South African Petrol Price and Consumption Cointegration Analysis

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Abstract: In this study, the relationship between the quarterly data of consumption and price of petrol from 2005-2017 is considered. The two series are found to be integrated of the same order I(1) based on the ADF test. Though both variables do not have long-run equilibrium relationship based on Engle-Granger and Johansen tests but there exists a unidirectional causality from consumption to the retail price of petrol. The VAR Models estimated are found to be significant and stable and without any defects (i.e., no heteroskedasticity, no serial correlation and residuals of these VAR Models are found to be normally distributed).

Key words: VAR, augmented Dickey-Fuller, cointegration, significant, correlation

INTRODUCTION

Petrol is the quintessential commodity in the modern industrial economy. Although, the industrial revolution was initially powered by coal, since, the first commercial petrol well was drilled in Pennsylvania in 1859 petrol has gained increasing prominence in terms of its share of the world’s primary energy supply. It now accounts for over 35%, the largest share. As an energy source petrol is used for electricity generation, heating and most importantly as a liquid fuel for transportation. The world’s transport systems (including ships, trains, airplanes and road transport) depend on petrol for some 90% of their energy (Leggett, 2005). Consequently, the tourism sector in most countries is also highly reliant on petrol. Industrial agriculture depends heavily on petrol and natural gas for the production of fertilizers, herbicides and pesticides as well as to power mechanised farm machinery and transport products to markets.

The amount of fuel available is one of the influences of consumption and price. When an item is abundant, then the price tends to be cheaper and consumptions can also be high because of affordability. South Africa Yearbook (2008/09) reports that South Africa has limited oil reserves and that almost 95% of South Africa’s crude oil requirements are imported from the Middle East and Africa. Thus, with only 5% being produced locally, there is an indication of scarcity and expectations of low consumption from consumers. Some several studies (Girma and Paulson, 1999; Gjolberg and Johnsen, 1999; Serlitis, 1994) have investigated the relationship between the prices of petrol and refinery products. These studies have established the existence of long-run price relationships between crude Petrol and refined products. Insights to these relationships convey valuable information for forecasting in the petrol industry. In this study, interest is to represent cointegration long term relationship of nonstationary petrol prices and consumption rates in South Africa using statistical methods.

Cointegration: The ADF test is used to test the null hypothesis that the series has a unit root against the alternative hypothesis of no unit root. This test is based on simple regression of series $Y_t$ on series $Y_{t-1}$ (that is the one period lagged value of $Y_t$) and check if the estimate of $\theta$, the coefficient of $Y_{t-1}$ as in Eq. 1 is equal to 1 or not:

$$Y_t = \theta Y_{t-1} + e_t$$  \hspace{1cm} (1)

where $e_t$ denotes a serially uncorrected white noise error term with a mean of zero and a constant variance. Reparametrising 1 from both sides becomes:

$$\Delta Y_t = \delta Y_{t-1} + e_t$$  \hspace{1cm} (2)

where $\delta = (-1)$ and $\Delta$ is the first difference operator. In this study, we will estimate Eq. 2 and test for the null hypothesis of $\delta = 0$ against the alternative of $\delta \neq 0$. If $\delta = 0$, then $\theta = 1$ which implies that the series in question has a
unit root (the series is nonstationary). According to Erdogdu (2007), it is important to note that the above null hypothesis, the t-value of the estimated coefficient of Yt - 1 does not follow the t-distribution even if the sample size is large. This implies that, this t-value does not have an asymptotic normal distribution. Thus, the decision rule now based on the Dickey-Fuller (DF) critical values of the τ (tau) statistic. But the DF test is based on an assumption that the residuals are not correlated.

However, in practice, the residuals in the DF test usually show evidence of serial correlation. In order to solve the resulting problem of serial correlation of the residuals, Dickey and Fuller came up with a test known as the Augmented Dickey-Fuller (ADF) test. In this test, the lags of the first difference are included in the regression equation, so as to make the residuals or error terms white noise. Its regression equation is given below:

\[
\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{\rho} \Delta Y_{t-i} + \epsilon_t
\]

Including intercept and time, t, in Eq. 4 now yields:

\[
\Delta Y_t = \beta_1 t + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{\rho} \Delta Y_{t-i} + \epsilon_t
\]

The ADF unit root testing procedure uses this model:

\[
\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{j=1}^{i} \delta_j \Delta Y_{t-j} + \epsilon_t
\]

Where:
- \( \alpha \) : The intercept (a constant)
- \( \beta \) : The coefficient time
- \( t \) : The coefficient of \( Y_{t-1} \)
- \( \rho \) : The lag order of the autoregressive process
- \( \Delta Y_t \) : The first difference of \( Y_t \)
- \( Y_{t-1} \) : The one time period lag values
- \( \gamma \Delta Y_{t-j} \) : The changes in lagged values
- \( \epsilon_t \) : The white noise

In ADF Model, \( \gamma \) is now the parameter of interest. If \( \gamma = 0 \), then, the series \( Y_t \) has unit root and therefore, it is integrated of order \( d = 1 \).

Choice of the appropriate number of lags has been a problem in the field of econometrics. The following six criteria; Langrange Multiplier (LM) test, Schwarz Information Criterion (SIC), the Hannan-Quinn Criterion (HQC), the general to specific sequential Likelihood Ratio test (SLR), Akaike Information Criteria (AIC) and a small sample correction to test (SLR) were suggested for the selection of lag order in 2005 by Ivanov, Kilian et al. However, in this study, the number of lags is chosen based on SIC as it has been argued by many econometricians that the SIC should be applied to small sample and AIC to large sample. This study adopts the ADF test which is the most notable and commonly used among many unit root tests.

The VAR developed by Sims (1980) is regarded as an improvised multivariate model where each variable is regressed on its own lags and the lags of other variables in a finite-order system. And the objective of this approach is study the system dynamic response to innovations the system having to depend on restrictions embedded in the structural models. The VAR can thus be represented as below following the representation of Bernake and Blinder (1992):

\[
\beta(y_t) = \theta(L)y_t + \delta(L)x_t + u_t
\]

Where:
- \( y_t \) : A (k×1) vector of endogenous variables
- \( x_t \) : A q vector of exogenous variables
- \( \beta, \theta \) : Matrices of the estimated coefficients and \( \delta \)
- \( L \) : The lag operator
- \( I \) : The lag order
- \( u_t \) : The vector of innovations or shocks which are independently and identically distributed

The reduced form of Eq. 1 becomes:

\[
y_t = \alpha(L)y_t + \epsilon_t
\]

where \( (L) = \beta^{-1}(L) = \alpha_t L + \alpha_{L^2} + ... + \alpha_{L^k} \), \( \epsilon_t = \beta^{-1}u_t \). And this can be written in the form of MA as:

\[
y_t = \frac{1}{1-\alpha(L)} \epsilon_t = K(L) \epsilon_t
\]

The impulse response functions and variance decomposition can be estimated for Eq. 8 when the estimated VAR is either stationary or not. Vector error correction model can be estimated if all the variables which are integrated of the same order are cointegrated and this can be used to estimate the impulse response functions and variance decomposition. Based on Eq. 4 the following three cases are discussed by Cochrane (2005):

\[
\Delta y_t = \alpha(L)y_{t+1} + \sum_{i=1}^{\rho} \alpha_i \Delta y_{t-i} + u_t
\]

Case 1: We run a normal VAR in level if \( \alpha(L) \) is full rank and any linear combination of \( Y_{t-1} \) is stationary.

Case 2: We run VECM using Eq. 5 when the rank of \( \alpha(L) \) lies between 0 and full rank and there exist some linear combinations of \( y_t \) that are stationary.
\[
\Delta y_t = \alpha \beta y_{t-1} - \sum_{j=1}^{\infty} \alpha^j \Delta y_{t-j} + u_t
\]

(10)

**Case 3:** We can run the normal VAR in first difference if the rank of \(\alpha(L)\) is zero and \(\Delta y_t\) is stationary with no cointegration.

Lack of cointegration among variables leads to the estimation of unrestricted Vector Autoregressive Model (VAR). The most primary thing to consider before the estimation of VAR is the correct number of lag to use in the model. This is considered very important based on the study undertaken by Braun and Mittnik (1993) when they showed that the impulse response functions and variance decompositions of VAR estimates with different lag length as compared to the true lag length are inconsistent. It was indicated by Lutkepohl (1993) that autocorrelated errors are generated when the VAR lag length is underfitted while increase in the mean square forecast errors set in as a result of overfitting the VAR lag length. Proper inference about the cointegration vector and rank is affected by the VAR order selection as indicated by Johansen (1991) and Gonzalo (1994). VAR models can be estimated either by using symmetric lags or asymmetric lags. By symmetric lags we mean the use of same lags for each variable in the model while asymmetric is the opposite. Interestingly, based on economic theory there is no compelling reason on whether to use symmetric or asymmetric lags. In this study, our choice of lag based on the lag number mostly chosen by the information criteria such as the AIC, LR, HQ and SIC.

**MATERIALS AND METHODS**

In South Africa, the official data collectors of Statistics for petrol prices and consumption are Statistics South Africa (Stats SA) and the Department of Energy. Also, the study can only depend on data collected over the past years since they are time series. Thus, secondary data on average monthly Retail Fuel Price (RFP) and quarterly Fuel Sales Volumes (FSV) were collected from the record of Department of Energy, Pretoria Head Office, South Africa for the period of 2000-2017 and 2005-2017, respectively. The accuracy of these data was verified using the data sets from Stats SA.

The two variables are pre-tested to determine their respective order of integration using augmented Dickey-Fuller test. After they are found to be integrated of the same order Johansen cointegration test was carried out to determine the existence of cointegrating relationship among the variables. VAR lag order selection method was used to determine the appropriate number of lag to use based on different criteria information. Causality among the variables was determined using Granger-causality test. Finally, the Impulse Response Function (IRF) and variance decomposition were estimated to further establish the relationship between petrol price and consumption. All analyses are carried out using Eviews 10.

**RESULTS AND DISCUSSION**

**Graphical representation of the series:** Figure 1 is the time series plot of both series. There is no cointegrating relationship between consumption and its retail fuel price. As shown in Fig. 1, both series seem to meander without any tendency to come together. However, we cannot conclusively say that there is no cointegration between the two variables until further analyses are carried out.

Figure 2 shows the scatter plot of the two variables. Since both series decline over time, there appears to be a negative relationship between the two.

**Order of integration:** The ADF test is used for the unit root testing of the two variables. And their p-values are reported in Table 1.

The results in Table 1 show that, the level series of each variable is not stationary while the first difference series of each variable is stationary. This implies that petrol price and consumption are integrated of the same order one. The VAR lag order selection criteria was used in determining the appropriate optimal lag to use in this study. Hannan-Quinlin information criterion (HQ), sequential modified Likelihood Ratio test (LR) and Schwarz Information Criterion (SIC) indicated 2 lags as

**Fig. 1:** Time series plot of consumption and retail fuel price

**Fig. 2:** Scatter plot of consumption and retail fuel price
Table 1: ADF results of level series of consumption of unit root testing

| Series                  | p-values | Decision   | p-values | Decision   |
|-------------------------|----------|------------|----------|------------|
| Level series            | 0.6073   | Do not reject $H_0$ | 0.9446   | Do not reject $H_0$ |
| First differenced series| 0.0000   | Reject $H_0$       | 0.0000   | Reject $H_0$       |

Table 2: Results of trace statistic

| Hypothesized No. of CE(s) | Trace statistic | Critical value at 5% | p-values | Decision |
|---------------------------|-----------------|----------------------|----------|----------|
| None                      | 13.97203        | 15.49471             | 0.0837   | Do not reject $H_0$ |
| At most 1                 | 2.395956        | 3.841466             | 0.1216   | Do not reject $H_0$ |

Table 3: Results of max-eigen statistic

| Hypothesized No. of CE(s) | Max-eigen statistic | Critical value at 5% | p-values | Decision |
|---------------------------|---------------------|----------------------|----------|----------|
| None                      | 11.57608            | 14.26460             | 0.1276   | Do not reject $H_0$ |
| At most 1                 | 2.3959561           | 3.841466             | 0.1216   | Do not reject $H_0$ |

Granger-causality test: Granger-causality test is performed to determine if the two variables Granger-cause each other or not and the results of this test are given in Table 4.

The Granger-causality test results show that, the null hypothesis of retail fuel price does not Granger-cause
Fig. 3(a-d): Stability graph of retail fuel price model; Response to Cholesky one SD (df adjusted) innovations, (a) Response of D(CONS) to D(CONS), (b) Response of D(CONS) to D(RFP), (c) Response of D(RFP) to D(CONS) and (d) Response of D(RFP) to D(RFP)

**Table 4: Results of Pairwise Granger-causality test**

| Null hypothesis         | F-statistic | p-values | Decision |
|-------------------------|-------------|----------|----------|
| RFP does not Granger    | 0.38942     | 0.6797   | Do not reject H₀ |
| cause CONS              |             |          |          |
| Cons does not Granger   | 11.5387     | 9×10⁻⁵   | Reject H₀ |
| cause RFP               |             |          |          |

**Table 5: Variance decomposition of D(CONS)**

| Period | SE     | D(CONS) | D(RFP) |
|--------|--------|---------|--------|
| 1      | 1.20E⁺⁰⁸ | 100.0000 | 0.000000 |
| 2      | 1.38E⁺⁰⁸ | 98.99327 | 1.006727 |
| 3      | 1.44E⁺⁰⁸ | 92.66950 | 7.330502 |
| 4      | 1.47E⁺⁰⁸ | 92.08361 | 7.916394 |
| 5      | 1.48E⁺⁰⁸ | 91.87740 | 8.122604 |
| 6      | 1.49E⁺⁰⁸ | 91.91456 | 8.085436 |
| 7      | 1.49E⁺⁰⁸ | 91.81124 | 8.188762 |
| 8      | 1.49E⁺⁰⁸ | 91.75299 | 8.247006 |
| 9      | 1.49E⁺⁰⁸ | 91.74976 | 8.250240 |
| 10     | 1.49E⁺⁰⁸ | 91.73692 | 8.263085 |

**Table 6: Variance decomposition of D(RFP)**

| Period | SE     | D(CONS) | D(RFP) |
|--------|--------|---------|--------|
| 1      | 73.20581 | 29.92248 | 70.07752 |
| 2      | 73.74121 | 30.55337 | 69.44663 |
| 3      | 82.99530 | 43.94872 | 56.05128 |
| 4      | 83.92814 | 44.65845 | 55.34152 |
| 5      | 85.45414 | 45.19624 | 54.80376 |
| 6      | 85.68542 | 45.47406 | 54.52594 |
| 7      | 85.97605 | 45.64968 | 54.35032 |
| 8      | 86.12228 | 45.82531 | 54.17469 |
| 9      | 86.16192 | 45.81964 | 54.18036 |
| 10     | 86.20979 | 45.86261 | 54.13379 |

**Variance decomposition:** The results of variance decomposition are shown in Table 5 and its graphs are attached in appendix XI.

In Table 5, the contribution of retail fuel price to consumption increases slightly from 0% to maximum of 8.26% in period 10. In both the short-term and long-term, almost 8.26% forecast error variance in consumption is explained by the retail fuel price while the remaining percentage is explained by consumption itself. This means that, retail fuel price does not have strong influence on consumption. In other words, retail fuel price has strong exogenous impact on consumption in both short-term and long-term.

In Table 6, the contribution of retail fuel price to decreases throughout the ten period and reaches a...
minimum of 54.13% in the long-run. Right from the short-run period into the future, consumption accounts for almost 45.87% forecast error variance in retail fuel price. In the long-run, consumption is a strong influencer of retail fuel price. In other words, consumption has strong endogenous impact on retail fuel price.

**CONCLUSION**

The retail fuel price and its consumption are integrated of order one I(1) but they do not have long-run equilibrium relationship. Thus, unrestricted VAR Models are estimated to study the relationship between the two variables. And there exists a one-way Granger-causality among the two variables and this runs from consumption to the retail fuel price. The two VAR Models are homoskedastic, normally distributed do not have serial correlation, significant and stable. It can be seen from the IRF and variance decomposition of the two variables that, the shock to the retail fuel is mainly caused by the consumption that is consumption is seen to have a strong endogenous impact on the retail fuel price. But retail fuel price has a strong exogenous influence on the consumption, meaning its own lagged values have strong impact on itself. Since, the lagged period of consumption significantly impacts the retail fuel price in South Africa, the policy makers are encouraged to focus on this when determining the future price of petrol. Also they need to take into consideration as they plan for future in order to prevent the drastic increase in the retail fuel price of petrol bearing in mind that the consumption of petrol will not drop except in the case of natural disaster such as war, terrorism, famine, earthquake, etc. Otherwise, if this is not prevented, it would lead to increase in the price of almost everything (i.e., cost of living) which may later result into high inflation rate.

**APPENDIX**

Appendix I: Lag selection criterion; VAR lag order selection criteria; Endogenous variables: CONS RFP; Exogenous variables: C; Date: 11/17/18; Time: 10:21; Sample: 2005Q1 2017Q4; Included observations: 40

| Lag | LogL  | LR     | FPE    | AIC    | SC     | HQ     |
|-----|-------|--------|--------|--------|--------|--------|
| 0   | -1073.342 | NA     | 7.69e+20 | 53.76709 | 53.85154 | 53.79763 |
| 1   | -1028.623 | 82.72967 | 1.00e+20 | 51.73116 | 51.98449 | 51.82275 |
| 2   | -1018.557 | 17.61508* | 7.43e+19* | 51.42787 | 51.85009* | 51.58053* |
| 3   | -1015.989 | 4.238194 | 8.02e+19 | 51.49944 | 52.09555 | 51.71316 |
| 4   | -1010.340 | 8.755360 | 7.45e+19 | 51.41701* | 52.17700 | 51.69180 |
| 5   | -1007.669 | 3.873566 | 8.07e+19 | 51.48344 | 52.41232 | 51.81929 |
| 6   | -1005.699 | 2.658939 | 9.11e+19 | 51.58496 | 52.68273 | 51.98188 |
| 7   | -1004.235 | 1.830461 | 1.06e+20 | 51.71174 | 52.97840 | 52.16972 |
| 8   | -1000.588 | 4.193914 | 1.12e+20 | 51.72939 | 53.16494 | 52.24844 |
| 9   | -997.7181 | 3.013241 | 1.25e+20 | 51.78591 | 53.39034 | 52.36602 |
| 10  | -997.0283 | 0.655323 | 1.58e+20 | 51.95142 | 53.72474 | 52.59259 |
| 11  | -991.8075 | 4.437717 | 1.62e+20 | 51.89037 | 53.83259 | 52.59262 |
| 12  | -987.5495 | 3.193462 | 1.79e+20 | 51.87847 | 53.98858 | 52.64078 |

* Indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final Prediction Error; AIC: Akaike Information Criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Appendix II: ADF results of level series consumption; Null hypothesis: CONS has a unit root; Exogenous: none; Lag length: 2 (Automatic-based on SIC, maxlag = 2)

Augmented Dickey-Fuller test statistics:

| Variable | Coefficient | SE | t-statistic | Prob* |
|----------|-------------|----|-------------|-------|
| CONS(-1) | -0.000511   | 0.006232 | -0.081940 | 0.9351 |
| D(CONS(-1)) | -0.509278 | 0.135366 | -3.72244 | 0.0005 |
| D(CONS(-2)) | -0.402596 | 0.136706 | -2.94497 | 0.0051 |
| R² | 0.271572 | Mean dependent var | -938302.4 |
| Adjusted R² | 0.259902 | SD dependent var | 1.42E-08 |
| SE of regression | 1.24E+08 | Akaike info criterion | 40.16865 |
| Sum squared resid | 7.07E+17 | Schwarz criterion | 40.28447 |
| Log likelihood | -981.1319 | Hannan-Quinn criter. | 40.21259 |
| Durbin-Watson stat | 2.289301 | | |

*MacKinnon (1996) one-sided p-values; Augmented Dickey-Fuller test equation; Dependent variable: D(CONS); Method: least squares; Date: 11/28/18; Time: 19:48; Sample (adjusted): 2005Q4 2017Q4; Included observations: 49 after adjustments

Null hypothesis: CONS has a unit root; Exogenous: constant; Lag length: 0 (automatic-based on SIC, maxlag = 4)
### Appendix III: ADF results of first difference series consumption; Null hypothesis: D(CONS) has a unit root; Exogenous: None; Lag length: 2
(Automatic-based on SIC, maxlag = 2)

| Test                  | t-statistic | Prob.* |
|-----------------------|-------------|--------|
| Augmented Dickey-Fuller test statistic | -5.252907 | 0.0001 |

**Test critical values (Level%):**

- 1: -3.565430
- 5: -2.919952
- 10: -2.597905

*MacKinnon (1996) one-sided p-values

### Appendix IV: ADF results of level series retail fuel price; Null Hypothesis: RFP has a unit root; Exogenous: None; Lag length: 0 (Automatic-based on SIC, maxlag = 2)

| Variables | t-statistic | Prob.* |
|-----------|-------------|--------|
| Augmented Dickey-Fuller test statistic | 1.252198 | 0.2163 |

**Test critical values (Level%):**

- 1: -2.611094
- 5: -1.947381
- 10: -1.612725

*MacKinnon (1996) one-sided p-values; Augmented Dickey-Fuller test equation; Dependent variable: D(RFP); Method: least squares; Date: 11/28/18; Time: 19:12; Sample (adjusted): 2006Q1 2017Q4; Included observations: 48 after adjustments

### Appendix V: ADF results of first difference series retail fuel price; Null hypothesis: D(RFP) has a unit root; Exogenous: none; Lag length: 1
(Automatic-based on SIC, maxlag = 2)

| Variable | Coefficient | Std. Error | t-statistic | Prob.* |
|----------|-------------|------------|-------------|--------|
| D(RFP(-1)) | -1.262001 | 0.194635 | -6.483925 | 0.0000 |

**Test critical values (Level%):**

- 1: -3.565430
- 5: -2.919952
- 10: -2.597905

*MacKinnon (1996) one-sided p-values; Augmented Dickey-Fuller test equation; Dependent variable: D(RFP,2); Method: least squares; Date: 11/28/18; Time: 19:43; Sample (adjusted): 2005Q2 2017Q4; Included observations: 49 after adjustments
Appendix VI: Johansen cointegration test; Date: 11/19/18; Time: 19:04; Sample (adjusted): 2005Q4 2017Q4; Included observations: 49 after adjustments; Trend assumption: Linear deterministic trend; Series: CONS RFP; Lags interval (in first differences): 1 to 2

Unrestricted cointegration rank test (trace)

| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|---------------------------|------------|-----------------|---------------------|---------|
| None                      | 0.210414   | 13.97203        | 15.49471            | 0.0837  |
| At most 1                 | 0.047721   | 2.395956        | 3.841466            | 0.1216  |

Trace test indicates no cointegration at the 0.05 level; * Denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values

Unrestricted cointegration rank test (maximum eigenvalue)

| Hypothesized No. of CE(s) | Max-Eigen | Max-Eigen Value | 0.05 Critical Value | Prob.** |
|---------------------------|-----------|-----------------|---------------------|---------|
| None                      | 0.210414  | 11.57608        | 14.26460            | 0.1276  |
| At most 1                 | 0.047721  | 2.395956        | 3.841466            | 0.1216  |

Max-eigenvalue test indicates no cointegration at the 0.05 level; * denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values

Unrestricted cointegrating coefficients (normalized by \(b'*S11*b = I\)):

| CONS       | RFP       |
|------------|-----------|
| -1.34E-08  | -7.56E-05 |
| -4.61E-10  | -0.003711 |

Unrestricted adjustment coefficients (alpha):

D(CONS)        45154339  12607180
D(RFP)         -28.48854  6.751161
1 Cointegrating equation(s): Log likelihood

Normalized cointegrating coefficients (standard error in parentheses)

| CONS            | RFP            |
|-----------------|----------------|
| 1.000000        | 5665.152       |
| (82001.1)       | (82001.1)      |

Adjustment coefficients (standard error in parentheses)

D(CONS)        -0.602965  (0.21340)
D(RFP)         3.80E-07   (1.3E-07)

Appendix VII: Vector autoregressive model; Vector autoregression estimates; Date: 11/19/18; Time: 19:41; Sample (adjusted): 2005Q4 2017Q4

Included observations: 49 after adjustments; Standard errors in ( ) and t-statistics in [ ]

| Variables     | D(CONS)     | D(RFP)     |
|---------------|-------------|------------|
| D(CONS(-1))   | -0.625822   | -3.34E-08  |
|               | (0.17054)   | (1.0E-07)  |
|               | [-3.66959]  | [-0.37031] |
| D(CONS(-2))   | -0.364727   | 2.36E-07   |
|               | (0.17584)   | (1.1E-07)  |
|               | [-2.07415]  | [ 2.20613] |
| D(RFP(-1))    | -226206.3   | 0.074940   |
|               | (295571.)   | (0.17069)  |
|               | [-0.76532]  | [ 0.41455] |
| D(RFP(-2))    | 471029.9    | -0.164305  |
|               | (242602.)   | (0.14749)  |
|               | [ 1.94157]  | [ -1.11404]|
| C             | -4932008    | 20.03639   |
|               | (1.9E+07)   | (11.3426)  |
|               | [-0.26434]  | [ 1.76647] |
| R^2           | 0.342871    | 0.268127   |
| Adj. R^2     | 0.283132    | 0.201593   |
| Sum sq. resids | 6.38E+17  | 235800.0   |
| SE equation  | 1.20E+08    | 73.20581   |
| F-statistic  | 5.739487    | 4.029920   |
| Log likelihood | -978.6082 | -277.2615  |
Appendix VIII: Vector autoregression estimates of consumption; Dependent variable: D(CONS); Method: least squares (Gauss-Newton/Marquardt steps); Date: 11/19/18; Time: 19:44; Sample (adjusted): 2005Q4 2017Q4; Included observations: 49 after adjustments; 
\[ D(CONS) = C(1)*D(CONS(-1)) + C(2)*D(CONS(-2)) + C(3)*D(RFP(-1)) + C(4)*D(RFP(-2)) + C(5) \]

| Variables  | Coefficient | SE   | t-statistic | Prob.   |
|------------|-------------|------|-------------|---------|
| C(1)       | -0.625822   | 0.170543 | -3.669593  | 0.0007  |
| C(2)       | -0.364727   | 0.175844 | -2.074149  | 0.0439  |
| C(3)       | -226206.3   | 295570.7 | -0.765321  | 0.4482  |
| C(4)       | 471029.9    | 242602.1 | 1.941574   | 0.0586  |
| C(5)       | -4932008    | 18567601 | -0.264343  | 0.7927  |

R²: 0.342871, Adjusted R²: -0.938302, SE of regression: 1.20E+08, Akaike info criterion: 40.14727

Appendix IX: Vector autoregression estimates of retail fuel price; Dependent variable: D(RFP); Method: least squares (Gauss-Newton/Marquardt steps); Date: 11/19/18; Time: 19:49; Sample (adjusted): 2005Q4 2017Q4; Included observations: 49 after adjustments; 
\[ D(RFP) = C(6)*D(CONS(-1)) + C(7)*D(CONS(-2)) + C(8)*D(RFP(-1)) + C(9)*D(RFP(-2)) + C(10) \]

| Variables | Coefficient | Std. Error | t-Statistic | Prob.   |
|-----------|-------------|------------|-------------|---------|
| C(6)      | -3.84E-08   | 1.04E-07   | -0.370309   | 0.7129  |
| C(7)      | 2.36E-07    | 1.07E-07   | 2.061262    | 0.0326  |
| C(8)      | 0.074940    | 0.179688   | 0.415500    | 0.6805  |
| C(9)      | 0.164305    | 0.147486   | -1.114035   | 0.2713  |
| C(10)     | 20.03E36    | 11.342E62  | 1.766470    | 0.0843  |

R²: 0.268127, Adjusted R²: 0.201593, SE of regression: 73.20581, Akaike info criterion: 11.52088

Appendix X: Granger-causality test; Pairwise granger causality tests; Date: 11/24/18; Time: 12:47; Sample: 2005Q1 2017Q4; Lags: 2

| Null hypothesis | Obs | F-Statistic | Prob.   |
|-----------------|-----|-------------|---------|
| RFP does not Granger cause CONS | 50  | 0.38942     | 0.6797  |
| CONS does not Granger cause RFP  | 11.5387 | 9.0E-5     |

Appendix XI: Variance decomposition
Variance decomposition of D(CONS):

| Period | SE     | D(CONS) | D(RFP) |
|-------|--------|---------|--------|
| 1     | 1.20E+08 | 100.0000 | 0.00000 |
| 2     | 1.38E+08 | 98.99327 | 1.006727 |
| 3     | 1.44E+08 | 92.66950 | 7.33052 |
| 4     | 1.47E+08 | 92.08361 | 7.916394 |
| 5     | 1.48E+08 | 91.87740 | 8.122604 |
| 6     | 1.49E+08 | 91.91456 | 8.05436 |
| 7     | 1.49E+08 | 91.81124 | 8.188762 |
| 8     | 1.49E+08 | 91.75299 | 8.247006 |
| 9     | 1.49E+08 | 91.74976 | 8.25024 |
| 10    | 1.49E+08 | 91.73692 | 8.263085 |

Variance decomposition of D(RFP):

| Period | D(RFP) |
|-------|--------|
| 1     | 73.20581 |
| 2     | 73.74131 |

1587
3  82.99530  43.94872  56.05128
4  83.92814  44.65848  55.34152
5  85.45414  45.19624  54.80376
6  85.68542  45.47406  54.52594
7  85.97605  45.64968  54.35032
8  86.12228  45.82531  54.17469
9  86.16192  45.81964  54.18036
10 86.20979  45.86621  54.13379

Cholesky Ordering: D(CONS) D(RFP)

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