Oh, S., Heo, E., Structural change and asymmetry analysis of petroleum product prices in Korea.
International Symposium on the Fusion Technology of Geosystem Engineering, Rock Engineering and Geophysical Exploration
Seoul, Korea, Nov. 18-19, 2003

Structural change and asymmetry analysis of petroleum product prices in Korea

Sunah Oh, Eunnyeong Heo
Seoul National University, Seoul, Korea

Abstract: This paper examines structural breaks and asymmetries of prices of four domestic petroleum products, i.e., gasoline, kerosene, diesel, and bunker-C, following the changes in the pricing policies pertaining to petroleum products in Korea from the government-controlled pricing system to the market pricing system. We use the monthly wholesale market price data for the sample period between July 1988 and December 2001. Using the four methods: the Chow test, the CUSUM/CUSUMQ tests, the Bayesian approach and the Dufour test, the structural behaviors of the petroleum product prices are examined. We found that structural change occurred in all petroleum products, with the exception of Kerosene, at the point of pricing policy change from government-controlled to the spot-price related pricing system. We, also conducted asymmetric analysis using the Borenstein, Cameron, and Gilbert (1997)'s model and found evidences of price asymmetry for all four product types, but in different pattern for each product.

1. Introduction

Following the petroleum crisis in the early 1974 and in 1979 and the sudden crash in oil prices worldwide in the mid 1980s, petroleum product prices in Korea, which had continuously maintained a stable price under the government-controlled flat-pricing system, dropped and has remained at a low level ever since. This drew the attention to the need to develop a pricing policy that would reflect the current market situation to replace the then current one. As a result, the Korean government adopted the spot-price related pricing system, which was implemented in 1994 and consequently the pricing policy was changed to the market pricing system in January 1997. Under the current system, petroleum product prices would be autonomously set by the oil refiners in accordance with the market conditions so long as such acts are not in violation of the fair trade act.

It is only natural that the reform of national policies pertaining to the oil industry would entail a structural change in the oil refiner's pricing schemes of petroleum products. But despite the significance of this issue, there have only been a few researches conducted on this subject, and as a result, both scientists and the general public have only limited knowledge on this. Further, whenever the price of oil in the international market changes, we start question the rationale behind the adjustment of petroleum product prices by the domestic oil refiners. In this regard, it is important to study in depth the background of the changes in the refiner's pricing schemes and what its implications are.

In this study, we analyzed the structural changes and asymmetry of petroleum product prices based on the monthly wholesale price for the period between 1988 and 2001 to learn how the change in the pricing policies, as described above, influenced the refiner's pricing schemes of petroleum products. The analysis was done on four petroleum products, i.e., gasoline, kerosene, diesel, and bunker-C which constitute more than 65% of the production of oil refineries in Korea.

The rest of this paper is structured as follows. In Section 2, we cover the preliminary analysis on the characteristics of the time series data by the unit root and cointegrating tests. In Section 3, we analyze and compare the structural changes by applying the four structural change analysis methods; the Chow test, the CUSUM.CUSUMQ tests, the Bayesian approach and the Dufour test. Also, we analyze the structural change in petroleum product pricing scheme bearing in mind the social and economic causes, such as the issue of international supply and demand during the Gulf War, the change in the political and market psychology, etc. In Section 4, based on the empirical results from Sections 2 and 3, we analyze the asymmetry in prices using the Borenstein, Cameron, and Gilbert (1997, hereafter BCG)'s model. Finally, some concluding remarks are offered in Section 5.

2. Characteristics of Data

2.1. Data Analysis

In our analysis, we used the monthly wholesale price, found in the monthly statistical report on petroleum supply and demand released by the Korea National Oil Corporation, of the four types of petroleum products mentioned above for the sample period between July 1988 and December 2001. In our calculation of the wholesale price (1995 constant Korean Won/ liter). Figure 1. shows the movement of prices of the four petroleum products pertaining to the sample period above.

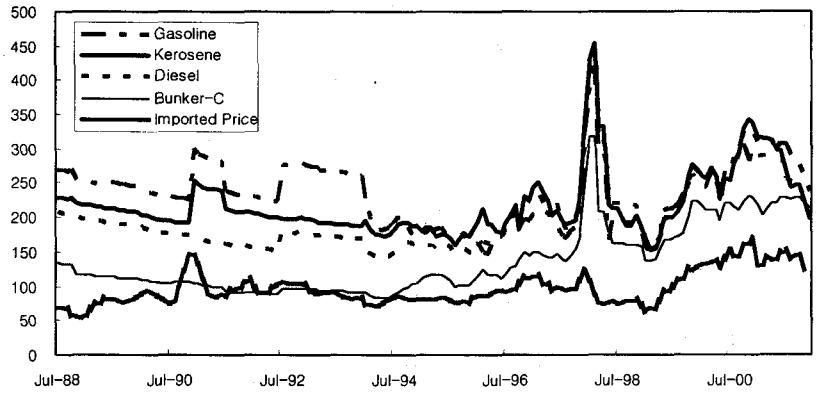

Fig. 1. Petroleum Product Prices & Imported Oil Price in Korea.

From this figure, we can see almost no change in the prices under the government-controlled pricing system up to 1993, except for the two instances where oil prices rose due to the Gulf War in 1990 and the sudden leap in the exchange rate in 1992. However, following the implementation of the spot-price related pricing system in January 1994, we observe that there was extreme volatility in petroleum product prices in Korea.

2.2. Unit Root Test

Upon performing unit root test of the petroleum products prices and imported crude oil price, we reject the null hypothesis that, with the exception of the kerosene, all other petroleum products were found to be non-stationary at the 5% significance level. However, even in the case of kerosene, we reject the null hypothesis because the p-value was also less than the 1% significance level. And, performing unit root test on the 1st difference, we could conclude that the time series was non-stationary.

Table 1. Results of unit root test.

Variables	t-stats	P-value	Decision
Gasoline	0.1818	0.2971	exist**
Δ Gasoline	-5.9318	<0.001	non-exist**
Kerosene	0.0138	0.0279	exist*
Δ Kerosene	-6.4707	<0.001	non-exist**
Diesel	0.1561	0.1378	exist**
Δ Diesel	-4.7693	<0.001	non-exist**
Bunker-C	0.2133	0.0720	exist**
Δ Bunker-C	-5.8964	<0.001	non-exist**
Imported Price	0.0605	0.1317	exist**
Δ Imported Price	-6.2030	<0.001	non-exist**

2.3. Cointegration Test

Based on the unit root test, we concluded that the time series data of petroleum product prices and the imported price of crude oil were non-stationary. If regression analysis is performed on the non-stationary time series, we would find a spurious regression irrespective of whether there is any correlation whatsoever between the two variables. This is confirmed by the increase in the value, R^2 and t-value with the increase in the number of samples, as opposed to the decrease of the value of DW. A low DW indicates that there is auto correlation in the error term, and such inconsistency in the error term may make the values, R^2 and t-value to appear very high.

Table 2. Results of cointegrating test.

Variables	t-stats	P-value	Decision
Gasoline	-3.4049	0.0083	exist*
Kerosene	-3.5487	0.0052	exist*
Diesel	-3.4306	0.0077	exist*
Bunker-C	-2.6021	0.0730	exist**

3. Structural Change

3.1. Theoretical Background

In analyzing the structural change of petroleum product prices, we used the four most widely used structural change analysis methods, as mentioned in the previous section. These four methods can be further classified into two groups: The first includes the Chow test and the Dufour test which can be applied where the exact break point and frequency of the structural change is known, and the second group includes the CUSUM/CUSUMQ tests and In-Moo Kim and Maddala (1991)'s Bayesian approach, which can be applied where the exact break point and frequency of the structural change is unknown.

1. Chow test: Typically, the Chow test is applied when the break point, which usually occurs only once, is known.
2. Dufour test: If two or more break points are known, we can use this test to verify whether structural change had indeed occurred.
3. CUSUM and CUSUMQ tests: We can use the CUSUM test, which mainly perceives the systematic increase or decrease in the regression coefficients, and the CUSUMQ test, which mainly perceives the sudden movements of regression coefficients to predict the point of structural change.
4. Bayesian approach: We can use this approach to predict the point of structural change where the BIC (Bayesian Information Criterion) value is at its lowest.

3.2. Empirical Results

In this study, we first performed the Chow test, CUSUM/CUSUMQ test and the Bayesian approach to analyze the prices of domestic petroleum products, and then these results were applied to the Dufour test to confirm our findings. We used modified the Chow test procedure so that we could verity whether there could possibly be any other structural break points other than the known one. By doing so, we could confirm our assumptions.
The results of the four tests performed on the sample period are presented in Table 3.

First, in the case of gasoline, structural change was found to have occurred four times beginning in December 1990, December 1993, January 1998 and then in December 1999. In the case of Kerosene, structural change occurred three times beginning in November 1990, December 1997 and July 2000. In the case of Diesel, structural change occurred four times, beginning in July 1992, December 1993, July 1996 and December 1997. And lastly, in the case of Bunker-C, structural change occurred three times beginning in January 1994, July 1996 and December 1997. Among the three tests, the Bayesian approach showed the most number of break points and proved to be the most efficient method in that it provided the greatest amount of data on structural change. Moreover, when the results from the Bayesian approach were applied to the Dufour test, we found corroborating results.

Table 3. Structural Breaks on Domestic Petroleum Product Prices.

	Gasoline	Kerosene	Diesel	Bunker-C
Chow test	Jan. 1994 Nov. 1999	Nov. 1990 Dec. 1997	Jul. 1996 Dec. 1997	Jan. 1994 Oct. 1997
CUSUM / CUSUMQ tests	Dec. 1993 Dec. 1997	Jun. 1992 Dec. 1997	Jan. 1994 Dec. 1997	Jan. 1994 Dec. 1997
Bayesian approach	Dec. 1990 Dec. 1993 Jan. 1998 Dec. 1999	Nov. 1990 Dec. 1997 Jul. 2000	Jul. 1992 Dec. 1993 Jul. 1996 Dec. 1997	Jan. 1994 Jul. 1996 Dec. 1997
Dufour test	Dec. 1990 Dec. 1993 Jan. 1998 Dec. 1999	Nov. 1990 Dec. 1997 Jul. 2000	Jul. 1992 Dec. 1993 Jul. 1996 Dec. 1997	Jan. 1994 Jul. 1996 Dec. 1997

An examination of the structural changes following the change in the pricing policy suggests that ever since the implementation of the spot-price related pricing system in January 1994, the prices of all petroleum products responded sensitively to crude oil price. And analyzing the effect of such change from the perspective of structural change, we could see that, with the exception of Diesel, the other three petroleum products responded to the fall in the crude oil price. Thus, it is reasonable to say that the domestic pricing scheme of gasoline and kerosene, which show the highest consumption rate in the country and the price volatility of which consumers are most conscious, and Bunker-C which takes up the greatest portion of total oil production.

The empirical results, however, show that the implementation of the market pricing system did not show any changes in the price adjustment behavior. Thus, notwithstanding the fact that, with implementation of the market pricing system, refiners are given the power to adjust prices of petroleum products at their own will, we could not observe any significant changes. In fact, prices movements remained the same as that under the spot-price related pricing system.

Also, in addition to structural break in domestic prices due to the change in the pricing scheme in Korea, empirical results suggests that the structural changes of gasoline and kerosene prices in November and December 1990 were the result of the increase in international crude oil prices during the Gulf War. At this time, domestic petroleum prices were being regulated by the government-controlled pricing system and so the prices for Diesel and Bunker-C were fixed. Furthermore, during the period between December 1997 and January 1998, the rise in the domestic prices was due to the sharp leap in foreign exchange rate at that year as a result of the International Financial Crisis in South East Asia. Considering that the petroleum product prices were being set under the market pricing system, oil refiners adjusted prices to accommodate for the rise in production cost. These two cases may be regarded as instances where the prices sharply increase due to external factors. However, in the case of the domestic petroleum product prices, the sudden movement in the price of all petroleum products due to such external factors showed contradicting tendencies following the change in pricing policies in Korea.

4. Assymetric analysis

4.1. Theoretical Background

An analysis on the asymmetric response of the prices of domestic petroleum products through the comparison of the speed of adjustment of petroleum prices in accordance with the oil price rise and fall will explain whether the relevant market is a perfect competition market. Using the BCG model, we attempted to analyze how the increase and decrease of imported crude oil prices influences the domestic prices of each petroleum product type. According to this model, we found that the price of domestic petroleum products have not been responding sensitively to the increase and decrease of crude oil price. In other words, the asymmetry is neither dependent on the level of change in imported crude oil price nor sensitive to sample period.

Let's assume $\Delta C_t = C_t - C_{t-1}$, $\Delta R_t = R_t - R_{t-1}$

Then,

$$\begin{aligned} \Delta R^{t} &= \beta_0 \Delta C_t \\ \Delta R^{t}_{t+1} &= \beta_1 \Delta C_t \\ &\vdots \\ \Delta R^{t}_{t+n} &= \beta_n \Delta C_t \end{aligned} \tag{1}$$

Where the superscript on ΔR_t indicates the change in gasoline prices in response to that of crude oil price during time t, and n means the time taken to complete adjustment of the price following the change in crude oil price. Under this assumption, the complete change in retail price of gasoline at time t shall be assumed to be dependent on change during the previous time period n.

$$\Delta R^{t}_{t} = \Delta R^{t}_{t} + \Delta R^{t+1}_{t} + \cdots + \Delta R^{t-n}_{t} = \sum_{i=0}^{n} \beta_i \Delta C_{t-i} \tag{2}$$

However, Equation (2) imposes symmetric responses to increases and decreases in crude oil prices. Assuming that the adjustment of oil prices could be different for these two cases, let us then assume the following.

$$\begin{aligned} \Delta R^{t}_{t} &= \beta^{+}_{o} \Delta C_t \\ \Delta R^{t}_{t+1} &= \beta^{+}_{1} \Delta C_t \\ &\vdots \\ \Delta R^{t}_{t+n} &= \beta^{+}_{n} \Delta C_t \end{aligned} \qquad \text{if } \Delta C_t > 0 \tag{3}$$

$$\begin{aligned} \Delta R^{t}_{t} &= \beta^{-}_{o} \Delta C_t \\ \Delta R^{t}_{t+1} &= \beta^{-}_{1} \Delta C_t \\ &\vdots \\ \Delta R^{t}_{t+n} &= \beta^{-}_{n} \Delta C_t \end{aligned} \qquad \text{if } \Delta C_t < 0 \tag{4}$$

Here, $\Delta C^{+}_{t} = \max\{\Delta C_t, 0\}$ and $\Delta C^{-}_{t} = \max\{\Delta C_t, 0\}$. In this case, the adjusted form for the adjustment of retail gasoline price against crude oil changes, which allows for the possibility of price asymmetry, can be represented as

$$\Delta R^{t}_{t} = \sum_{i=0}^{n} \left(\beta^{+}_{i} \Delta C^{+}_{t-i} + \beta^{-}_{i} \Delta C^{-}_{t-i} \right) + \varepsilon_t \tag{5}$$

Here, considering the correlation between the oil production cost and selling price in the long run and their tendency to regress towards each other, if we include the first error correction term derived from $R = \phi_o + \phi_1 C$ to Eq. (5) gives

$$\Delta R^{t}_{t} = \sum_{i=0}^{n} \left(\beta^{+}_{i} \Delta C^{+}_{t-i} + \beta^{-}_{i} \Delta C^{-}_{t-i} \right) + \theta_1 \left(R_{t-1} - \phi_o - \phi_1 C_{t-1} \right) + \varepsilon_t \tag{6}$$

Lastly, following the confirmation that the error term generates white Gaussian noise, if we include the differential variable of gasoline price to Eq. (6), bearing in mind the short-run adjustment process within the long-term correlation, this give

$$\Delta R^{t}_{t} = \sum_{i=0}^{n} \left(\beta^{+}_{i} \Delta C^{+}_{t-i} + \beta^{-}_{i} \Delta C^{-}_{t-i} \right) + \sum_{i=1}^{n} \left(\gamma^{+}_{i} \Delta R^{+}_{t-1} + \gamma^{-}_{i} \Delta R^{-}_{t-i} \right) + \theta_1 \left(R_{t-1} - \phi_o - \phi_1 C_{t-1} \right) + \varepsilon_t \tag{7}$$

In the BCG model, comparing β^{+}_{o} of ΔC^{+}_{t} and β^{-}_{o} of ΔC^{-}_{t}, if $\beta^{+}_{o} > \beta^{-}_{o}$, then we recognize that domestic prices respond more quickly to the increase than to the decrease of imported crude oil prices. On the other hand, if $\beta^{+}_{o} < \beta^{-}_{o}$,

then we can assume that petroleum product prices respond more quickly to the decrease, rather than to the increase of imported crude oil price.

4.2. Empirical Results

Although the prices of petroleum products are greatly influenced by the imported crude oil price, there are some instances where the adjustment of retail prices of petroleum products are not instantaneous to the change of imported crude oil price. Such deviation can be assumed to be the result of the manipulation of prices by the government and the oil refiner, inducing different degree of change. Thus, by analyzing the relationship between imported crude oil price and domestic petroleum product prices, we would be able to examine the oil refiner's pricing schemes following the change in the pricing polices of petroleum products in Korea.

As mentioned in the previous section, we applied the BCG model to analyze the price asymmetry of petroleum product prices. First, the empirical results obtained by BCG's error correction model exhibited asymmetry in prices of all the petroleum product types, with the exception of kerosene. Especially, gasoline price was found to respond more sensitively to the decreases in imported crude oil price than to the increases. Moreover, when we considered the effect of the previous retail prices of petroleum products to the current retail prices, we were able to confirm the asymmetry of prices.

Next, under the assumption that the change in the domestic pricing policy may influence the speed of adjustment of petroleum prices, we applied the threshold BCG model to analyze the price asymmetry of petroleum prices. In the threshold BCG analysis, we examined price asymmetries using two different models: the partial constraint model where the invariable terms remains constant for all sample period and where the regression coefficients of imported crude oil price are different; and perfect constraint model, where the invariable term is different at various sample periods. In the case of the former, we could find price asymmetry for all petroleum product types. Similarly, in the case of the perfect constraint model, we could find asymmetry in the prices of all petroleum product types, where R^2 increased and γ_1 and θ_1 was high. Even though, both cases showed similar results, but by considering structural change, the perfect constraint model proved to be show more significant than the BCG model.

Compared to Uhm (2001)'s results, we could observe contrasting observations. According to Uhm (2001), who took into consideration only the periods up to June 2000, $\beta_0^+ > \beta_0^-$, indicating that the increase in imported crude oil price had a greater effect on the changes of the retail price of gasoline more than when it decreases. In our study, we analyzed data for the period up to December 2001 and found that the decrease in the imported crude oil price showed a greater effect on the retail price of gasoline price than when it increases. An explanation to such contrasting results could be due to the fact that we considered an additional 18 months as our sample period.

5. Conclusions

This paper investigates the structural changes following the change in the domestic pricing policy for the petroleum products and those resulting from unexpected events. We, then, analyzed the price asymmetry between imported crude oil prices and the domestic petroleum product prices. From the results of the analysis, we can confirm that the time series data for all domestic petroleum products and imported crude oil prices were non-stationary. Further, by performing the cointegrating test on these samples, we could also confirm cointegrating relationship among domestic petroleum product prices and imported crude oil price, which consequently indicates a long-run stable relationship.

In this study, we examined whether the change of pricing policy affects the oil refiner's pricing schemes and analyzed whether there are other external factors that could have contributed to such structural change. Applying the Chow test, the CUSUM /CUSUMQ tests, Bayesian approach and the Dufour test, we found structural breaks where the pricing policy was changed from the government-controlled pricing system to the spot-price related pricing system in 1994, whereas the prices of petroleum products showed to remain stable where the spot-price related pricing system was changed to the market pricing system in 1997. Another point to be noted is that during the Gulf War in 1990, the prices of gasoline and kerosene were being regulated by the government and further during the Asian Financial Crisis in 1997, we observed structural breaks for the prices of all four petroleum product types.

From the asymmetric analysis, we found the followings; first, the prices of gasoline and kerosene showed stabilizing tendencies in contrast to those of diesel and Bunker-C. Despite the fact that the gasoline and kerosene take up only 15% as opposed to 50% for diesel and Bunker-C, oil refiners tend to adjust prices of gasoline and kerosene at a moderate level as opposed to the other types because consumers are more conscious about price changes of the former than the latter. Another reason for the price asymmetry can be found in level of competition within the rele-

vant markets. In our study, we observed that there was relatively little competition in the market for gasoline and kerosene and imported products

We found that political and economical factors do influence the price setting of petroleum products in Korea. Thus, when carrying out an analysis on price fluctuations of petroleum products or on relevant policies, it is important to take these external factors into consideration. However, since it was only recently that the pricing policy had been changed to the market pricing system and because this system is currently only being applied to the petroleum industry, it is important that further study be conducted in this area as it will provide a forecast, especially, when the other energy industries, including electricity and gas, become privatized.

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