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Fundamentals Affecting Oil Prices: An Empirical Study

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Abstract

This paper studies the oil price volatility and investigates the factors that affect the spot oil price and might have contributed to the oil price increase. After approaching the oil price volatility, a linear model for spot oil price determination is estimated. Five variables: the spot oil price, the oil demand and supply, the $ exchange rate value and activity in future markets validate a long-run relationship. Together these variables allow the model to perform well and explain the winner situation of oil exporter countries in the short and long term. However the estimation of the Vector Error Correction Model (VEC) shows that the oil supply influences negatively the spot oil price in long term and, the oil demand as well as the Special Drawing Receipt (SDR)/$ exchange rate are significant for oil price determination in the short term only while, the activity in future market is insignificant in determining spot oil price in short and long term.

الأساسيات الاقتصادية التي تؤثر على أسعار النفط: دراسة تجريبية

لطيفة غلاييني

ملخص

تدرس هذه الورقة تقلب أسعار النفط وتحقق في العوامل التي تساهم في هذه التقلبات. فبالإضافة إلى العرض والطلب على النفط الخام تدرس هذه الورقة تأثير عاملين اخرين على سعر النفط هما سعر صرف الدولار والظروف السائدة في الأسواق الآجلة للنفط. وقد تم إثبات وجود علاقة طويلة المدى بين سعر النفط وهذه العوامل الأربعة، مما أمكن بواسطة استخدام وسائل الإقتصاد القياسي من بناء نموذج لتحديد سعر النفط يكون فيه هذا الأخير متغيراً تابعاً والعوامل الأربعة السالفة الذكر متغيرات مستقلة. تسمح هذه المتغيرات للنموذج بأداء جيد لتبيان الحالة الرابحة للدول المصدرة للنفط من تقلبات أسعار النفط على المديين القصير والطويل.

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1. Introduction

Oil prices have been variable since the large price increases of the 1970s and 1980s. The wide price fluctuations in 2007, when daily spot prices for marker crudes nearly doubled between January and November, and fluctuations by more than US$20 a barrel in early 2008, reinforce the idea that oil prices are volatile. What factors influence the crude oil price and make it fluctuate? Does this oil price fluctuation favor exporter or importer countries? In other words, who are the winners in the crude oil price game – the oil exporters or the oil-importing countries?

The existing empirical literature on crude oil price does not give a satisfactory answer. Existing research has either exploited the statistical properties of the data – namely autocorrelation and non-stationary – or has focused on macroeconomic or financial variables as the determinants of oil prices. This paper takes a novel approach and demonstrates a linear model which describes the price determination process in the oil market. The oil price as the price of any other commodity is determined by the supply and demand of this commodity, but because oil contracts are settled in US dollar and the increasing speculation on oil contract, the model for crude oil price determination is expanded to include the supply and demand, the Special Drawing Rights (SDR)[(1)]/$ exchange rate and conditions in future markets as explanatory variables. Together, these factors allow the model to perform well and explain the winner situation of oil exporter countries in the short and long term.

2. Literature Review

There are three schools of thought in relation to the determination of crude oil prices, but none has been entirely successful in predicting the path of oil prices. The first school examines the interaction of demand and supply in the determination of the spot price. Microeconomic theory states that if there is excess demand, prices will rise to restore equilibrium. Alternatively, if there is excess supply, prices will fall. The presence of excess supply or demand is evidenced in crude oil inventories. Zamani (2004) presented a short-term quarterly forecasting model of the real West Texas Intermediate (WTI) price that accounts for both the role of the Organization of Petroleum and Exporter Countries (OPEC) and the physical oil availability of relative inventory levels. Zamani included in his model OPEC quotas, overproduction and non-Organization for Economic Development and Cooperation (OCDE) demand as explanatory variables. Ye et al. (2002, 2005 and 2006) used relative oil inventory levels to forecast oil prices.

The second school of thought posits that commodity markets are generally efficient and holds the view that futures prices have the power to forecast realized spot prices. A widely supported approach is taken by Chinn, LeBlanc and Coition (2005), postulating that the best predictor of future spot prices is futures prices. While they found that futures prices are unbiased predictors of future spot prices, the prediction error is large. Taback (2003) also found similar results but also observed that the explanatory power of futures prices is low for changes in spot prices.

Merino and Ortiz (2005), extending the various works of Ye et al. (op.cit.) investigated whether some explanatory variables can account for the fraction of oil price variations that is not explained by oil inventories. The authors acknowledged as possible sources of variation the following: (a) the difference between spot and futures prices; (b) speculation defined as the long-run positions held by non commercials of oil, gasoline and heating oil in the New York Mercantile Exchange (NYMEX) futures market; (c) OPEC's spare capacity along with the relative level of US commercial stocks; and (d) different long-run and short-run interest rates. Exploiting causality and co integration tests, the authors identified the importance of the speculation variable which, among others, appears to add systematic information to the model.

A different approach in forecasting oil prices is proposed by Lalonde et al. (2003), who tested the impact of the world output gap and the real US dollar effective exchange rate gap on WTI prices. A comparison with a random walk and with an Autoregressive of Order 1 (AR (1)) specification suggests that both variables play an important role in explaining oil price dynamics. Sanders et al. (2009) investigated the empirical performance of the Energy Information Administration (EIA) model for oil price forecasting at different time horizons. This model is a mixture of structural and time series specifications, which includes supply and demand as the main factors driving oil prices, and takes into account the impact of past forecasts. The authors found that EIA three-quarters ahead oil price forecasts, are particularly accurate.

The third approach is taken by Kaufmann et al. (2004) who used macroeconomic fundamentals such as GDP and interest rate to model fuel demand and supply and hence, explaining spot prices. A similar approach is taken by Krichene (2005) and Krichene (2007). In Kaufmann et al. (2007)[(2)], oil prices are driven by OPEC quotas and capacity utilization, which are shown to be statistically relevant over the period 1984-2002. Although the models capture supply and demand influences, significant forecast errors are evident in certain periods.

This paper presents a linear model for the oil market and proves a long-run relation between crude oil price and the world real gross domestic product, the world oil production, the SDR/$ and an open interest in the NYMEX.

3. Oil Market and Price Trend

Crude oil is produced in nearly every corner in the world.(3) If oil were a normal commodity, competition would eventually drive the price down to a level close to the current cost of production, which at the margin, is probably somewhere between $20 and $30 a barrel. However, the oil market is hardly a text book case of open competition. The OPEC cartel controls 40% of the supply and they possess about 78% of the world's total proven crude oil reserves. This gives OPEC a pivotal influence in shaping the direction of oil prices – but only when the cartel acts together to control production and balance supply and demand in the international market. Furthermore, geopolitics is an ever-present factor, as is speculation.

The most widely accepted theoretical approach to the economics of oil focuses on the prevailing oligopolistic market. According to Adelman (1993), the long-term marginal cost is a small fraction of the price of oil, even when making considerable allowances for the future values of the resources used up today (user cost). To support high price levels, the excess supply is restricted by a cartel. The market works in the following way – higher-cost producers sell all they can produce, while low-cost producers satisfy the remainder of the demand at current prices and cut back production if needed.

Econometric evidence on Saudi Arabia confirms the asymmetric behavior of the low-cost petroleum suppliers: the country restricts production in reaction to negative demand shocks but does not expand production in response to positive ones, in order to sustain high prices (De Santis, 2003). The oligopolistic structure of the oil market or the dominant role of Saudi Arabia is supported in a number of other empirical studies (Griffin, 1985; Alhajji and Huettner, 2000; and Dees et al., 2003).

Overview of the Supply

The power of the producing countries is, in general, rooted in the characteristics of oil. Producers incur no storage costs since petroleum is simply left in the ground whereas consuming countries have to cover the technical costs of building storage facilities, interest on the value of oil stocks and various risks. In addition, oil production is not labor-intensive and, therefore, the oil supply can be controlled easily by reducing depletion rates without affecting the labor market. Since there are no short-term substitutes for petroleum, changes in supply are also effective. Moreover, demand for crude oil is highly insensitive to price changes (Cooper, 2003).

Oil supply and its relation to crude prices can be looked at in two ways: long and short term. Short term does not really include how much oil is still sitting in the ground. While oil reserves are diminishing, there is still enough black stuff down there that the effects from immediate factors mitigate long-term ones. Thus, the major short-term factors include the production decisions of OPEC and non-OPEC countries, how much spare capacity there is for excess oil and external shocks that affect output, such as wars and politics.

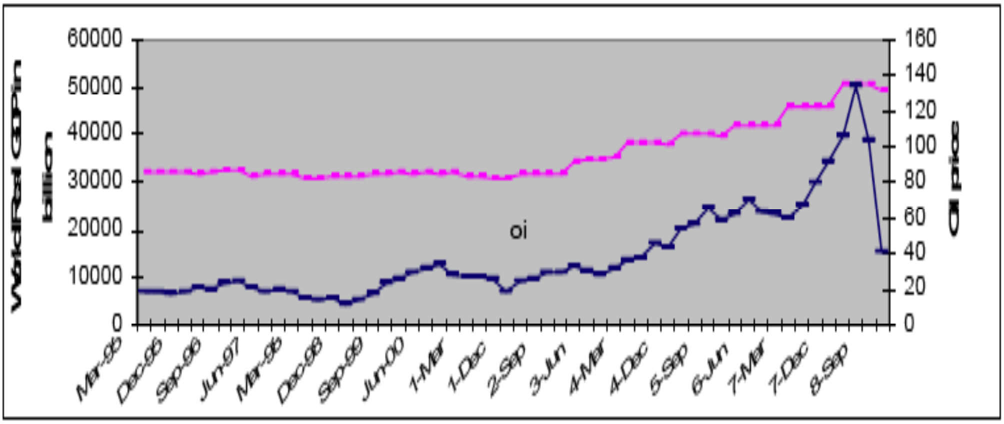
From a long-term perspective, oil supply depends mostly on just how much crude is left in the global reserves, and what kind of government is sitting on top of them. Other factors may also include exploration and how successful and efficient oil companies are at finding new wells. New developments in technology also play an important role, allowing for more efficient and profitable extraction and refining of oil previously unusable or inaccessible.

OPEC is the main player in the supply side – controlling 40% of the supply, and possessing about 78% of the world's total proven crude oil reserves. It behaves as a semi-cartel in normal times by aiming to maintain excess extraction capacity in order to influence crude oil prices. Non-OPEC producers, on the other hand, have relatively limited reserves and spare capacity, and generally behave as price takers. At certain times, OPEC has relatively clear influence on oil prices, as in 1996, when a flood of Saudi crude oil came on the market and drove down prices. In recent years, its policy has been to balance the market while allowing for an appropriate level of crude oil inventories in consuming nations.

The Demand for Oil

Unlike supply, demand for crude oil depends on the choices of many individual households and firms. In addition to demographic factors, oil prices are linked, like those of other commodities, to the levels of economic activity in the industrial nations. Demand, both from consumers and industrial users, tends to pick up when growth rates of gross domestic product increase and slows down when those growth rates decline. As world economic growth increases, the demand for oil increases which consequently pushes up oil price. Oil prices then, tend to be volatile, at least partly due to variations in the business cycle (Figure 1).

In December 1998, economic growth decreased and pushed down the demand for oil and therefore, reduced oil price. The world economy continued its recovery in 2003 and 2004 with gross domestic product (GDP) growth rates increasing in many regions. The strongest growth performances were in oil-importing United States and China, but better performance was also observed in Japan and Russia, as well as the emerging growth nations of Asia. US growth was 3.1% in 2003, and reached 4.6% during 2004. Chinese economic growth was 7.4% in 2003 and reached 6.8% in 2004, moderating only slightly for 2005.[4] In the United States, economic growth has been linked to high levels of oil consumption, of which increasing gasoline demand is an important component. In China, expanding exports have increased the industrial demand for oil, and rising consumer income has increased consumers demand for gasoline. US oil demand increased by 1.9% in 2003 to over 20 million b/d. Chinese oil demand increased by 11.5% in 2003 to almost 6 million b/d.[5]



Source: Prepared by the author based on Data and Statistics, International Monetary Fund (2004)

Figure 1. Variation of world real GDP and oil price from 1995, Q1 – Q4, 2008.

In both the United States and China, the increase in GDP growth and economic activity in general, has led to increases in energy demand. However, a feedback relationship exists which can mitigate this effect. To the extent that oil prices rise, reflecting increased oil demand, GDP growth rates might decline for two reasons. If the monetary authorities interpret increasing oil costs as generalized price inflation, they may adopt restrictive monetary policies which could slow the economy's growth. Also, if oil product prices rise, and consumers are unable or unwilling to reduce oil product consumption, consumers may reduce expenditures on other goods and services, again potentially slowing the rate of GDP growth.

While the United States and China increased their demands for crude oil and petroleum products as a result of their GDP growth, oil exporter countries, improved their GDP growth rate. High oil prices, based on rising oil demand, create an inflow of oil derived revenue, increasing GDP growth. The danger for these nations is that if prices go too high, and stay high, GDP growth in the consuming nations might decline, reducing the demand and price of oil. An additional factor is that high prices lead to increases in exploration and development budgets around the world. As new oil is found and brought to market, supply increases and prices might be reduced, damaging the oil exporting nation's growth. High oil prices can also stimulate industrial countries to develop and use alternative fuels (oil substitutes) more competitive, potentially reducing the demand for oil.

The Spot, Term and Future Markets

Initially, most trade flows were conducted under term contracts.(6) Since the early 1980s, however, the petroleum industry has become increasingly dependent on the spot market and spot prices.(7) Although the spot market accounts for less than 50% of physical oil sales, spot prices are the primary determinant of almost all other petroleum prices. They are, for example, used in most pricing formula for the term crude oil sales of OPEC and many other producing countries (Energy Intelligence, 2004).

The other recent development in the oil industry is the growing influence of the market for future contracts.(8) In 1983, NYMEX introduced the first crude oil futures contract. By 1990, there were 10 active oil futures contracts trading worldwide, with a combined daily volume equivalent to 150 million barrels a day, or 130% more than oil demand at the time. Today, total NYMEX oil futures trading activity represents the equivalent of 600 million barrels, which is about seven times the daily volume of current oil demand.

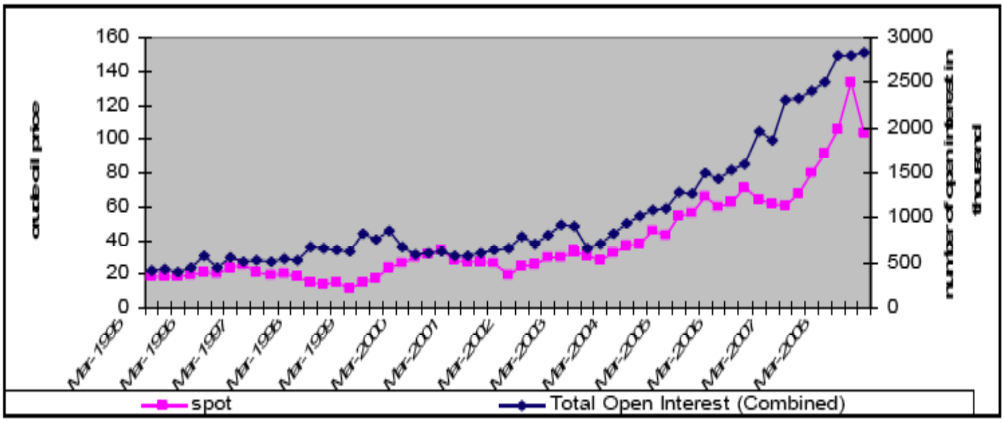
NYMEX and the Inter Continental Exchange (ICE) Futures in London control global benchmark oil prices which in turn set most of the freely traded oil cargo. They do so via oil future contract on two grades of crude oil – the WTI and the North Sea Brent. A third rather new oil exchange, the Dubai Mercantile Exchange (DME), trades Dubai crude.

The players in the energy markets are a diverse group of commercial and non-commercial investors. The set of so-called commercial traders – traditionally oil producers and energy companies that tend to hedge – has been expanded by the growing number of investment banks and hedge funds which own energy-producing facilities, and the emergence of specialized energy trading firms in the wake of financial market deregulation. Furthermore, the distinction between commercial and non-commercial traders is increasingly blurred as non-commercial traders may enter into swap arrangements in which commercial traders act as their agent.

Innovations in futures, options, and derivative instruments permit active trading, speculating, and hedging, i.e. linking markets for physical petroleum products with financial markets. While new investors could be instrumental in translating expected future fundamentals into current prices, excessive activity based on limited information may lead to a disconnect between the futures and physical markets. In particular, excessive activity by newcomers or "herd behavior" by investors may exaggerate the impact of concerns about current and future supply conditions at all points along the futures curve, including spot prices. Given that only about 5% of futures contracts are ever delivered as a physical product, increased uncertainty can encourage speculative behavior in the futures market. This, in turn, may push up futures prices beyond that warranted by future market fundamentals.

The large purchases of crude oil futures contracts by speculators have, in effect, created an additional demand for oil, driving up the price of oil for future delivery in the same manner that additional demand for contracts for the delivery of a physical barrel today drives up the price for oil on the spot market. As far as the market is concerned, the demand for a barrel of oil that results from the purchase of a futures contract by a speculator is just as real as the demand for a barrel that results from the purchase of a futures contract by a refiner or other user of petroleum. Figure 2 shows that crude oil price and oil open interest[9] move together with an upward trend.

On the other hand, causality tests suggest that speculative activity, as proxied by net non-commercial long positions, does not have a significant impact on spot prices, but it does moderately influence longer-dated futures prices. The results also suggest that speculative activity follows, rather than leads spot prices, as do longer-dated future prices, which supports the argument that changes in the fundamentals affect, via spot prices, perceptions regarding future physical market conditions.[10]



Source: Prepared by the author based on data from Commodity Futures Trading Commission 2010

Figure 2. Variation of crude oil price and total open interest, NYMEX: 3 March 1995 – 27 July 2010.

Oil Price and Traded Currency

Since oil is priced in dollars and generally paid for in dollars, exchange rate variations in the US dollar can affect the level and distribution of the world's oil demand and oil price as consequences. Several consequences may follow from this relationship. Firstly, if the value of the dollar declines against other currencies the dollars received by oil exporting nations are worth less in terms of world purchasing power. If oil exporters are able to exert market power in setting prices, or if market conditions permit oil exporters to dictate higher prices, they have incentives to increase the money price of oil in an attempt to preserve the purchasing power they earn through selling a barrel of oil.

Oil-importing countries have various reactions facing the dollar weakness. For the United States, of course, any increase in the dollar price of oil is immediately felt as an increased price burden, possibly leading to decreases in demand. For the euro-area consumers, the situation is different. Since the value of the euro has increased in terms of dollars, the effect of any increase in dollar-denominated oil prices is offset by the amount of euro appreciation. For example, if the euro appreciates by the same percent that the price of oil in dollars increases, the two effects cancel each other. The result is that the demand for oil in the euro area is less likely to be affected by high oil prices as long as the euro appreciates.

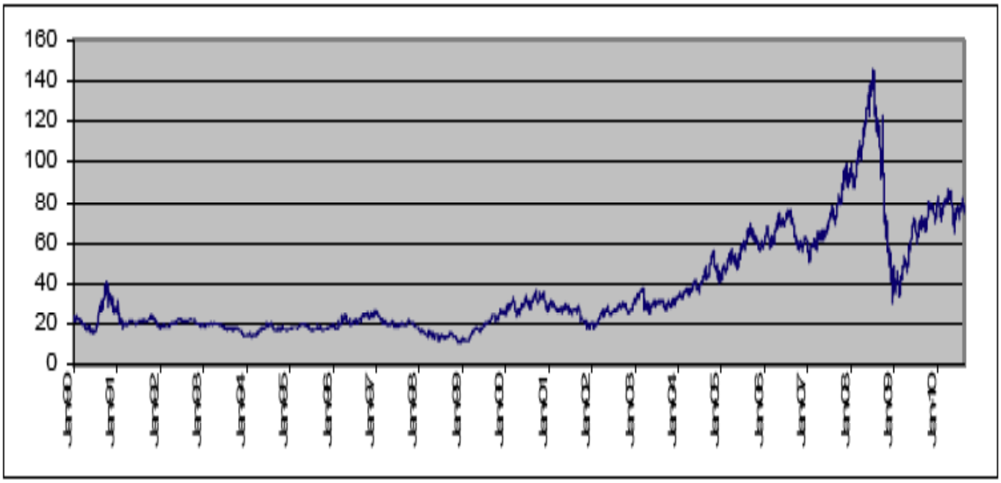
Nations that intervene in world currency markets to prevent the dollar from falling relative to their currencies – for example, Japan, Korea and Taiwan – are implicitly choosing to forego the associated real reduction in oil prices an appreciating currency would bring, to preserve the export advantage for their goods that a lower exchange rate brings. Since these nations are both large oil importers as well as major exporters on world markets, the choice can have important implications for their economies. China also foregoes (when the Yuan exchange rate was fixed with the $) any exchange rate-based benefit with respect to oil purchases in favor of supporting export industries.

4. Crude Oil Price Volatility

This section aims to provide an approach to the oil price volatility for data on daily crude oil prices (Energy Information and Administration, 2010) denoted by p_t, and covering March 1995 - March 2010. Figure 3 provides a starting point to the analysis of oil price behavior over the last 20 years. The graph shows that daily prices of WTI crude – one of the marker crudes – have varied continuously. Leading up to 2008, oil prices experienced a steady, upward trend. In 2008, oil prices climbed to an unprecedented high of $147 per barrel in July, only to fall dramatically in a very short period of time to a low of $30 per barrel in December 2008. Since the end of 2008, oil prices have risen in 2009 and are now near $70 per barrel in 2010.

Discounting the exceptional circumstances of the first Persian Gulf War, prices had tended to fluctuate within a narrower band for most of the 1990s. From 1999 to 2004, the biggest difference between the high and low price in any given year was $16; from 2005 on, the average variance was $52; but in 2008, it was $115.

The analysis of the volatility of a price series is based on the returns of the data, which are the period-by-period changes in the data. For example, returns on daily prices are the differences between prices in two consecutive days. In this study, as in many others, the preferred measure of the return is the difference in the logarithms of prices over two consecutive periods: $R_t = \log p_t - \log p_{t-1}$. Such a calculation gives an approximate percentage change in price when the magnitude of variation from one period to the next is small compared to the price levels themselves.



Source: Prepared by author based on data from Energy Information and Administration (2010)

Figure 3. Crude oil price (WTI, daily: January 1990 through August 2010).

Methodology

A GARCH[11] formulation was used to test whether the variance of returns is stationary and if price levels eventually revert back to a mean and, if they do, over what time period. The GARCH formulation tests an Equation specification[12] for the mean of the return series (Equation 1) in logarithms and Equation 2 for the conditional variance of the returns:

$$R_t = \log p_t - \log p_{t-1} = c + \varepsilon_t \qquad \text{(Equation 1)}$$

$$\sigma^2_t = \omega + \alpha \varepsilon^2_{t-1} + \beta \sigma^2_{t-1} \qquad \text{(Equation 2)}$$

where $\varepsilon_t \sim N(0, \sigma^2_t)$ and $\sigma^2_t = E(\varepsilon^2_t)$

The prior step is to analyze whether oil price are stationary. The standard test for the presence of a unit root is the Augmented Dickey Fuller (ADF) [13] test. This test was carried out on all the series used in this study. After determining the process stationarity, Box-Jenkins[14] procedure is applied in order to build and choose the appropriate model. This procedure consists of building and estimating the model once its type is known. The Ordinary Least Square (OLS) method is usually used in the case of auto regressive model (AR), but if the model is moving average (MA) or autoregressive-moving-average

(ARMA) – the maximum likelihood method is used since these models are not linear.

Results

Stationary Analysis. According to the calculated ADF value presented in Table 1, hypothesis of a unit root cannot be rejected for all variables in levels. The results further suggest that taking first differences remove these roots from the series implying that oil price series is integrated of order 1 (I(1)).

Table 1: Unit Root Test for Oil Price

Variables	Models	Lag	Calculated ADF in levels	Lag	Calculated ADF in Differences
Oil Price P_t	Intercept	2	−1.029670	1	−47.13202***
	Trend & Intercept	0	−2.688806	1	−47.12868***
	None	2	0.218364	1	−47.12430***

***Significant at the 1% level, ** Significant at 5% level, * Significant at 10% level

Source: Author's calculation

Model Building. The correlogram of the oil price presented in Table 1A in the Appendix shows the autocorrelation coefficients computed for the oil price series at different lag. It is clear that the autocorrelation function (ACF) tapers off and the partial autocorrelation (PACF) cuts off. It may be concluded then that this model is autoregressive (AR) of order one since PACF cuts off at 1. The AR 1 model is specified as:

$$P_t = \alpha P_{t-1} + u_t \qquad \text{(Equation 3)}$$

$$u_t = \rho\, u_{t-1} + \epsilon_t \qquad \text{(Equation 4)}$$

The parameter ρ is the first order serial correlation coefficient. In effect, the AR 1 model incorporates the residual from the past observation into the regression model for the current observation. Since the oil process is not stationary, the series has to be differentiated and the model estimation (computed data presented in Table 2A in the Appendix) is:

$$\Delta P_t = \underset{(0.872057)}{0.017373} - \underset{(-2.838898)}{0.045657}\, \Delta P_{t-1} + e_t$$

According to equation estimation, the variable ΔP_{t-1} is significant at 1%. After estimating the model, the next step is to test if there is autocorrelation between the residuals. Auto correlation test shows whether the serial correlation coefficients are significantly different from zero. The null hypothesis of the test is that there is no serial correlation in the residual up to the specified order. The test reported in Table 3A in the Appendix accepts the hypothesis of no serial correlation up to order 2, since the probability is greater than 5% and the Durbin Watson is around 2. The serial correlation test indicates that the residuals are not serial correlated and the equation can be used for hypothesis test or forecasting but the R-squared is very low.

Volatility Test. To test and measure the volatility, the ARCH and GARCH models are used. The test results reported in Table 4A in the Appendix indicate that the probability of each ARCH and GARCH is high. The estimation of Equation 2 is the following:

$$\sigma^2_t = 8.65E{-}08 + 0.053035\,\varepsilon^2_{t-1} + 0.932891\,\sigma^2_{t-1}$$
$$(5.328880)\ (12.032338)\qquad (150.7912)$$

The sum of ARCH and GARCH ($\alpha + \beta$) is very close to one, indicating that volatility shocks are quite persistent that is often observed in high frequency financial data. The fitting of the GARCH model shows high price volatility and periods of volatility clustering in the data sample under study.

6. Oil Price Determination Process

This section models the oil price determination process with crude oil price as the dependent variable.

Model Explanation

Since the world oil demand is mainly influenced by the world gross domestic product, the oil demand is represented in this study by the world real gross domestic product. However, the oil supply is represented by the world oil production. The two other explanatory variables are the SDR/$ exchange rate and the total[15] open interest representing respectively the variation of the $ value and the speculation in the oil market.

The following equation represents a model for oil price determination:

$$LogPrice_t = b_0 + b_1 LogGDP_t + b_2 LogOutput_t + b_3 LogRate_t + b_4 LogSpeculation_t + u_t \qquad \text{(Equation 5)}$$

in which U_t = noise disturbance term at time t, Price is the nominal crude oil price. GDP is the world real GDP which is calculated in dividing the world GDP by the world consumer price index (CPI). Production is the volume of world oil production per day (OPEC and non-OPEC countries). Rate(16) is the value of one SDR in terms of $. Speculation is the oil open interest contract in NYMEX. Quarterly data from the first quarter of 1995, Q1 to the last quarter of 2008 are used for all variables.(17) All variables except exchange rate are in logarithm form:

$Price_t$ = crude oil nominal price, in US$ per bl, $P_t = Log(Price)_t$;
$Output_t$ = world crude oil output, in millions of barrels per day, $q_t = Log(Output)_t$;
GDP_t = real GDP for world economy, $Y_t = Log(GDP)_t$;
$Rate_t$ = the value of SDR in terms of $, $X_t = Log(Rate)_t$;
$Speculation_t$ = the total open rate contract, $S_t = Log(speculation)_t$;

It is expected that the regression coefficient associated with the GDP to be positive – an increase in real world GDP will increase oil demand and increase oil prices. It is also expected that the production coefficient will be negative – an increase in oil production will increase the oil supply and reduce real oil price by reducing reliance on current production and thereby lowering the risk premium associated with a supply disruption.

A positive relationship is also expected between exchange rates SDR/$ and crude oil prices. This effect may be understood in two ways. The first way is since all oil contracts are concluded in $, the increase in exchange rate which means a depreciation in the $ value makes the oil less expensive, the demand for crude oil then increases and also the oil prices. The other way is that an increase of the SDR/$ exchange rate value reduces the real oil price, producers will react by reducing their production. The nominal oil price will then increase as response to the decrease in production.

Finally, the speculation coefficient is expected to be positive. In fact, high oil price volatility implies profit opportunities. The future contracts become important financial assets for the speculator and the development of paper oil market activity increases the future oil prices affecting the spot oil prices positively.

Econometric Methodology

The concept of co-integration, first introduced into the literature by Granger (1981), is relevant to the problem of the determination of long-run or equilibrium relationships in economics. From a statistical point of view, a long-term relationship means that the variables move together over time so that short-term disturbances from the long-term trend will be corrected.

If the similarly integrated series in any given model are co-integrated, then linear combinations of these variables will converge to stationary long-run equilibrium relationships. Thus, the non-stationary property of the series must be considered first. Testing for co-integration is the second stage of pre-testing. Passing this stage is a prerequisite to move on to the model building.

To test for co-integration, the method developed by Johansen in Johansen and Juselius (1988) is used. This method allows knowing the number of co-integrating vectors. It also allows using the vector error correction model (VEC)[18] to estimate Equation 5. The VEC[19] has co-integration relations built into the specification so that it restricts the long-run behavior or the endogenous variables to converge to their co-integrating relationships while allowing for short-run adjustment dynamic.

The co-integration term is known as the error correction term since the deviation from long-run equation is corrected gradually through a series of partial short-run adjustment. The Johansen procedure VEC has three steps: (a) The first step is to determine the co integration order of the variables; (b) The second is to determine the model and determine the rank[20] (r) of π; and (c) The third and final step is to determine the model order using Akaike (1974) and Schwarz (1978) criteria information.

Results and Discussion

Stationary Test. Table 2 indicates that all variables are stationary in first difference.

Co-integration Test. Since all variables being I(1), the test for co-integration is the next step. By using the log-level form of the series, a multivariate co-integration relationship is estimated to establish the existence of a long-run equilibrium relationship. The Johansen's Maximum Likelihood co- integration test relations are estimated with the intercept and linear deterministic trend in a Vector Auto Regression (VAR) model of order 1 with a lag length of 1, which is found to be the most parsimonious for the data series. The Johansen co-integration tests are based on the Maximum Eigenvalue of the stochastic matrix as well as the Likelihood ratio test which is in turn, based on the trace of the stochastic matrix.

Table 2. Unit Root Tests for Individual Series in Log

Variables	Lag	Calculated ADF in Levels	Lag	Calculated ADF in Differences
Pt	0	-1.352627	0	-3.975680***
	1	-2.804193	0	-3.817831**
	0	0.338087	0	-4.058995***
Yt	0	-2.744762	0	-6.765271***
	0	-1.629020	0	-7.604679***
	0	2.179798	0	-6.152061***
Qt	0	-0.79332	0	-5.955879***
	1	-1.919926	0	-5.995184***
	0	2.077912	0	-5.658203***
St	0	3.231538	1	-10.25595***
	0	1.362664	2	-10.36686***
	0	2.167697	1	-3.007523***
Xt	0	-1.399521	0	-6.866813***
	0	-2.262387	0	-7.195887***
	0	-0.029410	0	-9.218446***

*** Significant at the 1% level,** Significant at 5% level, * Significant at10% level

Source: Author's calculation

Table 5A in the Appendix shows the summary results of the Johansen's Maximum Likelihood co-integration test. For the null hypothesis of r = 0, the calculated trace statistics is larger than its critical value and calculated maximum Eigenvalue is also larger than its critical value at 5% level of significance. From the results, it is evident that both the trace test and maximum Eigenvalue test indicate one co-integrating equation as the null hypothesis of r = 0 is rejected. Thus, it may be concluded that there is a unique long-run equilibrium relationship between the variables.

Vector Error Correction Model. According to Akaike (1974) and Schwarz (1978), it is concluded that it is better to take the model in lag 2. Both the short- and long-run estimates as well as diagnostics are presented in Table 6A in the Appendix. It may be observed that the model fits the observed data fairly and significance of estimated relationships as indicated by the adjusted R^2 (0.506553) and F-statistic (3.546295) of the relevant error correction equation. The error correction coefficient (-0.425784), which measures the speed of adjustment towards long-run equilibrium carries the expected negative sign and it is highly significant at the 1% level.

The Long-Run Model Estimation:

$$P_t = -0.3432097Y_t - 6.264824Q_t + 0.187254S_t + 2.277338X_t - 0.067494\text{Trend} - 124.3669$$
$$(0.98814) \quad (2.55504) \quad (-1.03638) \quad (1.70298) \quad (-6.41120)$$

In the long run, the variable production is statistically significant with high elasticity level (-6). The negative sign of the production coefficient indicates the inverse relation between the volume of oil production and oil price as expected. A decrease of the world production by 1% increases the oil price by 6%. All other explanatory variables are not statistically significant. On the other hand, the estimation shows a significant trend in the long-run equilibrium price.

The Short-Run Model Estimation:

$$\Delta P_t = -0.425784\, e_{t-1} - 0.030893\, \Delta P_{t-1} + 0.329185\, \Delta P_{t-2} + 0.00663\, \Delta Y_{t-1}$$
$$(-5.04962) \quad (0.25244) \quad (2.36444) \quad (0.03583)$$
$$+ 0.574039\, \Delta Y_{t-2} + 1.243717\, \Delta Q_{t-1} + 2.57053\, \Delta Q_{t-2} + 0.85256\, \Delta S_{t-1}$$
$$(2.97119) \quad (0.68751) \quad (1.22812) \quad (0.51929)$$
$$- 0.192335\, \Delta S_{t-2} + 3.677654\, \Delta X_{t-1} + 1.882559\, \Delta X_{t-2} - 0.004688$$
$$(-1.33974) \quad (2.94669) \quad (1.56280) \quad (-0.21961)$$

The short-run equilibrium estimation shows that the variable price in time t-2 is statistically significant and affects the oil price in time t. It also shows that the variable real GDP is statistically significant at the 1% level. Then an increase in real GDP in time t-2 has an increasing effect on oil price in time t. The variable exchange rate in time t-1, which measures the value of $ in terms of SDR is significant. The positive sign of the coefficient indicates that a depreciation of the value of dollar increases the oil price in the short run.

The estimated parameters suggest that an increase in real GDP by one unit, results in an increase of oil price by 57% in six months ahead, while an increase by one unit in exchange rate ($ depreciation) results in an oil price increase by 367% in three months ahead. However, the variable speculation is not statistically significant in determining oil price.

6. Conclusion

Oil price fluctuated with an upward steady trend during the two last decades. This paper builds a linear model for oil price determination using five variables: (a) the spot crude oil price; (b) the real world real GDP; (c) the world oil production; (d) the SDR/$ exchange rate; and (e) the total open interest. The co-integration test shows that these variables move together, it validates the existence of a long-run relationship between these economic and financial variables. The VEC results allow however, estimating the adjustment dynamic of variables in the short term.

In relation to the real world GDP, in the short run, the variable real world GDP affects positively the oil price. An increase in real world GDP increases the oil demand and the oil price by consequences. In the long run however, the relation between oil price and real world GDP is negative. This may be explained by the fact that high oil price stimulates industrial countries which aim to sustain economic growth to develop and use oil alternatives affecting negatively the oil demand and consequently, the oil price. Furthermore, in order to control inflation caused by high oil price, the monetary authorities in oil-consuming countries may adopt restrictive monetary policies which could slow the economy's growth. Additionally, if oil product prices rise, and consumers are unable or unwilling to reduce oil product consumption, consumers may reduce expenditures on other goods and services, again potentially slowing the rate of GDP growth. To validate these observations, further investigations are needed such as extending the model to include variables representing the use of oil substitutes, the monetary policy and the consumption of manufactured products in oil consuming countries.

On other hand, relatively to SDR/$ exchange rate, in the short run, depreciation in the dollar value, an increase in the variable SDR/$ exchange rate, affects positively the oil price as expected. The invoice of oil importing-countries is then appreciated. In the long run however, oil-importing nations develop strategies in order to reduce the impact of dollar depreciation on the oil price and hence, on the inflation. Therefore, in the long run, the variable exchange rate becomes insignificant after being significant in the short run but with the positive expected sign.

Furthermore, since OPEC is the main player in the supply side, the OPEC production policy is a determinant factor for the oil price level in the long run. The crude oil market is then a-semi cartel equilibrium in the long run.

To recapitulate:

- In the short run, the oil price responds to the world real GDP growth and increases slowly. The oil sale return is then higher for oil exporting-countries. Furthermore, since a depreciation in the $ value increases the oil price, exporter countries preserve their profit level in weak dollar period.
- In the long run, the oil exporting-countries can make a real influence on the oil price by their production level. Moreover, in the long run, the oil price is mainly directed by the OPEC production policy.
- Oil exporting-countries are the winners of the oil supply and demand game in the short, as well, as the long run.

Footnotes

(1)SDR: These rates are the official rates used by the IMF to conduct operations with member countries. The rates are derived from the currency>s representative exchange rate, as reported by the issuing Central Bank.

(2) Kaufmann (1995) outlined a model for the world oil market that accounts for changes in the economic, geological and political environment. This model is divided into three blocks: (a) demand; (b) supply; and (c) real oil import price. In a new specification, Kaufmann et al. (2004 and 2007) placed much more emphasis on OPEC's behavior, since it accounts for OPEC overproduction besides OPEC quota and capacity utilization. Furthermore, the modified model outlines the impact of a new variable – the number of days of forward consumption proxied by the ratio of OECD oil stocks to OECD oil demand.

(3) It is classified according to its grade and origin. The grade of oil is determined by its relative weight gravity. The American Petroleum Institute (API) gravity is a specific gravity scale developed for measuring the relative density of various petroleum liquids, sulphur content (sweet or sour) and viscosity (light, intermediate or heavy). In terms of origin, oil is classified into <streams> which are then priced in relation to a <benchmark> grade. One such benchmark oil stream is Brent Crude which comes from the Brent and Ninian pipeline systems in the East Shetland Basin of the North Sea. Oil produced in Europe, Africa and the Middle East tends to be priced off this benchmark. The other benchmarks are West Texas Intermediate (WTI) for North American oil (a light, sweet crude); Dubai, a benchmark for Middle East oil flowing to the Asia-Pacific region; Tapis from Malaysia, used as a reference for light Far East oil; and Minas, from Indonesia which is used as reference for heavy Far East oil. There is also the OPEC basket which is a mix of light and heavy crude and is therefore heavier than both Brent and WTI.

(4) International Monetary Fund, World Economic Outlook (2004)

(5) BP Statistical Review of World Energy (2004).

(6) Commitments to supply petroleum for a price and time period specified in advance.

(7) Spot market prices are for current delivery of physical oil.

(8) In the futures oil markets, a contract can be entered into at a known price to purchase oil in a given number of months, enabling the purchaser to lock in the future price of oil and eliminate price uncertainty. If the price at the future date turns out to be higher than the futures contract price, the purchaser clearly benefits. If it is lower, the purchaser would have been better off not having entered into the contract. A seller of oil participates in the futures markets in the same way, with the impact of the difference between actual and futures prices reversed. There are variants of this basic setup with varying degrees of sophistication and cost.

(9) The total number of futures contracts, long or short in a delivery month or market that has been entered into and not yet liquidated by an offsetting transaction or fulfilled by delivery. Also called open contracts or open commitments.

(10) Haigh, et al. (2007) found similar results using a different framework, while Merino and Ortiz (2005) suggested that speculation could have an impact on prices once the effect of inventories is taken out. Extending the analysis to include inventories, however, did not change the basic results.

(11) Generalized Autoregressive Conditional Heteroskedasticity (GARCH). GARCH model is consistent with the volatility clustering often seen in financial returns data, when large changes in return are likely to be followed by further large changes.

(12) This specification is often interpreted in a financial context, when an agent trader predicts this period>s variance by forming a weighted average of a long-term average (the constant), the forecasted variance from last period (the GARCH term: α), and information about volatility observed in the previous period (the ARCH term: β). If the asset return is unexpectedly large in either the upward or the downward direction, than the trader will increase the estimate of the variance for the next period.

(13) Dickey and Fuller (1981)

(14) Box-Jenkins found a way for building the appropriate model. Their procedure follows three steps: (a) Identification of the model; (b) Estimation of the model; and (c) Diagnostic checking (validation).

(15) In this study, the total open interest is considered because as already mentioned, the distinction between commercial and non-commercial traders is increasingly blurred as non-commercial traders may enter into swap arrangements in which commercial traders act as their agent.

(16) A rate increase means $ depreciation.

(17) Data of oil price and production are obtained from the Illinois Oil and Gas Association (IOGA), the Exchange rate of US dollar per SDR from the IMF (International Monetary Fund) and also the world gross domestic product and CPI from the same source. The open interest is obtained from the Commodity Future Trading Commission (CFTC).

(18) Enders, 2004.

(19) A VEC model is a restricted VAR designed for use with non-stationary series that are known to be co-integrated.

(20) $\Delta Z_t = a_0 + \pi Z_{t-1} + \pi_1 \Delta Z_{t-1} + \varepsilon_t$, where $Z_t = (Pt, Y_t, Q_t, X_t, S_t)$ is the endogenous variable matrix and n is the number of variables. If r = n, all the variables are stationary, then variables are considered in levels since no spurious regression and no need to use the Error Correction model. In this case, the VAR model is used to accomplish the regression. If r=0, there is no co-integration vector, the Error Correction model cannot be used, but the VAR in difference. If $r \leq n-1$, there is co-integration vector. When $r = n-1$, the Johansen procedure can be used.

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Appendix

Table A.1 Correlogram of the Oil Price Series

Sample: 1 3863
Included observations: 3863

Autocorrelation	Partial Correlation		AC"	PAC	Q-Stat	Prob
|********	|********	1	0.998	0.998	3850.1	0.000
|********	| |	2	0.996	0.050	7687.1	0.000
|********	| |	3	0.994	0.044	11512.	0.000
|********	| |	4	0.993	−0.011	15325.	0.000
|********	| |	5	0.991	−0.015	19125.	0.000
|********	| |	6	0.989	0.030	22913.	0.000
|********	| |	7	0.988	−0.004	26690.	0.000
|********	| |	8	0.986	−0.008	30454.	0.000
|********	| |	9	0.984	0.011	34207.	0.000
|********	| |	10	0.983	0.015	37949.	0.000
|********	| |	11	0.981	0.014	41680.	0.000
|********	| |	12	0.980	−0.006	45399.	0.000
|********	| |	13	0.978	−0.053	49107.	0.000
|********	| |	14	0.976	−0.020	52801.	0.000
|*******|	| |	15	0.974	−0.005	56482.	0.000
|*******|	| |	16	0.972	−0.019	60150.	0.000
|*******|	| |	17	0.970	0.002	63804.	0.000
|*******|	| |	18	0.968	0.016	67446.	0.000
|*******|	| |	19	0.967	0.020	71075.	0.000
|*******|	| |	20	0.965	−0.008	74692.	0.000
|*******|	| |	21	0.963	−0.002	78297.	0.000
|*******|	| |	22	0.961	−0.007	81889.	0.000
|*******|	| |	23	0.960	0.008	85468.	0.000
|*******|	| |	24	0.958	−0.023	89035.	0.000
|*******|	| |	25	0.956	0.024	92590.	0.000
|*******|	| |	26	0.954	−0.032	96132.	0.000
|*******|	| |	27	0.952	0.010	99661.	0.000
|*******|	| |	28	0.950	−0.014	103177	0.000
|*******|	| |	29	0.948	−0.025	106679	0.000
|*******|	| |	30	0.946	−0.028	110166	0.000
|*******|	| |	31	0.944	0.004	113640	0.000
|*******|	| |	32	0.942	−0.046	117098	0.000
|*******|	| |	33	0.940	−0.033	120539	0.000
|*******|	| |	34	0.937	0.010	123966	0.000
|*******|	| |	35	0.935	0.015	127377	0.000
|*******|	| |	36	0.933	−0.010	130772	0.000

Table A.2 Oil Price Model Estimation

Dependent Variable: D(P)				
Method: Least Squares				
Sample (adjusted): 3 3863				
Included observations: 3861 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.017373	0.019922	0.872057	0.3832
D(P(-1))	-0.045657	0.016083	-2.838898	0.0046
R-squared	0.022084	Mean dependent var		0.016628
Adjusted R-squared	0.001826	S.D. dependent var		1.238911
S.E. of regression	1.237780	Akaike info criterion		-3.265034
Sum squared resid	5912.373	Schwarz criterion		-3.568276
Log likelihood	-6301.148	F-statistic		8.059344
Durbin-Watson stat	2.004166	Prob(F-statistic)		0.004551

Source: Author's calculation

Table A.3 Test for Serial Correlation in the Residuals

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	2.671524	Probability		0.009411
Obs*R-squared	3.330137	Probability		0.009419
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.056314	0.129380	-0.435258	0.6634
D(P(-1))	3.386355	7.693997	0.440130	0.6599
RESID(-1)	-3.388376	7.693228	-0.440436	0.6596
RESID(-2)	0.105993	0.351671	0.301399	0.7631
R-squared	0.002417	Mean dependent var		-1.06E-17
Adjusted R-squared	0.001641	S.D. dependent var		1.237620
S.E. of regression	1.236604	Akaike info criterion		-3.263651
Sum squared resid	5898.085	Schwarz criterion		-3.270135
Log likelihood	-6296.478	F-statistic		3.114350
Durbin-Watson stat	2.000167	Prob(F-statistic)		0.025176

Source: Author's calculation

Table A.4 Estimation of the ARCH Model

Dependent Variable: DLOG(P) Method: ML - ARCH (Marquardt) - Normal distribution Sample (adjusted): 2 3863 Included observations: 3862 after adjustments Convergence achieved after 12 iterations Variance backcast: ON GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)				
	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000688	0.000337	2.040133	0.0413
	Variance Equation			
C	8.65E-06	1.62E-06	5.328880	0.0000
RESID(-1)^2	0.053035	0.004408	12.03238	0.0000
GARCH(-1)	0.932891	0.006187	150.7912	0.0000
R-squared	-0.000142	Mean dependent var		0.000390
Adjusted R-squared	-0.000920	S.D. dependent var		0.024994
S.E. of regression	0.025005	Akaike info criterion		-4.708430
Sum squared resid	2.412299	Schwarz criterion		-4.701948
Log likelihood	9095.979	Durbin-Watson stat		2.016771

Source: Author's calculation"

Table A.5 Johansen Cointegration Test

Sample (adjusted): 3 53 Included observations: 51 after adjustments Trend assumption: Linear deterministic trend (restricted) Series: P Y Q S X" Series: P Y Q S X" Lags interval (in first differences): 1 to 1 Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Hypothesized No. of CE(s)	Eigenvalue
None *	0.491471	90.11906	None *	0.491471
At most 1	0.453631	55.63114	At most 1	0.453631
At most 2	0.220991	24.80361	At most 2	0.220991
At most 3	0.145467	12.06727	At most 3	0.145467
At most 4	0.076341	4.050047	At most 4	0.076341

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Source: Author's calculation

Table A.6 Vector Error Correction Estimation

Vector Error Correction Estimates
Sample (adjusted): 4 53
Included observations: 50 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1				
P(-1)	1.000000				
Y(-1)	0.343209				
	(0.34733)				
	[0.98814]				
Q(-1)	6.264824				
	(2.45195)				
	[2.55504]				
S(-1)	-0.187254				
	(0.18068)				
	[-1.03638]				
X(-1)	2.277338				
	(1.33727)				
	[1.70298]				
*TREND(1)	-0.067494				
	(0.01053)				
	[-6.41120]				
C	-124.3669				
Error Correction:	D(P)	D(Y)	D(Q)	D(S)	D(X)
CointEq1	-0.425784	0.034796	0.000579	-0.168256	0.034490
	(0.08432)	(0.08620)	(0.00740)	(0.08917)	(0.01197)
	[-5.04962]	[0.40366]	[0.07826]	[-1.88686]	[2.88101]
D(P(-1))	0.030893	-0.086953	0.019917	-0.293007	-0.031276
	(0.12238)	(0.12511)	(0.01074)	(0.12942)	(0.01737)
	[0.25244]	[-0.69503]	[1.85496]	[-2.26403]	[-1.80011]
D(P(-2))	0.329185	-0.036225	0.034586	0.064254	0.020479
	(0.13922)	(0.14233)	(0.01222)	(0.14724)	(0.01977)
	[2.36444]	[-0.25452]	[2.83135]	[0.43640]	[1.03604]
D(Y(-1))	0.006631	-0.140908	-0.005019	-0.363669	-0.024947
	(0.18507)	(0.18920)	(0.01624)	(0.19572)	(0.02628)
	[0.03583]	[-0.74474]	[-0.30912]	[-1.85807]	[-0.94944]
D(Y(-2))	0.574039	-0.243912	0.020443	0.275659	0.007804
	(0.19320)	(0.19751)	(0.01695)	(0.20432)	(0.02743)
	[2.97119]	[-1.23492]	[1.20598]	[1.34916]	[0.28452]

Table A.6 continued ...

D(Q(-1))	1.243717	0.892431	0.067664	0.803991	0.190870
	(1.80900)	(1.84937)	(0.15872)	(1.91310)	(0.25683)
	[0.68751]	[0.48256]	[0.42631]	[0.42025]	[0.74317]
D(Q(-2))	2.057053	0.533687	0.002579	0.334808	-0.060143
	(1.67496)	(1.71233)	(0.14696)	(1.77134)	(0.23780)
	[1.22812]	[0.31167]	[0.01755]	[0.18901]	[-0.25291]
D(S(-1))	0.085256	-0.080569	-0.015059	-0.162128	0.018463
	(0.16418)	(0.16784)	(0.01440)	(0.17362)	(0.02331)
	[0.51929]	[-0.48004]	[-1.04545]	[-0.93378]	[0.79212]
D(S(-2))	-0.192335	0.079164	-0.042294	-0.069541	0.007120
	(0.14356)	(0.14676)	(0.01260)	(0.15182)	(0.02038)
	[-1.33974]	[0.53940]	[-3.35778]	[-0.45804]	[0.34931]
D(X(-1))	3.677654	0.354232	-0.093062	1.331154	-0.182009
	(1.24806)	(1.27591)	(0.10950)	(1.31988)	(0.17719)
	[2.94669]	[0.27763]	[-0.84985]	[1.00854]	[-1.02718]
D(X(-2))	1.882559	0.713199	0.005746	1.095911	-0.285411
	(1.20461)	(1.23149)	(0.10569)	(1.27392)	(0.17102)
	[1.56280]	[0.57914]	[0.05436]	[0.86026]	[-1.66884]
C	-0.004688	0.046352	0.002857	0.054464	-0.001420
	(0.02135)	(0.02182)	(0.00187)	(0.02258)	(0.00303)
	[-0.21961]	[2.12384]	[1.52554]	[2.41242]	[-0.46866]
R-squared	0.506553	0.114012	0.446490	0.383390	0.384257
Adj. R-squared	0.363713	-0.142458	0.286264	0.204898	0.206015
Sum sq. resids	0.441072	0.460976	0.003395	0.493296	0.008891
S.E. equation	0.107737	0.110141	0.009453	0.113936	0.015296
F-statistic	3.546295	0.444543	2.786618	2.147938	2.155821
Log likelihood	47.31730	46.21386	168.9867	44.51978	144.9226
Akaike AIC	-1.412692	-1.368555	-6.279467	-1.300791	-5.316903
Schwarz SC	-0.953807	-0.909669	-5.820581	-0.841906	-4.858017
Mean dependent	0.035103	0.032370	0.003334	0.039095	-0.001116
S.D. dependent	0.135063	0.103045	0.011189	0.127776	0.017166
Determinant resid covariance (dof adj.)		2.17E-14			
Determinant resid covariance		5.50E-15			
Log likelihood		466.1176			
Akaike information criterion		-16.00470			
Schwarz criterion		-13.48083			

Source: Author's calculation