08	−0.01	0.09	0.04
	−1 to −6		−0.20	0.06	0.01	0.06	0.01	0.09
Korea	0 60 6	−0.16	−0.09	−0.02	−0.09	−0.11	0.01	0.13
	−1 to −6		−0.15	0.02	0.05	−0.05	−0.11	0.03

In applying the Ljung−Box Q−statistics tests, we bear in mind that the lead−lag relation of variables can be found. Under a null hypothesis of no serial correlation, Q is asymptotically distributed as a χ^2. The fact that future lags of the independent variable have coefficients significantly different from zero shows the precedence of the dependent variable over the independent. Table Ⅳ−2 contains estimates of formulation (3). The evidence shows that the logarithmic difference in oil price have significant coefficients at a 5% confidence level with stock market returns at lags 1 to 6 in each country At lags −1 to −6, however, there is no significance. This result suggests a unidirectional theory of causality. And we find that in recent two decades crude oil variable have precedence over stock market returns for the United States, Japan and Korea. Instead there are no significant relation between changes of oil price and stock market returns at lags −1 to −6 for three experimented countries.

Table Ⅳ−2. Precedence Analysis of Cross Correlation Between Changes of Oil Price and Stock Market Returns for the United States, Japan and Korea.

This table contains estimates of statistic (3):

$$Q^{*}=T(T+2)[\sum_{j=1}^{K}\frac{\Pi_j^2}{T-J}]$$

where π_j is the jth lag autocorrelation coefficient of residuals, K is the number of autocorrelation used, and is selected according to the formula $K+\min(T/2, \sqrt[3]{T})$, with a maximum value for K of 36. T is the number of sample observations. The hypothesis tests are conducted using Ljung−Box Q−statistics. Estimation period is 1975. 2∼1995. 12.

country	Ljung−Box Q−statistics	significance level
U.S.A.	Q(1 60 6)=717.40	0.0000
	Q(−6 to −1)= 3.48	0.7463
	Q(−6 to 6)=973.88	0.0000
Japan	Q(1 60 6)=528.16	0.0000
	Q(−6 to −1)= 8.76	0.1873
	Q(−6 to 6)=789.92	0.0000
Korea	Q(1 60 6)=479.18	0.0000
	Q(−6 to −1)= 10.96	0.0894
	Q(−6 to 6)=743.14	0.0000

This study tests whether changes in oil price have exogeneity to stock returns for the United States, Japan and Korea markets. We compute a two−sided distributed lag of stock market returns on oil, including lagged stock market returns. Table Ⅳ−3 reports the result of implementing test described in (12) by using Geweek, Meese and Dent's exogenous procedure.

Table Ⅳ−3. Exogeneity Analysis of Oil to Stock Market Returns for the United States, Japan and Korea.

This table contains estimates of regression(10),(11):

$$a_{11(0)}X_1(t)=\alpha_1(t)+\sum_{s=1}^{\infty} a_{12}(s)X_1(t-s)+\sum_{s=-\infty}^{\infty} a_{13}(s)X_2(t-s)+e_1(t)$$

$$a_{21(0)}X_2(t)=\alpha_2(t)+\sum_{s=-\infty}^{\infty} a_{22}(s)X_1(t-s)+\sum_{s=1}^{\infty} a_{23}(s)X_2(t-s)+e_2(t)$$

where $e_1(t)$ and $e_2(t)$ are mutually orthogonal. Under these conditions, if the null hypothesis $H_0(1):\{a_{13}(s)=0,\ s<0\}$ is rejected and $H_2(0):\{a_{22}(S)=0,\ s<0\}$ is not rejected, we suggest that X_2 be exogenous relationship with X_1. And if the two null hypotheses are not rejected, it is possible to say that X_2 has the feedback relationship with X_1. Estimation period is 1975. 2~1995. 12. ( ) is significance level

	R^2	D.W.	F(13.220) lags −6 to 6	F(6.220) lags −6 to −1
OIL on KOR	0.157	2.010	1.615	1.684
			(0.082)	(0.125)
KOR on OIL	0.284	1.976	2.025	2.223
			(0.019)	(0.041)
OIL on USA	0.423	1.977	1.472	1.202
			(0.129)	(0.306)
USA on OIL	0.274	1.999	1.375	2.482
			(0.172)	(0.007)
OIL on JPN	0.106	1.952	1.684	1.399
			(0.065)	(0.215)
JPN on OIL	0.278	2.005	1.525	2.199
			(0.109)	(0.044)

Table Ⅳ−3 reports that exogeneity test result of oil to the stock market returns for the United States, Japan and Korea during the past two decades. Under the condition that error terms are mutually orthogonal, the evidence shows that future lags of the stock market returns on oil have F(6,220)−statistics significantly different from zero for every three countries. The result also reports that future lags of oil on stock market returns have F(6,220) −statistics insignificantly different from zero for the United States, Japan and Korea. In other words, F(6,220)−statistics estimated for future lags −6 to -1 have significance in oil as dependent variable but no significnace as independent variable for each experimented country. This test result helps us determine that changes of oil price be exogenous with stock market returns for the United States, Japan and Korea.

The precedence of oil reported in table Ⅳ-2 and the exogeneity of oil in table Ⅳ-3 provide a useful information in prediction about stock market returns during the past two decades. Consequently, we conclude that changes of crude oil price would contain any information exploitable in forecasting the United States, Japan and Korea stock markets and have the predictive value of leading indicators.

Ⅴ. Conclusion

In this article, we show that changes in oil price have precedence, exogeneity on stock market returns in the United States, Japan and Korea during the past two decades. The precedence and exogeneity of provide an opportunity to test whether it has the predictive value of leading indicator to forecast the stock markets. The evidence suggests that the logarithmic difference of crude oil price contains any information exploitable in forecasting the stock market returns for the United States, Japan and Korea. The result of statistically significant characteristics of oil prices on stock market returns suggests that either changes in oil price are useful in predicting stock returns, or the stock markets are inefficient. Thus if we can manage our portfolio having consideration for the characteristics of crude oil price what is called one of the international common factors, it would be able to expect the excess stock market returns.

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