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Kyoung Cheon Cha*, Kyung Min Lee

Asymmetric and Non-proportional Response of Retail Gasoline Prices to Crude Oil Prices in Korea

In this research, we proposed an applied model, instead of the conventional Error Correction Model (ECM), to explain the non-stationary case of phenomenon of rockets and feathers. The model elucidates the asymmetric response of the retail gasoline price to changes in the crude oil price by including non-proportionality. We analyzed retail gasoline prices in South Korea from January 2003 to March 2011. The study found that the retail gasoline price responds to the crude oil price non-proportionally as well as asymmetrically.

Keywords: crude oil price, asymmetric response, non-proportional response, rockets and feathers

The volatility of gasoline price has been an important topic in the field of market policy. When crude oil prices are volatile for some reasons such as political issues or unstable global economy, consumers become sensitive to price changes in retail gasoline prices, which affect their wealth and quality of life. Consumers complain that retail sellers obtain unreasonable profits by increasing retail gasoline prices rapidly when crude oil prices increase and by decreasing prices slowly otherwise. On the other hand, retail sellers argue that other factors including exchange rates affect the adjustment time to changes in crude oil prices. To resolve this conflict, the government has often tried to intervene in or regulate the retail gasoline market, for example, through setting price regulations.

Because of these complaints from both sides and the externalities created, the asymmetric response of the retail gasoline price to the crude oil price has been extensively studied in recent years. This phenomenon was defined as “rockets and feathers” by Bacon (1991) from the fact that the retail gasoline price rises rapidly like a rocket in response to an increase in crude oil prices, but declines slowly like a feather in response to a decrease in crude oil prices.

The ECM (error correction model) which has been applied in most previous studies is used to deal simultaneously with both short-term dynamics and long-term equilibrium within an equation. However, this method can only treat non-stationary variables (i.e., Random-walk model including unit-root), thus rendering it unavailable for verifying the asymmetric response with stationary variables. Furthermore, a linear relationship has been assumed between the retail gasoline price and the crude oil price, but the response to changes in crude oil prices could differ with the deviation size.

It is expected that the model suggested in this paper can improve the analysis of price adjustment over the previous models in the literature. It can also be used to create price policies for particular products that are sensitive to raw material prices like fruits, beef, and vegetable.

Theoretical Backgrounds and Hypotheses

Many researchers have confirmed the asymmetric response of the retail gasoline prices. Analyzing monthly data from 1983 to 1990, Karrenbrock (1991) argued that although retail gasoline prices asymmetrically respond to wholesale prices in the short-term, this asymmetric response is fully adjusted in two months. Some researchers examined US data. Borenstein and Shepard (1996) identified the asymmetric pattern of weekly retail gasoline prices between 1986 and 1992. Investigating weekly data from 1986 to 1998 with a vector autoregression (VAR) model, Borenstein et al. (1997) discovered that although the adjustment of wholesale prices to crude oil prices is symmetrical, the adjustment of retail gasoline prices is considerably asymmetrical, thus concluding that asymmetric response is different in each distribution process.

An analysis of monthly UK data from January 1982 to June 1995 with ECM indicated that retail gasoline prices asymmetrically respond to not only changes in crude oil prices but also in exchange rates (Reilly and Witt 1998).
Peltzman (2000) reported that the response of 77 consumer and 165 producer goods to cost changes are two times larger when the cost increases than when it decreases. Galeotti et al. (2003) asserts that the asymmetric response exists in both home heating oil and motor gasoline prices. Examined by the exponential general autoregressive conditional heteroskedastic (EGARCH) model, the daily data between September 13, 1991 and September 15, 2006 showed asymmetric response (Narayan and Nanayan 2007).

In contrast to these researchers determining the existence of asymmetric adjustment of retail gasoline prices, other researchers found no evidence that support asymmetry. Shin (1994), investigating monthly data from January 1986 to May 1992, argued that the adjustment of retail gasoline prices to changes in crude oil prices is symmetrical in the US. Analyzing the weekly data of 13 cities in Canada between 1990 and 1996 through the Threshold Auto Regressive (TAR) model within the ECM frame, Godby et al. (2000) found no evidence for the asymmetric response of retail gasoline prices. In an analysis of data from 1985 to 1998 using ECM, asymmetry existed only in weekly data but not in daily data (Bachmeier and Griffin 2003). These different research results need more explications.

Although they found different results and interpretations, previous research has been commonly devoted to verifying whether an asymmetric response exists by employing the error correction model (ECM). Eq. (1) is the Asymmetric Error Correction Model (AECM) commonly adopted to formulate the relationship between the retail gasoline price (\(p_t\)) and the crude oil price (\(p_{cr_t}\)). In ECM, \(\alpha\) is if \(>0\) and zero otherwise. In contrast, \(\phi\) is if \(<0\) and zero otherwise.

\[
\Delta Gasoline_{pr_t} \left( \sum_{i=1}^{L} q_i \Delta \text{Crudeoil}_{pr_{t-i}} + \sum_{j=1}^{S} \alpha_{ij} \Delta \text{Crudeoil}_{pr_{t-j}} + \phi (\text{Gasoline}_{pr_{t-1}} - \theta - \beta \cdot \text{Crudeoil}_{pr_{t-1}}) + \nu_t \right)
\]

The ECM is used to deal simultaneously with both short-term dynamics and long-term equilibrium within an equation. However, this method can only treat non-stationary variables (i.e., Random-walk model including unit-root), thus rendering it unavailable for verifying the asymmetric response with stationary variables. Furthermore, a linear relationship has been assumed between the retail gasoline price and the crude oil price, but the response to changes in crude oil prices could differ with the deviation size.

In this research, an improved model is presented to verify the asymmetric and non-proportional response, thereby resulting in more accuracy and greater detail in describing the fluctuating process and producing better estimates of the response. In the proposed model, the rockets and feathers phenomenon will be explicated further. For this purpose, the following research hypotheses were constructed and investigated in the study.

H1: Domestic retail gasoline prices asymmetrically respond to changes in crude oil prices.

H2: Domestic retail gasoline prices non-proportionally respond to changes in crude oil prices.

In the following section, the paper introduces data and a new research model to test the asymmetric and non-proportional response of the retail gasoline price to changes in the crude oil price. The next section analyzes the empirical results of the research. Finally, the conclusion is shown.

---

**FIGURE 1**

Monthly Gasoline Price (Won/liter) and Dubai Price (Won/bbl)
Methodology

Data
Monthly data of retail gasoline and crude oil prices in South Korea were analyzed. The Retail gasoline prices from January 2003 to March 2011 were obtained from the Korean Statistical Information Service (KOSIS). The price of Dubai oil, the biggest share of crude oil in South Korea, was used as the international crude oil price; Dubai oil prices from January 2003 to March 2011 were obtained from the Korea National Oil Corporation (KNOC). Considering the volatility of exchange rates, the new variable of crude oil prices (DUBAI_WON) was made by multiplying the crude oil price to the exchange rates. The Won/Dollar exchange rates from March 2003 to March 2011 were collected from KOSIS. Fig. 1 plots both the retail gasoline price (tax added) (GASOLINE) and the Dubai crude oil price (DUBAI_WON).

Table 1 is the descriptive statistics of retail gasoline and Dubai oil prices. During the research period, the retail gasoline price fluctuated from ₩1,329 at the bottom to ₩1,923 at the peak; the standard deviation was ₩147. On the other hand, the fluctuation of the Dubai oil price was from ₩35,796 to ₩133,667 at the peak; the standard deviation was ₩23,515.

Though considered in the literature, time-lags are difficult to establish in response to differing factors such as exporting, refining, and selling. To solve this problem, cross correlation between the retail gasoline and Dubai oil price was calculated. In Fig. 2 the correlation was the highest as 0.965 when no time-lag existed, which implies that there is no time-lag between the retail gasoline and Dubai oil prices.

Research Model
The augmented Dickey-Fuller (ADF) unit-root test was used in this study. There are three options for doing the ADF unit-root test. Among these options, Eq. (2) is the test

\[ \Delta y = \mu + \beta \cdot \text{Trend}_t + \gamma \cdot y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \cdots + \delta_p \Delta y_{t-p+1} + \epsilon_t \]

\[ H_0 : \gamma = 0, \quad H_1 : \gamma < 0 \quad (2) \]

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\[ H_0 : \gamma = 0, \quad H_1 : \gamma < 0 \quad (2) \]

FIGURE 2
Cross Correlation of Monthly Gasoline Price and Dubai Price

<table>
<thead>
<tr>
<th>GASOLINE, DUBAI_WON(-i)</th>
<th>GASOLINE, DUBAI_WON(+i)</th>
<th>lag</th>
<th>lead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0.9650 0.9650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>0.9006 0.8959</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>0.7879 0.8011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>0.6521 0.6988</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.5251 0.5933</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>0.4264 0.4923</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>0.3511 0.4148</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>0.3059 0.3861</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>0.2872 0.3753</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>0.2776 0.3400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.2750 0.3030</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>0.2557 0.2713</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>0.2393 0.2485</td>
</tr>
</tbody>
</table>

TABLE 1
Descriptive Statistics of Monthly Gasoline Price and Dubai Price

<table>
<thead>
<tr>
<th></th>
<th>GASOLINE</th>
<th>DUBAI_WON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>Mean</td>
<td>1550.11</td>
<td>69755.92</td>
</tr>
<tr>
<td>Median</td>
<td>1539.79</td>
<td>62092.59</td>
</tr>
<tr>
<td>Maximum</td>
<td>1922.59</td>
<td>133667.30</td>
</tr>
<tr>
<td>Minimum</td>
<td>1328.50</td>
<td>35796.20</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>146.92</td>
<td>23515.99</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.44</td>
<td>0.70</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.41</td>
<td>2.93</td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>3.80</td>
<td>6.75</td>
</tr>
<tr>
<td>Probability</td>
<td>0.15</td>
<td>0.03</td>
</tr>
</tbody>
</table>
equation that includes both a constant and trend.

The result of the ADF unit-root test in Eq. (2) was that both retail gasoline prices (t-statistics: -4.274, p-value: 0.0054 with 2 lag length based on SIC) and crude oil prices (t-statistics: -4.258, p-value: 0.0058 with 3 lag length based on SIC) are stationary time series without unit-roots. Since variables do not include unit-roots, we don’t have to use difference of these variables for using the ECM. It is also unnecessary to do the Co-integration Test. Thus, we don’t estimate ECM in this study.

Unlike the previous research, this paper proposes asymmetric and non-proportional responses. To verify the non-proportional characteristic, the hyperbolic tangent (tanh) function and the hyperbolic sine (sinh) function were used in the model. The sinh function is a function whereby the more a variable \( x \) deviates from “0” to the left, the larger the marginal decrease of a variable \( y \) becomes. This implies that the sinh function can be used to explain the feathers phenomenon that when crude oil prices decrease, the retail gasoline price does not decline proportionally. Similarly, the tanh function can be used to describe the rockets phenomenon. Fig. 3 plots the sinh(x) function in case that \( x \) is less than zero, and the tanh(x) function in case that \( x \) is bigger than zero. The left vertical axis is the value of the sinh(x) function, while the right vertical axis is that of the tanh(x) function.

For the purpose of this research, the “Asymmetric & Non-Proportional Model” is presented in Eq. (3). The tanh(x) function is set for the “rockets” phenomenon in case that the changing proportion compared to the last month is “positive, >0,” and the sinh(x) function for the “feathers” phenomenon in case that the changing proportion compared to the last month is “negative, <0.” For the estimation of the function are multiplied by 10. This multiplication means

\[
\text{Gasoline } p_{t} = \alpha + \beta \cdot \text{Dubai won}_{t} + \\
\quad + \gamma_{1} \cdot \text{tanh}\left[\frac{\text{Dubai won}_{t} - \text{Dubai won}_{t-1}}{\text{Dubai won}_{t-1}}\right] \\%10 \\
\quad + \gamma_{2} \cdot \text{sinh}\left[\frac{\text{Dubai won}_{t} - \text{Dubai won}_{t-1}}{\text{Dubai won}_{t-1}}\right] \\%10 \\
\quad + \lambda \cdot \text{Gasoline } p_{t-1} + \tau \cdot \text{Demand gasoline}_{t-1} + \theta \cdot \text{Trend}_{t} + \epsilon_{t}
\]

where

\[
\text{Dubai won}_{t} = \text{Dubai } p_{t}(\$) \times \text{Exchange rate}_{t}(\text{won/\$})
\]

If the parameter \( \gamma_{1} \) in Eq. (3) is statistically significant, the “rockets” phenomenon is confirmed. This confirmation means that the increase in retail gasoline prices is non-proportionally more rapid than the increase in crude oil prices. Also, if the parameter \( \gamma_{2} \) is statistically significant, the “feathers” phenomenon is confirmed, thus showing that the decrease in retail gasoline prices is non-proportionally slower than the decrease in crude oil prices. It is assumed that changing ratios in the tanh(x) and sinh(x)
that when the price increases or decreases by 30% compared to the price last month, a value in the function would have a value of +/-3. For the comparison, Symmetric & Proportional Model in Eq. (4) and Asymmetric & Proportional Model in Eq. (5) are tested together.

\[
\text{Gasoline}_p r_t = \alpha + \beta \cdot \text{Dubai}_w o n_t + \\
+ \gamma_1 \left( \frac{\text{Dubai}_w o n_t - \text{Dubai}_w o n_{t-1}}{\text{Dubai}_w o n_{t-1}} \right) + \\
+ \lambda \cdot \text{Gasoline}_p r_{t-1} + \tau \cdot \text{Demand}_g a s o l i n e_{t-1} + \theta \cdot \text{Trend}_t + \epsilon_t
\]  

(4)

\[
\text{Gasoline}_p r_t = \alpha + \beta \cdot \text{Dubai}_w o n_t + \\
+ \gamma_1 \left( \frac{\text{Dubai}_w o n_t - \text{Dubai}_w o n_{t-1}}{\text{Dubai}_w o n_{t-1}} \right)^\gamma + \\
+ \gamma_2 \left( \frac{\text{Dubai}_w o n_t - \text{Dubai}_w o n_{t-1}}{\text{Dubai}_w o n_{t-1}} \right)^{-\gamma} + \\
+ \lambda \cdot \text{Gasoline}_p r_{t-1} + \tau \cdot \text{Demand}_g a s o l i n e_{t-1} + \theta \cdot \text{Trend}_t + \epsilon_t
\]  

(5)

Empirical Results

Table 2 shows the empirical results of the proposed model and other models. The ordinary least squares method is used for the estimation. To compare the superiority of models, Adj-R2 is presented in the table. The Akaike Information Criterion (AIC) is also used to evaluate the fitness of the models. AIC is defined as when K is the number of the parameters. To verify the serial correlation of the residuals after the estimation, the Durbin-Watson (DW) statistic

TABLE 2
Monthly Model Estimation Results

<table>
<thead>
<tr>
<th>Model Variables</th>
<th>Symmetric &amp; Proportional</th>
<th>Asymmetric &amp; Proportional</th>
<th>Asymmetric &amp; Non-Proportional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>476.4542</td>
<td>541.9080</td>
<td>545.3343</td>
</tr>
<tr>
<td></td>
<td>(***</td>
<td>(***</td>
<td>(***</td>
</tr>
<tr>
<td>(\text{Dubai}_w o n_t)</td>
<td>0.002560</td>
<td>0.003047</td>
<td>0.002906</td>
</tr>
<tr>
<td></td>
<td>(***)</td>
<td>(***</td>
<td>(***</td>
</tr>
<tr>
<td>(\frac{\text{Dubai}_w o n_t - \text{Dubai}<em>w o n</em>{t-1}}{\text{Dubai}<em>w o n</em>{t-1}})</td>
<td>206.2872</td>
<td>(***</td>
<td></td>
</tr>
<tr>
<td>(\frac{\text{Dubai}_w o n_t - \text{Dubai}<em>w o n</em>{t-1}}{\text{Dubai}<em>w o n</em>{t-1}})^\gamma</td>
<td>-131.5275</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\frac{\text{Dubai}_w o n_t - \text{Dubai}<em>w o n</em>{t-1}}{\text{Dubai}<em>w o n</em>{t-1}})^{-\gamma}</td>
<td>468.1897</td>
<td>(***)</td>
<td></td>
</tr>
<tr>
<td>tanh[((\frac{\text{Dubai}_w o n_t - \text{Dubai}<em>w o n</em>{t-1}}{\text{Dubai}<em>w o n</em>{t-1}})^\gamma \cdot 10)]</td>
<td>-16.75379</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sinh[((\frac{\text{Dubai}_w o n_t - \text{Dubai}<em>w o n</em>{t-1}}{\text{Dubai}<em>w o n</em>{t-1}})^{-\gamma} \cdot 10)]</td>
<td>30.37941</td>
<td>(***)</td>
<td></td>
</tr>
<tr>
<td>\text{Gasoline}<em>p r</em>{t-1}</td>
<td>0.567319</td>
<td>0.502161</td>
<td>0.511295</td>
</tr>
<tr>
<td></td>
<td>(***)</td>
<td>(***</td>
<td>(***</td>
</tr>
<tr>
<td>\text{Demand}<em>g a s o l i n e</em>{t-1}</td>
<td>0.001418</td>
<td>0.006538</td>
<td>0.003375</td>
</tr>
</tbody>
</table>

In the parenthesis, *** means 99%; ** 95%; and * 90% statistically significance.
is described. Since the DW statistic is, there is little serial correlation when DW is between 1.3 and 2.6.

Comparing the results, the proposed model has the lowest AIC and the best Adj-R2. The carry-over coefficients of the three models are between 0.50 and 0.57, much less than “1.” DW statistics of models are between 1.5 and 1.7.

Firstly, the Symmetric & Proportional model shows that every parameter is statistically significant except for the trend and the lag of gasoline demand. It is estimated that the absolute level and change differential of Dubai oil prices are positively related to the gasoline prices. This means that the retail gasoline prices respond to both the absolute level and the change differential of Dubai oil prices. Secondly, as seen in the Asymmetric & Proportional model in Eq. (5), when the Dubai oil price increased compared to the previous month, the response to the absolute level of Dubai oil price is statistically significant, while the response to the change differential of Dubai oil price is not. In other words, when crude oil prices increase, retail gasoline prices respond only to the absolute level; on the other hand, when crude oil prices decrease, retail gasoline prices respond to both the absolute level and change differential. This indicates that the response of retail gasoline prices to the change differential of crude oil prices is asymmetric.

Finally, the results of Asymmetric & Non-Proportional model show that the rockets phenomenon (tanh function) is not statistically significant, whereas the feathers phenomenon is statistically significant. When the crude oil price decreases, the response of retail gasoline prices to crude oil prices is non-proportional as well as asymmetric. When it increases, the retail gasoline price responds only to the absolute level of crude oil prices. From the overall results, we can confirm that the response of retail gasoline prices to crude oil prices is asymmetric and non-proportional.

Fig. 4 presents both results between the proportional and non-proportional models according to the decreasing ratio compared to the last month (0 ~ -0.21). As seen in the figure, the biggest decrease ratio is 21 percent in our dataset. And when the ratio of the decreasing crude oil prices is small (0 ~ 17.5 percent), the decrease in gasoline prices in the non-proportional model is less than that in the proportional model.

**Discussions**

In this paper, analyzing the relationship between the retail gasoline prices in Korea and Dubai oil prices, we provide an improved model to test the conventional rockets and feathers phenomenon, a phenomenon that the retail gasoline prices rise like rockets and decline like feathers responding to changes in crude oil prices. The results, overall, indicate that when crude oil prices decrease, the response of retail gasoline prices to crude oil prices is asymmetric and non-proportional. In contrast, when compared to the proportional model, the non-proportional model does not demonstrate a radical improvement in instrumental fitness. Nevertheless, the non-proportional response of retail gasoline prices cannot be disputed since the non-proportional model can produce better estimates of the rockets and feathers phenomenon by describing the non-proportional process in detail.

**Limitations and Future Research**

It is expected that the model suggested in this paper can
improve the analysis of price adjustment over the previous models in the literature. But we adopted the proposed research model to only one country. Therefore, the proposed model is required to apply to more countries and regions. The model also can be expended to different products and regional research. It can be used by other researchers to analyze price adjustment more accurately. It can also be further researched to create price policies for particular products that are sensitive to raw material prices like fruits, beef, and vegetable.

REFERENCES


