Estimation and Decomposition Analysis of Fundamental Prices and Premium of Crude Oil Prices — Focused on Decomposition Analysis of Premium from Financial Viewpoint —

Akira Yanagisawa
Leader
Energy Demand, Supply and Forecast Analysis Group
Energy Data and Modelling Center

Summary

In this paper, a quantitative decomposition analysis of the oil prices using a fundamental prices model and a premium model was carried out. In the 1st quarter of 2008, the most recent term, the fundamental prices were estimated at about $60/bbl. Because actual oil prices were $98/bbl, premium was estimated at about $40/bbl. The last half year (the 4th quarter of 2007 to the 1st quarter of 2008), saw a poor increase in supply, it was estimated that the non-trend supply factor contributed to about a six-dollar rise in the fundamental prices cumulatively. Meanwhile, depreciation of the dollar and decline in the stock market seemed to contribute to the surging of the premium by about $15/bbl and $3/bbl, respectively.

1. Introduction

The oil prices soar, which started around 2004, has entered its fifth year. The WTI crude oil price\(^1\) exceeded $130/bbl and is almost quadruple to that of January 2004, or $34/bbl. Some people say that full-scale oil price of $100/bbl has come and other people mention the possibility of it reaching $200/bbl. The adverse effect on the global economy by the soaring oil prices coupled with high prices of the other primary commodities and the subprime lending crisis is being observed.

Figure 1: WTI prices

Source: U.S. Department of Energy

It is widely accepted that current oil prices are not explained only by the fundamentals, i.e. the supply and demand factor. Other factors such as inflow of funds, depreciation of the dollar, etc.,

\(^1\) Near futures prices (closing prices) of light sweet crude oil listed at the New York Mercantile Exchange. Hereafter, the oil prices refer WTI prices.
referred as “premium” in this paper, also affect oil prices. There are, however, various interpretations on how much are fundamental prices — decided by supply and demand factor — are and how much premium — effects by inflow of funds, depreciation of the dollar, etc. — is. Furthermore, people find much obscurity when they try to know how these elements affect the oil prices.

In this paper, a quantitative decomposition analysis of the oil prices was carried out using a fundamental prices model and a premium model.

2. Estimation of fundamental prices

Fundamental oil prices were estimated by using a structural vector autoregressive model, or structural VAR, which contains oil demand, oil supply and oil prices, as in Yanagisawa (2008a)². Endogenous variables \( y \) in the model are the growth in the global oil demand compared with the same period of the previous year, the growth in the global oil supply compared with the same period of the previous year and the logarithm of the real oil prices³.

The real oil prices were deflated by the GDP deflator of the United States, the world’s largest oil consuming country.

\[
y = \begin{cases} 
\text{the growth in the global oil demand compared with the same period of the previous year,} \\
\text{the growth in the global oil supply compared with the same period of the previous year,} \\
\log \text{the real oil prices}
\end{cases}
\]

Changes of the variables are shown in the Figure 2:

Figure 2: Global oil demand, supply and real oil prices

Source: Oil Market Report from IEA (global oil supply and demand) and calculated by data from U.S. Department of Energy, etc. (oil prices)

The model was built on quarters considering the contents of analysis and restrictions of data availability. Estimation period was from the first quarter of 1992, where the effect of sudden rise in prices caused by the Gulf War was eliminated, to the first quarter of 2008, the most recent term. As

³ The sources of data used are as follows:
lag length, a single term was adopted according to the information criterion\(^4\), etc. In a matrix form, the model is represented as:

\[
S_0 Y_t = S_1 Y_{t-1} + c + v_t 
\]

where \(S\), \(c\) and \(v\) represent coefficient matrix, constant vector and shock (error) vector, respectively.

Estimated parameters are shown as follow:

\[
\hat{S}_0 = \begin{pmatrix} 116 & 0 & -3.52 \\ 0 & 81.0 & 0 \\ 0 & -11.3 & 10.2 \end{pmatrix}, \quad \hat{S}_1 = \begin{pmatrix} 36.2 & 29.0 & -3.61 \\ 9.67 & 58.8 & 0.204 \\ 38.2 & -36.4 & 10.2 \end{pmatrix}, \quad \hat{c} = \begin{pmatrix} 1.07 \\ -0.499 \\ 0.0693 \end{pmatrix}
\]

The fundamental prices were estimated by subtracting shocks on oil prices in the obtained model. The result is shown in Figure 3. In the 1st quarter of 2008, the most recent term, the fundamental prices were estimated at about $60/bbl. Because actual oil prices were $98/bbl, premium was estimated at about $40/bbl.

Figure 3: Fundamental prices and premium

Note: The 80% confidence interval\(^5\) is a range that includes eight near-average results among 10 simulations based on different origin points. It is the “width” of the estimation.

Figure 4 shows the results of decomposition analysis of the fundamental prices fluctuations compared with the previous term into the trend factor, non-trend demand factor and non-trend supply factor. The fundamental prices rose by about $2/bbl every term on average; it was estimated that the trend factor was responsible for about $1/bbl rise and that non-trend supply and demand factors together drove about $1/bbl rise. In the last half year (the 4th quarter of 2007 to the 1st quarter of 2008), saw a poor increase in supply, it was estimated that the non-trend supply factor contributed to about a six-dollar rise in the prices cumulatively.

\(4\) Guidelines for selecting from more than one candidate for the model that is considered to be excellent from the viewpoints of best fit and degree of freedom.

\(5\) It is different from a precise confidence interval based on probability distribution.
3. Oil prices in financial viewpoint

It is often said that the soaring of oil prices are affected largely by the inflow of funds, etc. In this chapter, therefore, the environment surrounding oil prices is described in view of financial engineering.

3.1 Effect of diversification in investment

Here, risk reduction by diversification, which forms the basis of the modern portfolio theory, is mentioned.

According to the basis of financial engineering, an excellent mix of assets, or portfolio, is one with high expected rate of return and low risk. Usually, for this risk, fluctuation, i.e., standard deviation (volatility) of expected rate of return is used\(^6\),\(^7\). For example, government bonds are deemed as non-risk assets because holding them till maturity ensures an expected rate of return. On the other hand, stocks are risk assets because their actual rate of return can be less or more than the expected ones. In stocks, those of power companies, railway companies and medicine companies, etc. are regarded as relatively low risk because they show less fluctuation in expected rate of return. Meanwhile, ICT companies and securities companies, etc. are regarded as high risk because their fluctuation in expected rate of return is large.

Now, suppose that there is a high-risk-high-return asset \(A\), with expected rate of return \(\mu_A\) and risk \(\sigma_A\), and a low-risk-low-return asset \(B\), with expected rate of return \(\mu_B\) and risk \(\sigma_B\) (\(\mu_A > \mu_B\), \(\sigma_A > \sigma_B\)). If a conservative investor sets up a portfolio containing the asset \(B\) only, the expected rate of return and risk of the portfolio are \(\mu_B\) and \(\sigma_B\) respectively of course. Suitable diversification into Asset \(A\) and \(B\), however, can lead to a better portfolio, which has both higher expected rate of return and lower risk than those of the low-risk-low-return asset \(B\).

Suppose that a portfolio \(X\), which contains \(w\) of the asset \(A\) and \(1-w\) of the asset \(B\), is set up. The expected rate of return \(\mu_X\) and risk \(\sigma_X\) of the portfolio \(X\) are expressed as follows:

\[
\mu_X = w\mu_A + (1-w)\mu_B
\]
\[
\sigma_X = \sqrt{w^2\sigma_A^2 + (1-w)^2\sigma_B^2 + 2w(1-w)\text{cov}(A,B)}
\]

\(^6\) It is different from “risk” in “risk of oil disruption” or “geopolitical risk”, etc.

\(^7\) Value at Risk, or VaR, is used often as risk, too.
where \( \text{cov}(A, B) \) is covariance\(^8\) between rate of return the asset A and that of the asset B. By changing \( w \), the expected rate of return \( \mu_X \) and risk \( \sigma_X \) of the portfolio X move on curve A-B in Figure 5. For example, a portfolio \( X_{\text{min}} \) is a more excellent portfolio showing higher expected rate of return and lower risk than those of the asset B. In case of low correlation, especially negative correlation, between the asset A and asset B, risk reduction by suitable diversification is possible.

**Figure 5: Changes in expected rate of return and risk by diversification**

Meanwhile, portfolios, which should be selected, are those on curve \( X_{\text{min}}-A \) because any portfolio on curve \( X_{\text{min}}-B \) is inferior to a portfolio on curve \( X_{\text{min}}-A \) which has the same risk but higher expected rate of return. The curve \( X_{\text{min}}-A \) is called the “efficient frontier”.

### 3.2 Crude oil as an alternative investment asset

Alternative investments are investments not in traditional asset such as stocks and bonds, etc., but typical for commodities, real estate and hedge funds, etc. It is said that the latter are increasing rapidly in recent years.

One reason why funds flow into alternative investments is their high rate of return. Table 1 shows the monthly excess return\(^9\) and the risk of crude oil and stocks (Dow Jones Industrial Average) based on data from January 1991 to March 2008. Crude oil recorded not only higher rate of return than the stocks but also almost same as — or rather better than — the stocks in Sharpe ratio\(^10\), which shows risk-adjusted rate of return. Crude oil is being regarded as an effective investment asset because the environment in crude oil is easy-to-use as commoditisation.

**Table 1: Excess return and risk of crude oil and stocks**

<table>
<thead>
<tr>
<th></th>
<th>Crude Oil</th>
<th>Stocks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Excess Rate of Return (annual rate, %)</strong></td>
<td>47.6</td>
<td>12.9</td>
</tr>
<tr>
<td><strong>Risk (%)</strong></td>
<td>137</td>
<td>46.1</td>
</tr>
<tr>
<td><strong>Sharpe Ratio</strong></td>
<td>0.35</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Note: Calculation is based on capital gain, excluding dividend and roll-over gain (loss).

\(^8\) Covariance divided by each standard deviation \( \text{cov}(A, B) / \sigma_A \sigma_B \) is correlation coefficient.

\(^9\) Excess return = rate of return – rate of return of non-risk asset (here, U.S. government securities, two years).

\(^10\) Sharp ratio = excess return ÷ risk.
Additionally, as another reason, low correlation between alternative investment asset and traditional asset is pointed out. As seen in the previous section, the risk reduction is possible by including low-correlation assets in a portfolio. Based on the above data, the correlation coefficient between excess return of the stocks and that of crude oil is -0.01, almost uncorrelated. Even if the stocks showed poor return, return of crude oil was not affected by the stocks. This shows possibility of risk reduction and high rate of return of a portfolio by investment in both stocks and crude oil.

3.3 Optimal portfolio

Suppose that, a conservative investor sets up a portfolio including two risk assets A, B and non-risk asset Rf. As shown above, portfolios that should be selected are on the efficient frontier. If the investor also invests in non-risk asset, it is known that the optimal portfolio of risk assets is a tangency portfolio P as shown in Figure 6. The investor changes investment allocation between non-risk asset and the tangency portfolio according to his/her risk tolerance. What’s important is that the tangency portfolio is the only portfolio of risk assets which should be selected.

Based on above data, allocation for crude oil accounts for 30% in the tangency portfolio\(^\text{11}\). In fact, an investor, who allocates crude oil to 30% of the portfolio, is rare except for hedge funds and investors focusing on commodities. However, the possibility of more inflow of funds into the crude oil market is suggested if we regard the allocation in the optimal portfolio as potential.

![Figure 6: Tangency portfolio](image)

3.4 Market expectation seen in options

We have viewed investment in crude oil in the viewpoint of the modern portfolio theory. In this section, we treat another characteristic element in this oil price soaring period, that is, self-fulfilling prophecy — as oil prices rise, speculators buy oil futures, leading to higher prices. As in Yanagisawa (2008b)\(^\text{12}\), the market expectation was estimated from option premium.

Option is the right to purchase or sell an underlying asset at a specific price — “strike price” — in future. “Call options” provide the holder the right to purchase the underlying asset and “put options” provide the holder the right to sell the underlying asset. Options are economically valuable and the value is called “option premium”. In New York Mercantile Exchange, or NYMEX, options with WTI futures as underlying asset, are listed.

While futures prices provide information of the average of expected future prices, option

---

\(^{11}\) The result may be different number by adopting other assumptions of expected rate of return and risk, or using VaR not volatility as risk. And be noted that these calculation is based on the simplified model.

premiums provide information on the distribution of expected future prices. Typically, “implied volatility”, variation of expected future prices estimated from European call option premium in the market applying the Black-Scholes equation is well known.

In the Black-Scholes model, however, only the implied volatility is available as information on distribution of expected future prices because it is assumed beforehand that the underlying asset prices follow log normal distribution. No additional information such as whether distribution of expected future prices is asymmetric or not, fat tail or not, is available. Therefore, I tried to estimate the distribution itself from option premium and strike price and to analyze market expectation from the estimated distribution.

For example, in the beginning of March 2008, the oil prices recorded the highest (at that time) day after day. It, however, seems that expectation of the market is not in a complete bullish position if we look at the probability distribution of future prices estimated by option premium (left of Figure 7).

Compared with one year ago (right of Figure 7),

- bigger variation (bigger volatility): uncertain for future prices
- fat tail (bigger kurtosis): recognizing possibility for big fluctuation of future prices

Volatility=0.12, skewness=+0.13, kurtosis=1.14 Volatility=0.09, skewness=-0.30, kurtosis=0.42

European style options allow the holder to exercise the right only on the expiration date and American style option allow the holder to exercise the right at any time up to the expiration date.

Kurtosis and skewness: kurtosis is a measure of the peakedness and fat tails of the probability distribution. Positive (excess) kurtosis means that the distribution has fat tail and sharp peak.

Skewness is a measure of the asymmetry of the probability distribution. Positive skewness means that the right tail is longer and the mass of the distribution is concentrated on the left.

Both skewness and kurtosis are zero for normal distribution. Many of financial data series have asymmetry and fat tail compared with log normal distribution.
• concentration on left and longer right tail (positive skewness): conscious of price falling are recognized clearly. As reason of such expectation of the market, resurgence of actual demand decline brought about by recession and concern about too rapid price rise are considerable. In fact, the oil prices entered an adjustment period in the following week.

4. Building a model on premium

4.1 Model structure

It is widely accepted that current oil prices are not explained only by supply and demand factor. However, people find much obscurity when they try to know how these elements affect the oil prices, especially premium. In this chapter, quantitative decomposition analysis of the premium using a model is tried.

As it is said that funds affect the premium significantly in general, the model was built being conscious of financial view as above. To be more precise, it is a single equation model as follows:

\[
\log \frac{WTI}{FND} = \beta_0 + \beta_1 \log DJI + \beta_2 TS + \beta_3 \log USDIDX + \beta_4 SPEC + \beta_5 SKEW + \beta_6 \log STOCK + \beta_7 TIME
\]

(4)

where

- \( WTI \): Oil prices (dollar per barrel)
- \( FND \): Fundamental prices estimated in the Chapter 2 (dollar per barrel). Hereafter fundamental prices.
- \( DJI \): Dow Jones Industrial Average (dollar). Hereafter “stock prices”
- \( TS \): Yield of U.S. government securities, two years (percent). Hereafter “interest rates”
- \( USDIDX \): Nominal effective exchange rate of the dollar (March 1973=100). Hereafter “exchange rates”
- \( SPEC \): Speculators’ long position (millions). Hereafter “speculators”
- \( SKEW \): Implied skewness estimated in the Chapter 3. Hereafter “expectation”
- \( STOCK \): Crude oil stocks in United States excluding SPR (billion barrels). Hereafter “oil stocks”
- \( TIME \): Time trend. Hereafter “trend”\(^{15}\)

As the oil prices \( WTI \) are sum of the fundamental prices \( FND \) and premium \( PREM \) as follows:

\[
WTI = FND + PREM
\]

(5)

\( \frac{WTI}{FND} \), the left side of Eq. (4), is equal to the ratio of the premium against the fundamental prices plus one (hereafter “premium ratio”). Such formulation was chosen because it seems that volatility of the premium is expanding as the oil prices — or the fundamental prices — rise.

Expected sign conditions of each exogenous variable are as follows:

- Stock prices \( DJI \): [-] It is said that relation between crude oil and stocks is uncorrelated or negative correlation in general. This is one reason why crude oil is focused as an alternative investment asset. Negative coefficient is expected according to the Capital Asset Pricing Model (CAPM) or the Arbitrage Pricing Theory (APT)\(^{16}\).

---

\(^{15}\) The sources of data used are as follows:

\(^{16}\) See Supplemental explanation.
Interest rates $TS: [+]
According to the CAPM, higher rate of return of a risk asset is expected than non-risk asset.
Meanwhile, for actual supply and demand for oil, high interest rates lead to drop of price through declining demand for oil by economic slowdown. Here, however, this effect is regarded as included in the fundamental prices.

Exchange rates $USDIDX: [-]
Smaller number of the nominal effective exchange rate of the dollar shows weaker dollar. It is said that dollar depreciation causes rise in oil prices via fostering undervalued oil prices evaluated in foreign currency.

Speculators $SPEC: [+]
It is said that speculators’ long position leads rise in oil prices in this oil price soaring period.

Expectation $SKEW: [-]
The Skewness estimated from implied probability distribution is adopted as market expectation. Negative number of skewness is regarded that market is at bullish position.

Oil stocks $STOCK: [-]
Increase in oil stocks expresses that the oil market is easy and regarded to bring downward pressure to oil prices. Oil stocks are one of most watched indicators in the market, too.

Trend $TIME: [±]
Time trend is proxy for market trend (“support” or “resistance” in the technical analysis). Therefore, it could either be positive or negative.

Estimation period is the beginning of year 2004, when current rise in the oil prices swung into full gear, to March 2008.

It may be better that building a model on data with as short frequency as possible considering the speed in the financial market. Weekly data, however, was adopted deliberating data availability, noise in the stock prices and oil prices, etc. Monthly fundamental prices were estimated by applying the spline interpolation for results from the fundamental model, which was based on quarterly data. The monthly fundamental prices were assumed to be unchanged in a month. Changes in each variable are shown in Figure 8.

---

17 (1) Assume that the quarterly fundamental prices are equal to one in the mid-month (ex. February for the first quarter). (2) Set up smooth curves connecting those (spline curves). (3) Interpolation the fundamental prices in the proceeding and following months (ex. January and March for the first quarter) by the spline curves. Therefore, some residuals came from the decomposition.
Figure 8: Changes in each variable in the premium model

Oil prices

Fundamental prices

Stock prices

Interest rates

Exchange rates

Speculators

Expectation

Oil stocks

Source: U.S. Department of Energy (oil prices and oil stocks), Stock prices: New York Stock Exchange (stock prices), Federal Reserve Board (interest rates and exchange rates), computed from U.S. Commodity Futures Trading Commission data (speculators), etc.
4.2 Estimation under assumed fixed price mechanism

If it is assumed that the oil price mechanism was fixed for the whole period, from the beginning of 2004 to March 2008, parameters are available by applying the ordinary least square, or OLS, for Eq. (4). The results are as follows. Numbers in parentheses are t-value.

\[
\log \frac{WTI}{FND} = 28.3 - 2.44 \log DJI + 0.103 TS - 1.55 \log USDIDX + 0.893 SPEC
\]

\[
- 0.0169 \text{SKEW} - 0.446 \log \text{STOCK} + 0.0025 \text{TIME}
\]

Coefficient of determination \(R^2: 0.739\), F-value: 86.5

Each variable satisfies the expected sign condition. Although the coefficient of determination is 0.74, it is enough fitting considering the endogenous variable is volatile prices\(^{18}\).

Figure 9: Estimated value under assumed fixed price mechanism

Elasticity of the oil prices (premium ratio) against each element\(^ {19}\) computed from the coefficient of regression is shown in Table 2. For the whole estimation period, it seems that the prices were sensitive against changes of stock prices and exchange rates.

Table 2: Elasticity under assumed fixed price mechanism

<table>
<thead>
<tr>
<th>Element</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock prices</td>
<td>-2.44</td>
</tr>
<tr>
<td>Interest rates</td>
<td>+0.38</td>
</tr>
<tr>
<td>Exchange rates</td>
<td>-1.55</td>
</tr>
<tr>
<td>Speculators</td>
<td>+0.02</td>
</tr>
<tr>
<td>Expectation</td>
<td>-0.0006</td>
</tr>
<tr>
<td>Oil stocks</td>
<td>-0.45</td>
</tr>
</tbody>
</table>

4.3 Estimation under assumed variable price mechanism

In case of under assumption of the fixed price mechanism, the results are obtained as described

\(^{18}\) By variables, only expectation (skewness) is not significant statistically. As interpretation, it is supposed that (1) the oil market is efficient; (2) expectation is vulnerable to multiple correlation as it is affected by the stock prices and speculators’ behaviour.

\(^{19}\) Percentage change of the oil prices against one percent change of a variable.
above. It, however, may be hard to regard the price mechanism as having been fixed for the whole period — more than four years. Looking back to changes of the oil prices and news picked up as factor by the market, it may be rather acceptable to regard the price mechanism as having been changed.

For estimation including structure change, usage of dummy variable, etc. are typical. In this paper, however, the local regression — one of the non-parametric regressions — was applied for expressing continuous structure change. As Figure 10 shows, the concept of local regression divides the estimation target into appropriate segments to perform the regression in each segment.

Figure 10: Concept of Local Regression

![Local Regression Diagram](image)

The estimated coefficient of regression by the local regression is shown in Figure 11. For convenience in comparing magnitude of both coefficients and changes in coefficients, regression was done under standardisation setting averages of all of exogenous variables to zero and variances of them are unity.

Figure 11: Coefficient of regression under assumed variable price mechanism

![Coefficient Diagram](image)

Additionally, elasticity of oil prices (premium ratio) against each element computed from the coefficient of regression is shown in Figure 12. Some elements are pretty overshooting in certain period. It is supposed that the market did not recognise the oil stocks as factor in periods showing positive coefficients.

---

20 Non-parametric regression does not mean that it uses no parameter. It does not perform parameterization. Normal (parametric) regression is designed to express the behaviour of the analysis target with a minimum number of regression coefficients (parameterization). On the other hand, non-parametric regression is designed to express the behaviours of the target without limiting the number of regression coefficients.
Nevertheless the stock prices and the oil stocks were the dominant factors till the beginning of 2006; these effects were getting weaker later. It seems that in 2007 when the dollar depreciation progressed due to the subprime lending problem, the exchange rates became dominant. Yet the behaviour of speculators had certain effect till the beginning of 2007, from then it was not regarded as a factor in particular.

![Figure 12: Elasticity under assumed variable price mechanism](image)

Table 3 shows the effect of each element to the oil prices.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Stock price</th>
<th>Interest rates</th>
<th>Exchange rates</th>
<th>Speculators</th>
<th>Oil stocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed change</td>
<td>-$500</td>
<td>+0.25%</td>
<td>Depreciation by 5%</td>
<td>+20,000 in net long</td>
<td>-10 Mbbl</td>
</tr>
<tr>
<td>Late Mar. ‘04</td>
<td>+$2/bbl</td>
<td>(-$0/bbl)</td>
<td>(-$1/bbl)</td>
<td>+$1/bbl</td>
<td>+$1/bbl</td>
</tr>
<tr>
<td>Late Mar. ‘05</td>
<td>+$6/bbl</td>
<td>+$3/bbl</td>
<td>(-$1/bbl)</td>
<td>+$1/bbl</td>
<td>+$2/bbl</td>
</tr>
<tr>
<td>Late Mar. ‘06</td>
<td>+$5/bbl</td>
<td>+$4/bbl</td>
<td>(-$1/bbl)</td>
<td>+$2/bbl</td>
<td>+$1/bbl</td>
</tr>
<tr>
<td>Late Mar. ‘07</td>
<td>+$4/bbl</td>
<td>+$1/bbl</td>
<td>+$11/bbl</td>
<td>+$1/bbl</td>
<td>(-$1/bbl)</td>
</tr>
<tr>
<td>Late Mar. ‘08</td>
<td>+$3/bbl</td>
<td>+$2/bbl</td>
<td>+$12/bbl</td>
<td>+$2/bbl</td>
<td>(-$1/bbl)</td>
</tr>
</tbody>
</table>

Notes:
(1) Assumed changes are not identical among the elements
(2) Numbers in parentheses do not satisfy the sign condition. It is supposed that the market did not recognise the element as factor at that period.
(3) No relationship among elements is considered.

Effect of speculators and oil stocks were relatively stable — increase by 20 thousand in the speculators net long position contributed $1/bbl or $2/bbl rise in the oil price and decrease by 10 million barrels in the oil stocks contributed from zero to $2/bbl rise. Meanwhile, the stock prices, the interest rates and the exchange rates show quite different effect by periods. The reason can be due to changes in the factors focused by the market\(^{21}\). Especially the stock prices and the exchange

---

\(^{21}\) In other words, the oil market might find a bullish factor in any elements.
rates have not only huge changes in their elasticity but also large volatility. Considering current unstable situation in the financial market, it seems that they will stay as disturbance factors in the oil prices.

It should be noted that the effects shown above are evaluated on the assumption that each element does not affect the other elements. In the real economy, they are closely related — e.g. tumble in the stock prices leads to increase in the speculators’ long position or depreciation of the dollar, inflow of funds into the commodity markets leads to decline in the stock prices or changes in the interest rates. The results in Table 3 evaluate the effects of these elements individually.

4.4 Decomposition analysis of premium

Here, the premium is decomposed using the parameters estimated above. If it were possible doing decomposition analysis for the level of the premium, the results would be easy to realize. It, however, is necessary to do so, that setting up the stock prices, the exchange rates, etc. which lead neither premium nor discount of the oil prices. As numerous elements are determined to be correlated mutually in the actual economy, setting up such reference levels are difficult in fact.

In this paper, therefore, decomposition analysis was applied for changes of the premium compared the previous quarter not the level itself. Namely, contribution of each element for the changes in the premium was estimated from premium computed by substituting the average of the previous quarter for the exogenous variables and premium computed by substituting the actual values for the exogenous variables. For example, contribution of the stock prices $DJI$ for the premium in a certain term is estimated by following equation:

$$\text{Contribution of } DJI = PREM(DJI, TS, USDIDX, \cdots) - PREM(\overline{DJI}, TS, USDIDX, \cdots) \tag{7}$$

where $PREM(\cdots)$ is the Eq. (4) solved for the premium, $\overline{DJI}$ is the average of the stock prices $DJI$ in the previous quarter.

The results of the decomposition analysis are shown in Figure 13.

Figure 13: Decomposition analysis of premium (changes from previous term)

Note: There may be cases in which components do not add up, due to the crossover term, the model residuals, etc.

The elements, which contributed to the changes in the premium, have changed vertiginously depending on periods. It, however, seems that the effects of the stock prices, the exchange rates and the fundamental prices were stronger than the others. In average, the premium had expanded about $2/bbl a quarter. Meanwhile the interest rates and the fundamental prices had contributed upward at about $2/bbl and about $1/bbl respectively, the stock prices had contributed downward at about
S$/bbl till 2006. In the last half of the year, it was characterised that the fourth quarter of 2007 and the first quarter of 2008, depreciation of the dollar, decline in the stock prices and rise of the fundamental prices contributed to the surging of the premium by about $15/bbl, $3/bbl and $15/bbl, respectively.

5. Summary of changes in oil prices

Figure 14 summarised the decomposition analysis of the fundamental prices and the premiums. The elements, which contributed to the changes in the oil prices, have changed depending on periods. In other words, if measures for mitigating the soaring oil prices are not suitable at that time, they will not be effective on full scale.

**Figure 14: Decomposition analysis of oil prices (changes from previous term)**

<table>
<thead>
<tr>
<th>Period</th>
<th>Trend</th>
<th>Non-trend demand</th>
<th>Non-trend supply</th>
<th>Stock prices</th>
<th>Interest rates</th>
<th>Exchange rates</th>
<th>Speculators</th>
<th>Expectation</th>
<th>Oil stocks</th>
<th>Trend</th>
<th>Fundamental</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd quarter of 2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Fundamental prices</td>
<td>Subtotal</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Premium</td>
<td>Subtotal</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Contribution for changes in oil prices ($/bbl)</td>
<td>Actual Fundamental prices</td>
<td>Subtotal</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>1st quarter of 2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Fundamental prices</td>
<td>Subtotal</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Premium</td>
<td>Subtotal</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
</tbody>
</table>
6. **In closing**

The oil prices have soared by $100/bbl from $30/bbl level to higher than $130/bbl in the last four years. In this background, you can find many elements; not only the actual supply and demand factor — continuously increasing oil demand mainly led by the emerging economies, relatively insufficient growth of the supply, worry about the low surplus production capacity, the geopolitical risk concerning unstable Middle East, etc. — but also the factors beyond the actual supply and demand — the easy money since the collapse of the ICT bubble resulting the inflow of funds into the oil market, the tumble of the stock price caused by the subprime lending crisis, the depreciation of the dollar led by the side-effects of actions for the financial crisis, etc.

In this paper, the elements, which seem to have large effect or wide influence, the oil prices were decomposed into the fundamental prices and the premiums. And each elements’ contribution for the fundamental prices and the premium were estimated and analysed quantitatively.

As the current oil prices is over $130/bbl, the premium is supposed to have expanded from $60/bbl to $70/bbl. The relationship between the funds and the oil prices are getting attention. It, however, may be noted that the rise of the fundamental prices leads the expansion of the premium too. It must be realised again that energy conservation, sufficient supply and promotion of the alternative energy are important measures though they may sound too orthodox.

Adverse effect on the global economy by the soaring oil prices coupled with high prices of the other primary commodities and the subprime lending crisis is being observed. The vicious circle — the oil prices soaring, worry about inflation, inflow of funds into the commodities market, the oil prices soaring — and the recession will lead to worries about stagflation. Once the stagflation occurs, it will be a grave damage for the world, especially for people in the developing countries with poor natural resources. Now radical measures to address the high oil prices problem are required. I hope this paper links a hint for measures.
Supplemental explanation  Capital asset pricing model and arbitrage pricing theory

Suppose that the optimal portfolio of an investor expands to the whole market under a certain assumption. The tangency portfolio, which satisfies the market equilibrium, is called the “market portfolio”. And line through both non-risk interest rates R_f and the market portfolio M is called the “capital market line”, or CML.

The rate of return $\mu_C$ and risk $\sigma_C$ of a portfolio C on the CML can be expressed as Eq (8), clearly from Figure 15:

$$\mu_C = r_f + \left(\mu_M - r_f\right) \frac{\sigma_C}{\sigma_M}$$

where $r_f$ is interest rates of non-risk asset, $\mu_M$ and $\sigma_M$ are the rate of return and the risk of the market portfolio, respectively.

Since the slope of Eq (8), $\frac{\mu_M - r_f}{\sigma_M}$, is equal to the slope which is obtained by substituting the market portfolio B for the asset B in Eq (2) and (3) and evaluating at the market portfolio ($w=0$), the following equation is available:

$$\mu_A = r_f + \left(\mu_M - r_f\right) \frac{\text{cov}(A,M)}{\sigma_M^2}$$

This is called the “capital asset pricing model”, or CAPM.

CAPM shows that the excess rate of return of the asset A is equal to the excess rate of return of the market portfolio multiplied by the beta coefficient $\beta_A$ of the asset A. The beta coefficient $\beta_A$ of the asset A is value being in proportion to the covariance between the excess rate of return of the asset A and one of the market portfolio.

In other words, the CAPM is a model expressing the excess rate of return of the asset A with the market portfolio. Meanwhile, a model expressing the rate of return of the asset A with multiple elements, which are regarded as affecting the asset A, the arbitrage pricing theory, or APT has been
developed:

\[ r_d = \gamma_0 + \gamma_1 x_1 + \gamma_2 x_2 + \cdots \]  

(10)

where \( r_d \) is the rate of return of the asset A, \( x_i \) is element, which is regarded as affecting the asset A.

As a view of the APT, the CAPM can be regarded as one special case using the market portfolio as its element.
References
Kunio Takezawa (2003), ‘Non-parametric Regression for Everyone’, Yoshioka Shoten

Contact: report@tky.ieej.or.jp