Revisiting the Question is Does OPEC Matter?

Jianwen Wu, Emmanuel Monroy, Crystal Hernandez & Keyi Long

City College of New York

December 21, 2016

1. Introduction:

The role of OPEC (Organization of the Petroleum Exporting Countries) in the global oil market has been studied by many economists with some conflicting results. Some economists and media outlets speculate that OPEC may have lost its ability to impact real oil prices. In a recent article published by *The Corner*, it was suggested that “OPEC’s power to control the market [has] increasingly diminished as its spare capacity dwindles to historically low levels” (Tapia, 2016). Additionally the article states that OPEC has historical produced more than their quotas, which also leads to a general decline in real oil prices. In an article published by the *International Business Times* it was stated that “over the last 20 years….OPEC [has had] diminished trading and price setting power” (O’Neal, 2016). On the academic spectrum economists by in large have not reached any general consensus on OPEC’s behavior or impact on global oil prices. It would appear that although there are numerous studies and publications regarding OPEC and its behavior there is no model that “represents the oil market structure and [that definitively] fits OPEC’s behavior” (Al-Qahtani, 2008). Instead economics have different and opposing opinions about what models and data incorporate and capture OPEC’s behavior.

One particular issue is with the classification of OPEC as a cartel. In the paper *OPEC Behavior: A Test of Alternative Hypotheses*, the authors study OPEC’s production by testing opposing models and analyzing the results. In particular, they tested the following four (4) models: Competition, Cartel, target revenue and property rights. There results, although controversial, suggest that OPEC operates like a cartel (Griffin, 1985). OPEC operates by setting oil production quotas for all the members within the group, so if the result from Griffin’s paper are correct OPEC might indeed have the ability to set and fix prices. So how powerful is OPEC and how much control does it have over the market? Years down the line a paper entitled *Does*

OPEC Matter? An Econometric Analysis of Oil Prices, was published, wherein the author's further investigate this relationship between price and OPEC production. Therein they attempt to determine and explain what model they are using to try to answer the question of OPEC's relevance and ability to control real oil prices. In their paper they estimate an equation using quarterly data from 1986 to 2000 for real oil prices (Kaufmann, 2004). The author's results sharply contrast with the belief that OPEC's market power has diminished and also finds issues with the way some "analysts interpret the negative relationship between oil prices and OPEC production" (Kaufmann, 2004). Instead there analysis showed that OPEC does indeed play a role in determining market oil prices around the world. Additionally, they came to the conclusion that there is more "convincing evidence that production Granger causes prices than the other way around." (Kaufmann, 2004). Which leads to a "negative relationship between prices and production" (Kaufmann, 2004). In this paper we seek to follow their model to: (1) replicate their results from 1986 to 2000 and (2) add a decade's worth of additional data to see if there any significant differences in the results. More specifically we seek to examine and replicate their findings with regards to the relationship between OPEC's behavior, real oil prices and OECD stocks (whole's abbreviation stands for The Organization for Economic Cooperation and Development). And to test the models used to answer the hypotheses regarding OPEC and OECD production behavior.

2. Literature Review

As previously stated, a number of articles and literature exist on models that seek to find an oil market structure that fits OPEC behavior. The following two papers papers are a small sampling that attempt to do just that, and also reflect papers reviewed in order to better understand oil prices and the model used in herein.

2.1 Does OPEC Matter? An Econometric Analysis of Oil Prices

This paper authored by Robert K. Kaufmann, Stephane Dees, Pavlos Karadeloglou and Marcelo Sánchez is takes on the arduous task of estimating an equation for real oil prices, and use quarterly data from 1986 to 2000 to test their hypothesis. Their decision regarding the timeframe was due in part due to limitations of data collection and the economic considerations. These considerations include the 1986 price collapse which lead to the OPEC's bringing back quotas, while the end date was selected because of limitations in ability to obtain capacity data for later dates. There results indicated that there was a "stochastic trend in real oil prices cointegrated with stochastic trends in OPEC capacity utilization, OPEC production quotas, the degree to which OPEC exceeds these quotas, and crude oil stocks in OECD nations" (Kaufmann, 2004). There results also suggested that the variables granger cause real oil prices but the opposite cannot be said. More specifically real oil prices do not granger cause OPEC's capacity or allocation. This is opposite to the held belief that OPEC's market power is vastly diminishing, wherein economist interpret a "negative relations between oil prices and OPEC production" (Kaufmann, 2004). Furthermore they find a "cointegrating relation among real oil prices, OPEC capacity utilization, OPEC quotas, and adherence to those quotas indicates that OPEC plays an important role in determining world oil prices" (Kaufmann, 2004).

2.2 Oil futures prices and stock management

This paper authored by Stefan Balabanoff, seeks to test future markets relevant to stock management by doing cointegration analysis and causality testing on the monthly of primary oil stocks and monthly of West Texas Intermediate spot (Balabanoff, 1995). The period which th author decided to sample is from January 1985 to June 1993, and his analysis uses both long and short term run relations. The reason this paper was included in the literature review is because the review the model undertaken in this paper is similar to the one which we will attempt to approach. Balabanoff attempts to answer his hypothesis by cointegration and runs many similar tests that we too shall employ. The Balabanoff commences by performing a unit root test to test for stationary of the data, followed by tests of conitegration which he bases off the unrestricted autoregression with distributed lags. And then he finalizes his paper by testing for causality. In our paper we will follow these steps while using a different model formulated to answer our question. In the end, Balabanoff concludes that there is indeed causal relationship among his selected variables " running from Stock levels to spot and future prices" (Balabanoff, 1995). Which lead Balabanoff to the conclusion that there is an observable relevance of futures prices in the management of crude oil inventories.

3. Model: A Cointegrating Relation for Real Oil Prices

Our first step was to create an estimated model for real prices that has variables that will encapsulate all the required data to analyze and find a relationship between real oil prices, OECD stocks and OPEC behavior. Additionally we need to check for a casual order between the aforementioned variables. For this model we are using the following endogenous variables; Price, Days , Caputil , Cheat, and Quota and the dummy variables; Ql, Q2, Q3 , War1, and War2. The variables stand for the following:

Price: Is the US crude oil import price in FOB (Free on Board or Freight on Board).

Quota: Is the OPEC Production or allocation

Cheat = Is a formula obtained by the following: Quota (OPEC) – Production (OPEC)

Capitul = Is a formula obtained by the following: Production (OPEC)/Capacity (OPEC)

Days = Is the formula obtained by: Crude Oil Stocks(OECD)/Crude Oil Demand (OECD)

Q1 = Dummy variable for first quarter. Used to deal with Seasonality

Q2 = Dummy variable for second quarter. Used to deal with Seasonality

Q3 = Dummy variable for third quarter. Used to deal with Seasonality

War1 = Dummy variable to deal with qulf war

War2 = Dummy variable to deal with Iraq war

Since our data is random, varies over time and depends on past volume it demonstrates a stochastic trend and for this reason and are using random walk model. Using this criterion and building on the work of Kaufmann and his colleagues we have formulated the following equation, which will herein be called equation 1:

$$Price_t = \alpha + \beta_1 * Days + \beta_2 * Quota + \beta_3 * Cheat + \beta_4 * Caputil + \beta_5 * Q1 + \beta_6 * Q2 + \beta_7 * Q3 + \beta_8 * War1 + \beta_9 * War2 + \mu$$

In order to test for cointgration we will proceed with the following: (1) Check that the cointegrating residuals are stationary (unit root test); (2) Check the variables for I(1); and (3) Estimate the cointegrating relationship by ordinary least squares.

4. Data

As stated above the variables for this equations are as follows: Price, Days , Caputil , Cheat, and Quota and four (4) 0 or 1 dummy variables: Quarters 1 through 4 and two respective Wars. The price for US crude oil was measured in US barrels using the consumer price index and valued to 1996, to keep with the results of the original study. OPEC production, quota and Cheat were converted to million barrels per day to have smaller and easier numbers to work with.

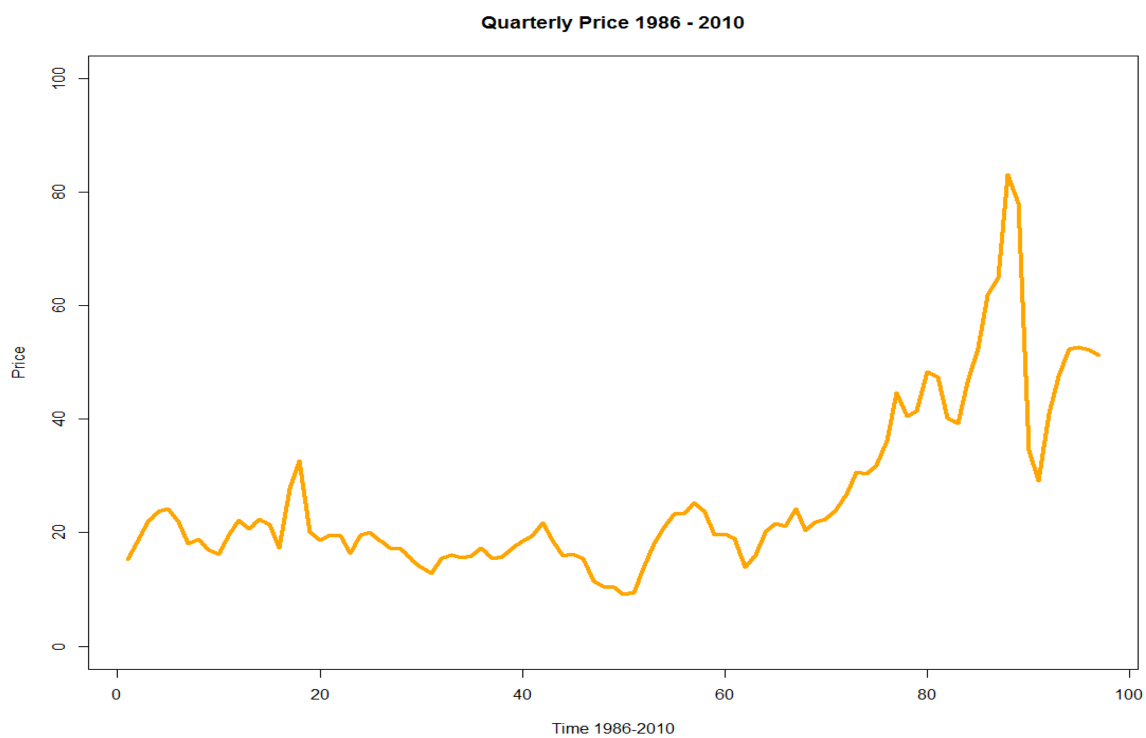
Respectively, War1 and War2 dummy variables are for the Gulf War (third and fourth quarters in 1990) and the Iraq War (first and second quarters in 2004). The data for OECD oil prices, oil stocks and demands for crude oil were all conveniently located on the Monthly Energy Review website and converted into quarterly data. The values for the OPEC Capacity were located on the Quandl Financial and Economic Data website and converted from monthly to quarterly data. Data for the Quota was obtained by the OPEC Annual Statistical Bulletin pdf located on their website was interpolated by taking into assumption a constant rate of change between the data. OPEC production was obtained from the website YCharts, by signing up for free 7 day trial period and covered from monthly data into quarterly data.

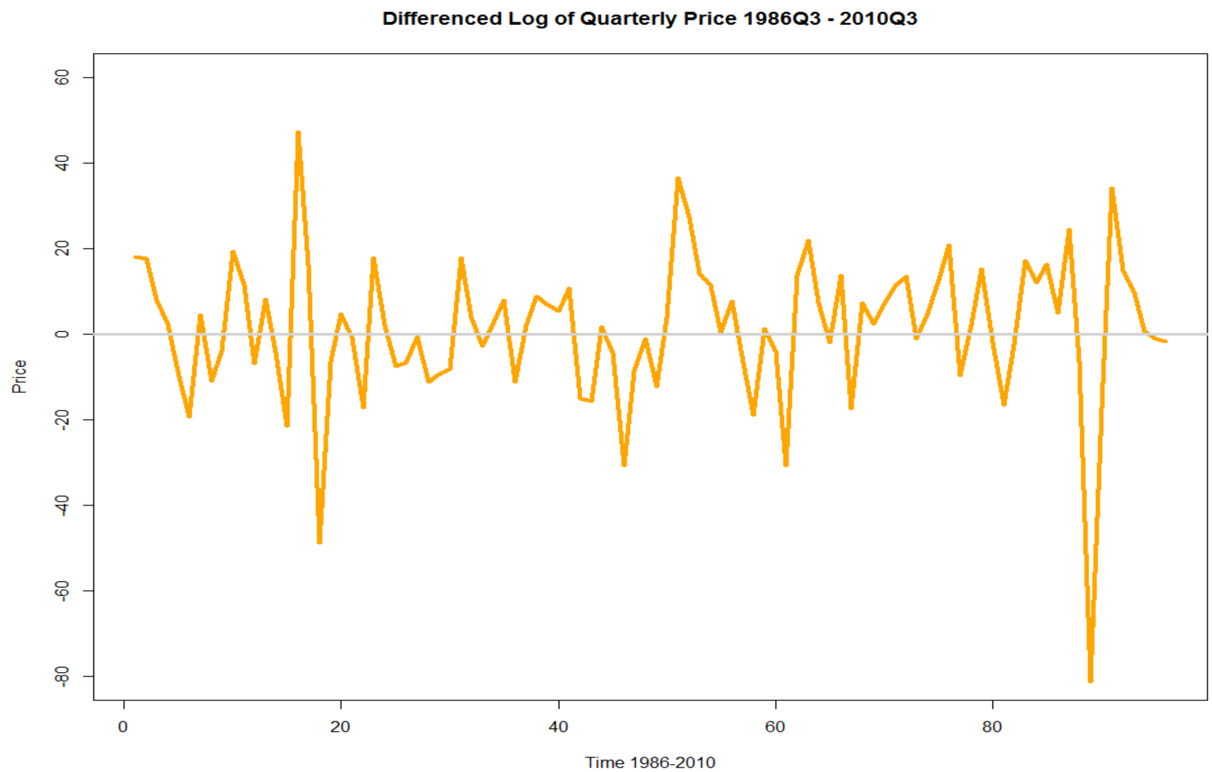
4.1 Time Series Data: Testing for Stationary

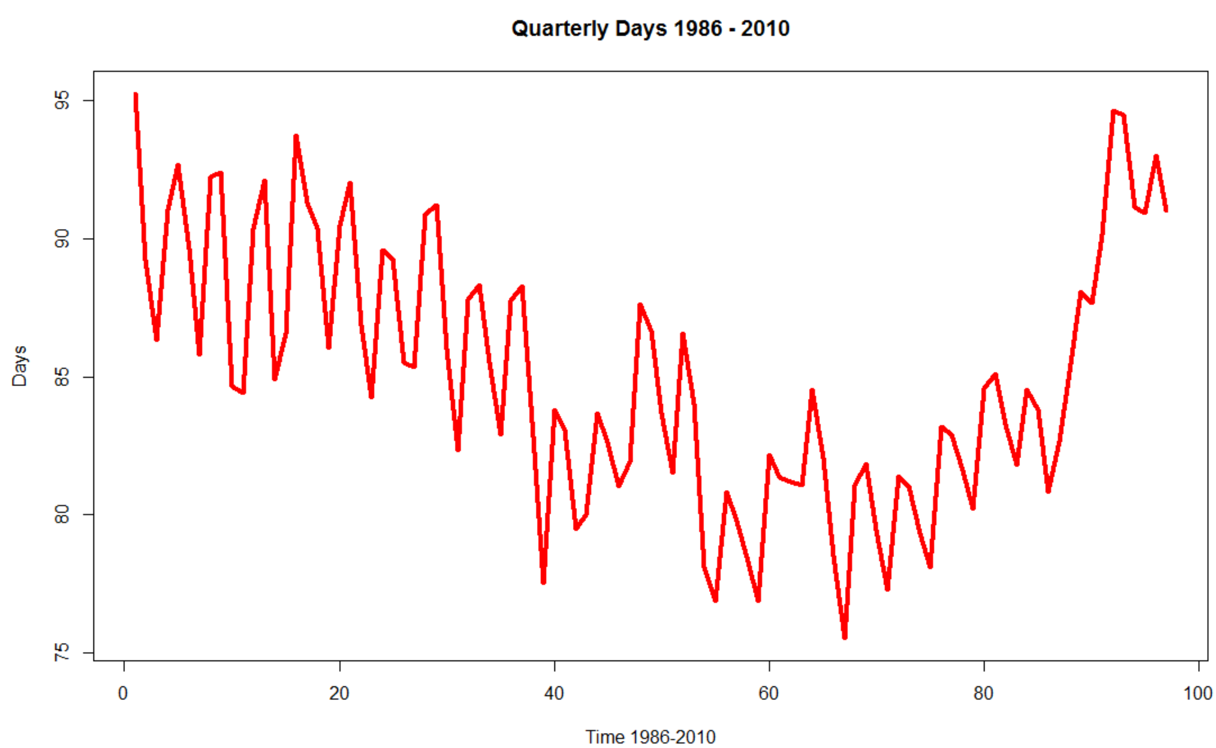
In order to get meaningful statistics from time series data we must first ensure that our data is stationary. What causes non-stationary data: non-constant means, variances or seasonal patterns. For this reason we added dummy variables to the dataset to adjustment for non-stationary. Additionally, we will fix possible trend lines by differencing it before fitting the model and therein refer to our data as trend stationary. If however the autocorrelation structure, variance and mean are not constant in time after this process, we hope that the time in between the "seasons" will be constant. Our next step is run a unit root test individual variables for stationary and see if they possess a unit root.

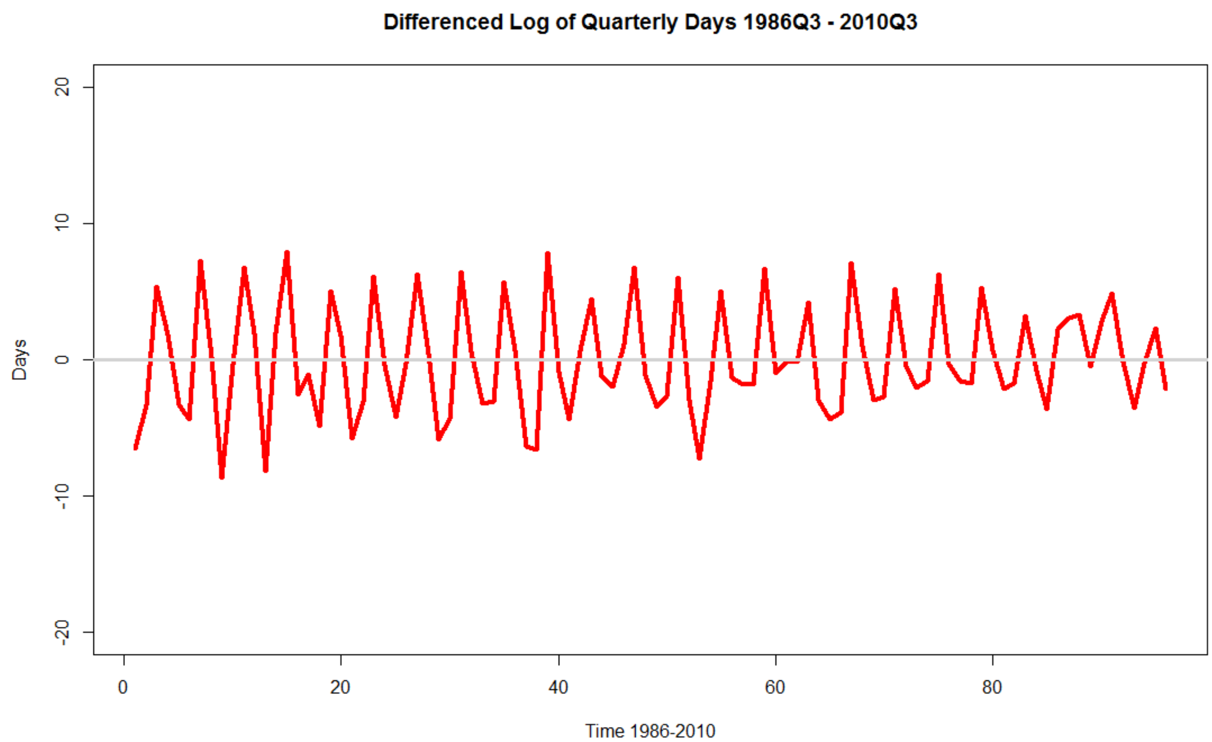
5. Dickey Fuller test for unit roots/ HEGY Test on Price and Days

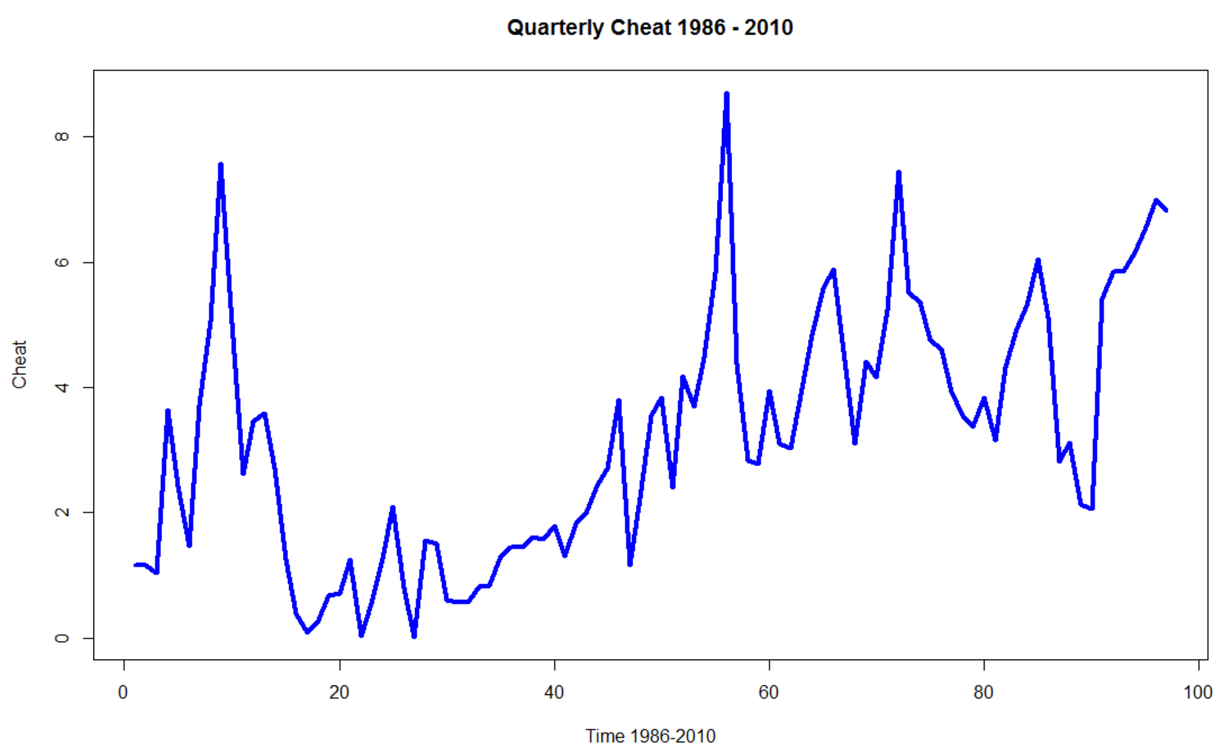
The Dickey Fuller tests the null hypothesis for a unit root, because we have various variables we be running the Augmented Dickey Fuller test, this model is based off the standard t-test for coefficients and uses lags to predict values of the dependent variable based on current values and the passed periods. Using the R code "AIC" we were able to obtain the appropriate number of lags and will herein test the null hypothesis of a unit root against the hypothesis of trend-stationary. Our result from the R show that the variables Quota, Cheat and Caputil show that we fail to reject not stationary so we have unit roots and the data does not have a seasonal root. Therefore these variables are stationary. We herein run the HEGY test on R for the variables Price and days, and find that the results indicate that both days and price are stationary at the .05 level but not at the .01 level so we consider these variables not to be stationary. Graphs in R of the original and differenced variables follow below.

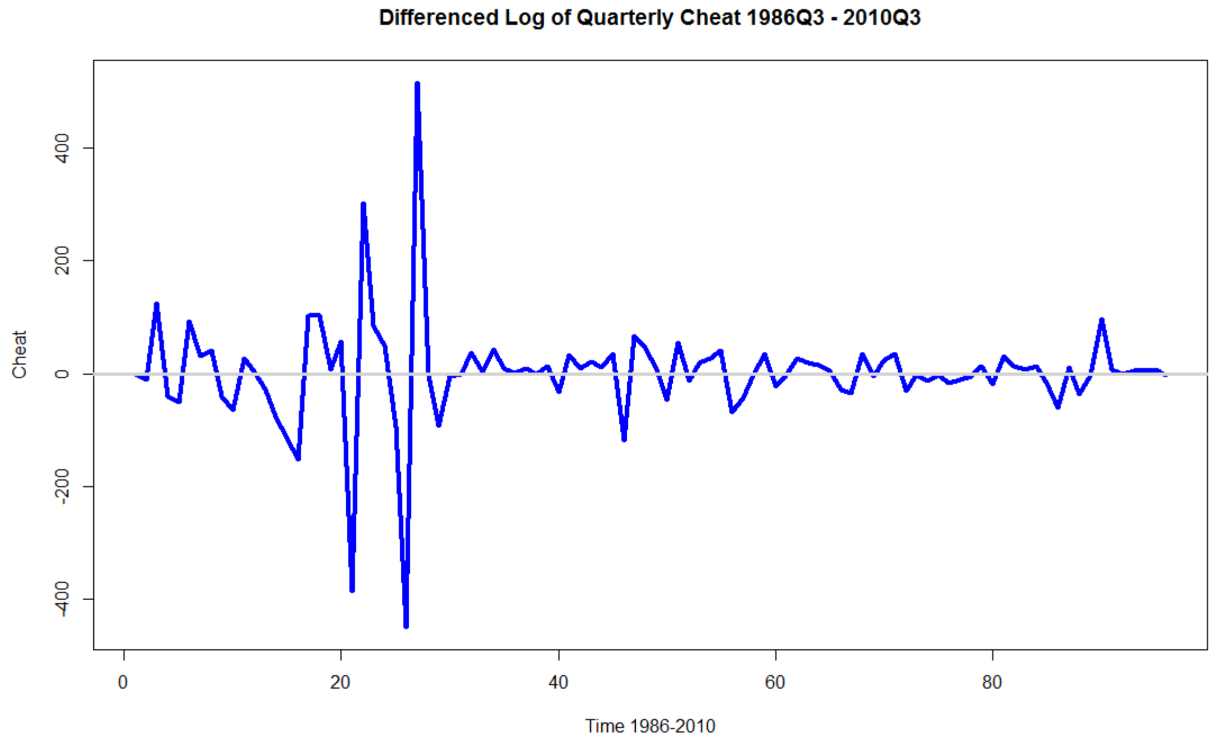


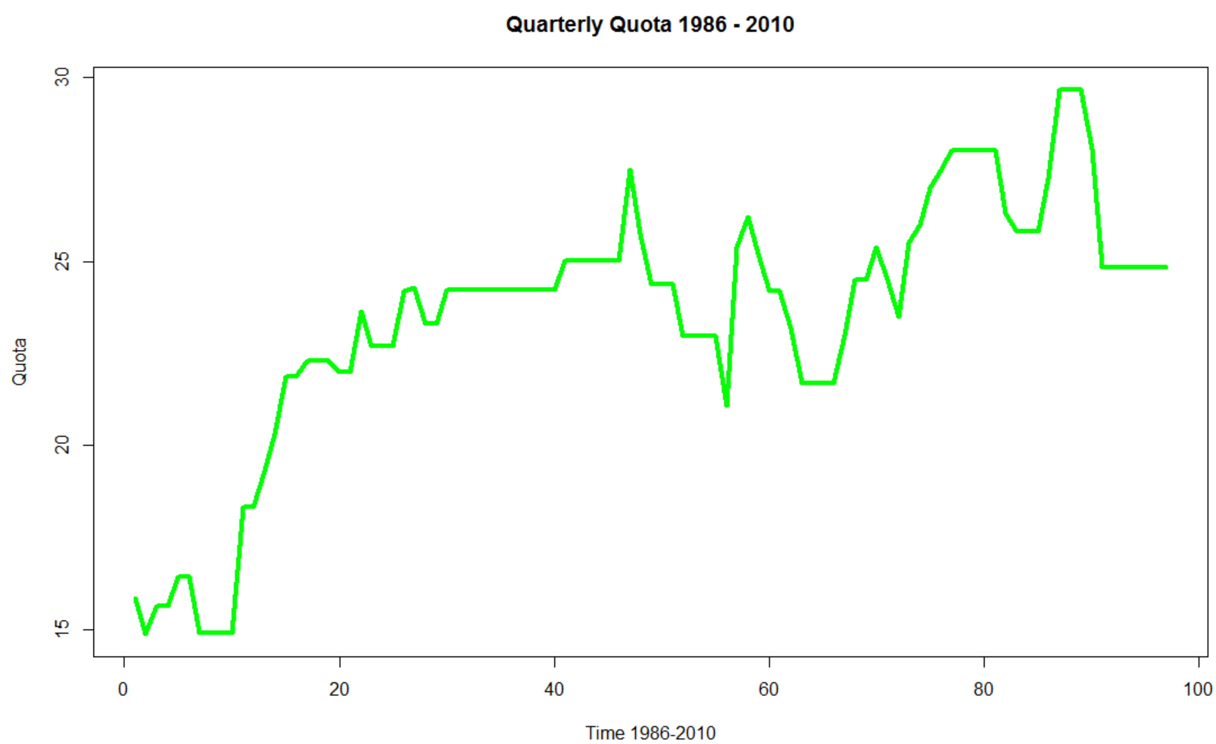

Differenced Log of Quarterly Price 1986Q3 - 2010Q3
Price
60
40
20
0
-20
-40
-60
-80
0
20
40
60
80
Time 1986-2010

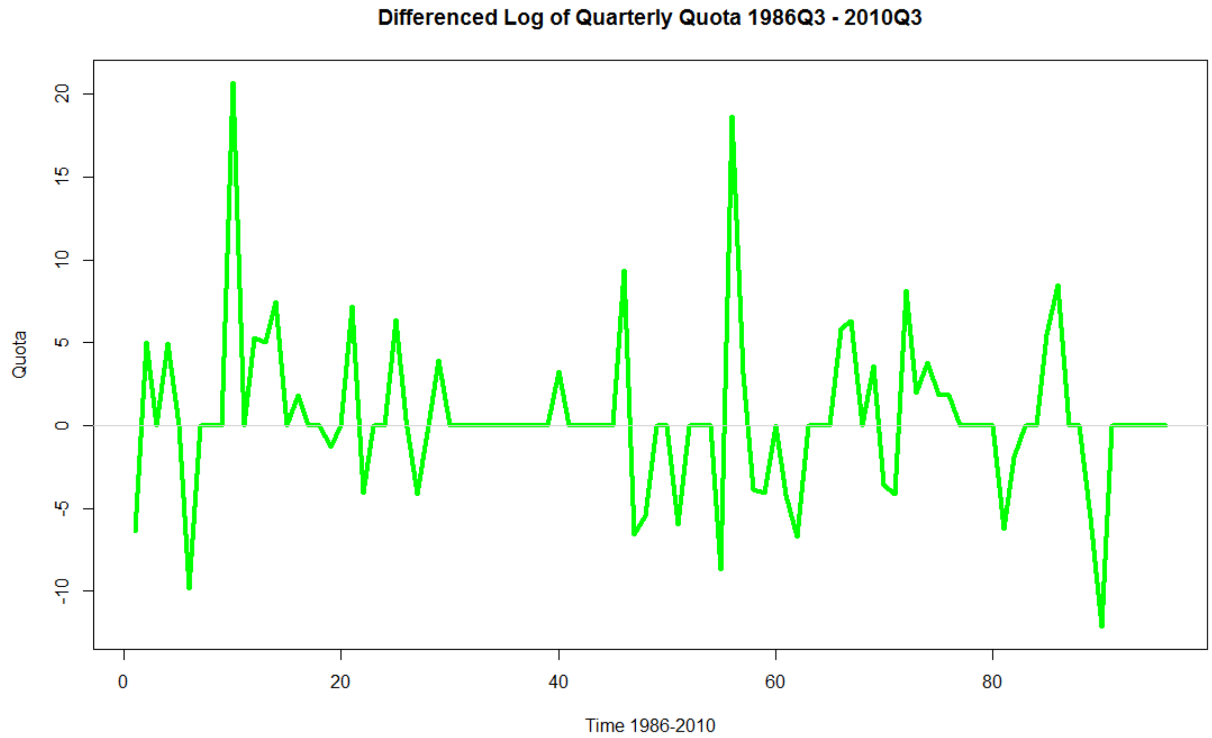

Quarterly Days 1986 - 2010
Days
95
90
85
80
75
0
20
40
60
80
100
Time 1986-2010

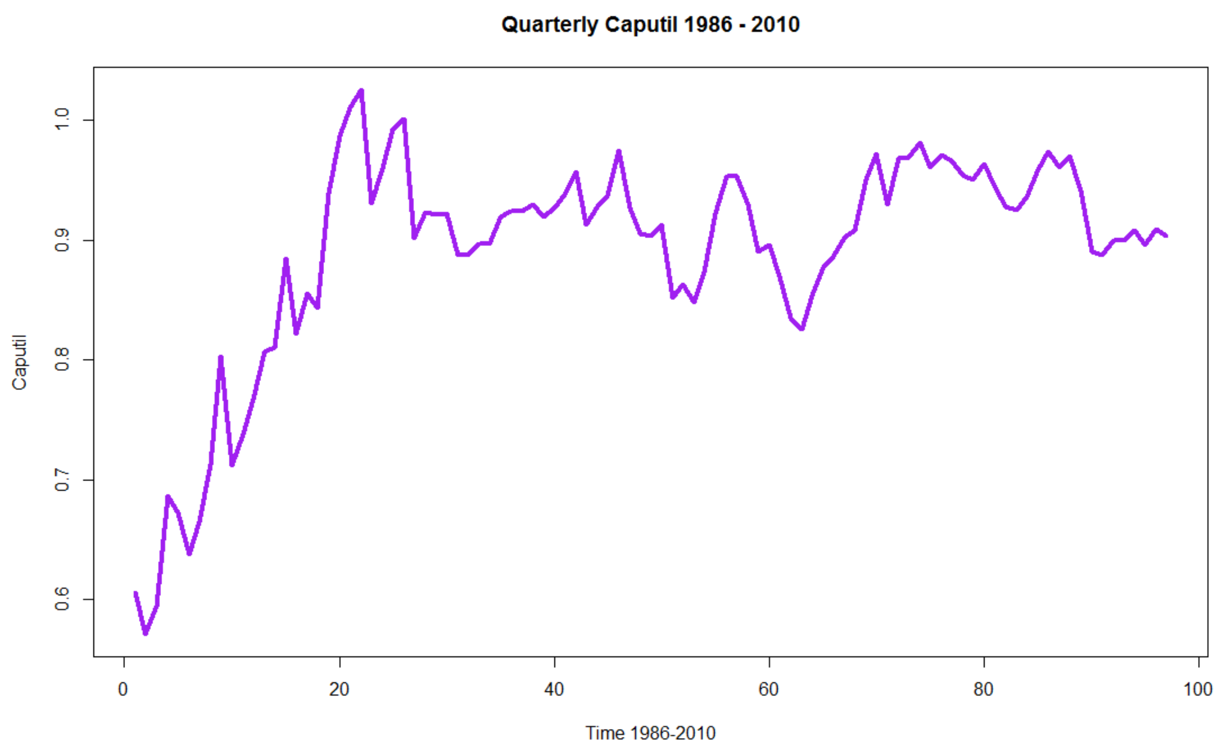

Differenced Log of Quarterly Days 1986Q3 - 2010Q3
Days
Time 1986-2010
20
10
0
-10
-20
0
20
40
60
80

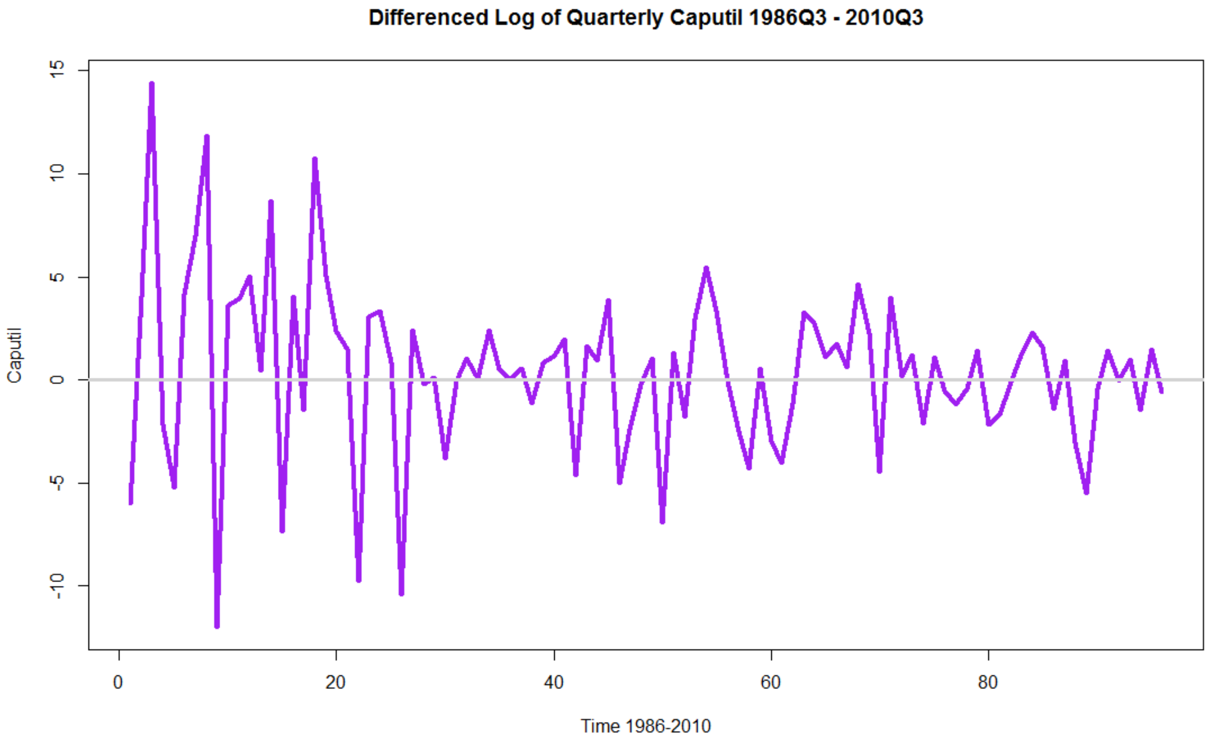

Quarterly Cheat 1986 - 2010
Cheat
Time 1986-2010
8
6
4
2
0
0
20
40
60
80
100

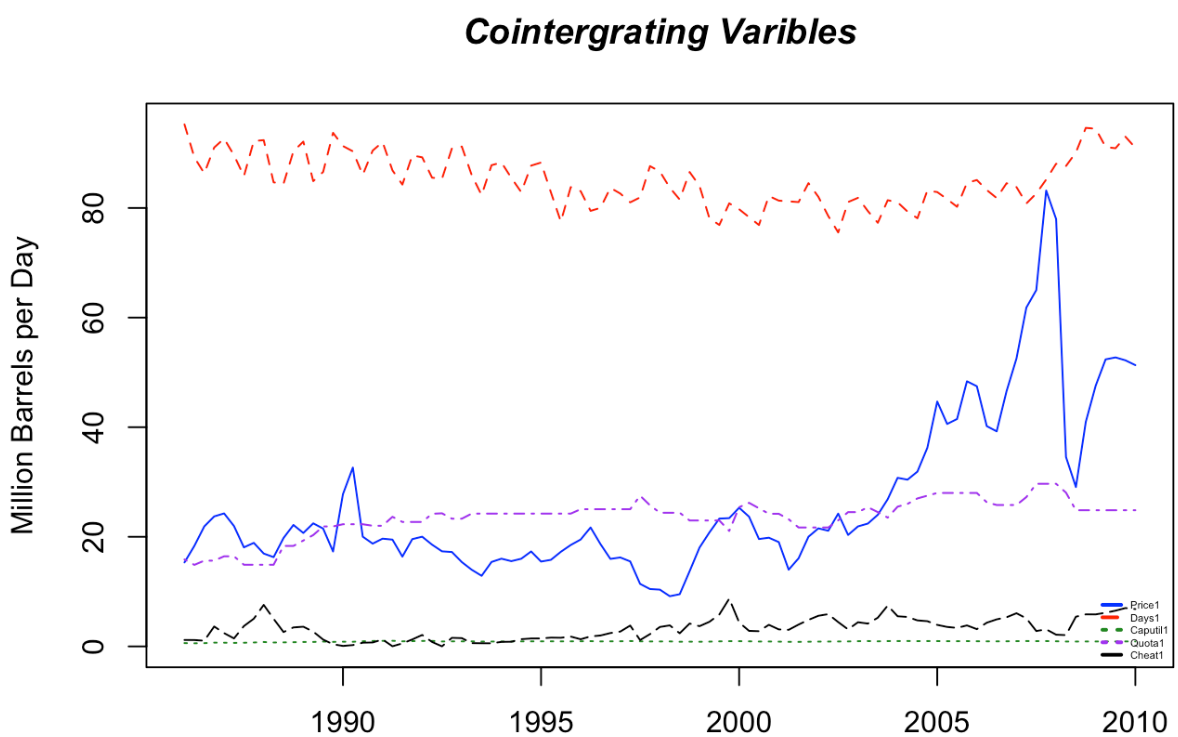

Differenced Log of Quarterly Cheat 1986Q3 - 2010Q3
Cheat
400
200
0
-200
-400
0
20
40
60
80
Time 1986-2010


Quarterly Quota 1986 - 2010
Quota
30
25
20
15
0
20
40
60
80
100
Time 1986-2010


Differenced Log of Quarterly Quota 1986Q3 - 2010Q3
Quota
-10
-5
0
5
10
15
20
0
20
40
60
80
Time 1986-2010


Quarterly Caputil 1986 - 2010
Caputil
0.6
0.7
0.8
0.9
1.0
0
20
40
60
80
100
Time 1986-2010


Differenced Log of Quarterly Caputil 1986Q3 - 2010Q3
Caputil
15
10
5
0
-5
-10
0
20
40
60
80
Time 1986-2010


Cointergrating Varibles
Million Barrels per Day
0
20
40
60
80
1990
1995
2000
2005
2010
Price1
Days1
Caputil1
Quota1
Cheat1

6. Cointergrating: Variables

So when non-stationary time series become stationary after being differenced they are called a I(1) series. The linear combination of these variables or I(1) series is now considered stationary or I(0), and are now also considered cointegrated. While the variables: Prices, Days, Quota, Cheat, and Caputil do not have constant values, some combination of them will, so we describe conitgratation as a long term relationship (Hamilton, 1994). From out outputs in R and the above graph we can now also see that the variables are I(1) because they do not possess a mean of zero and instead have a constant variance.

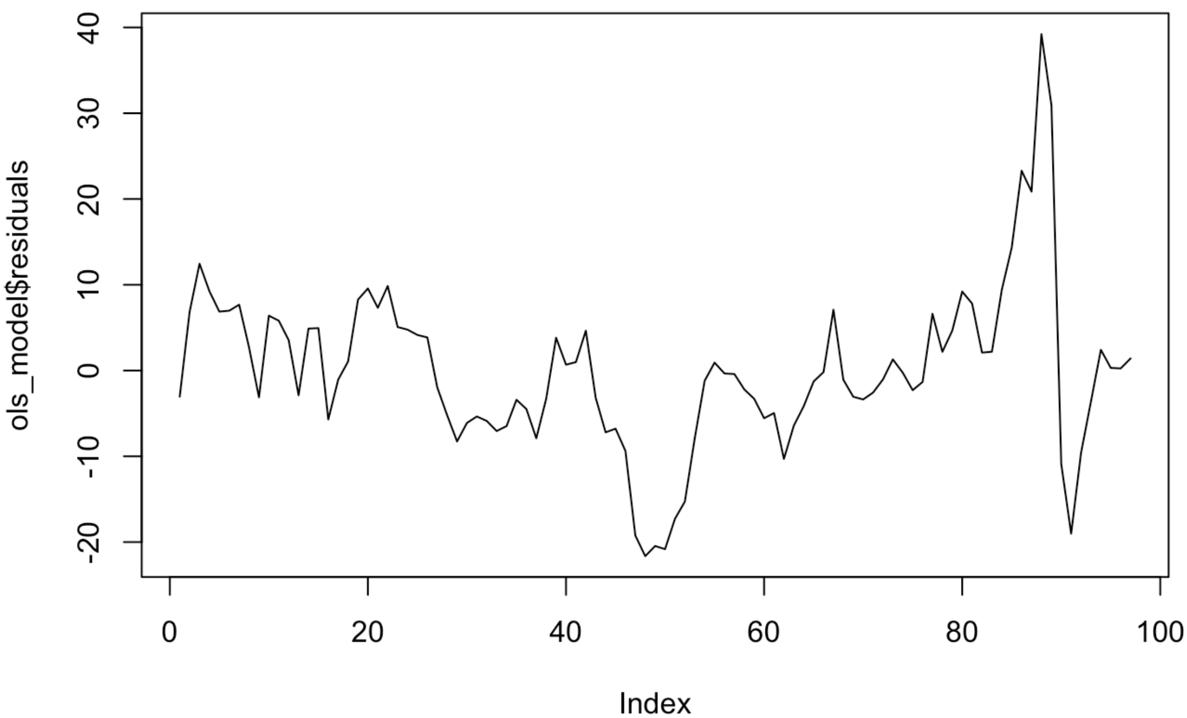
6.1 Cointergrating: Johansen Cointegration Test

In addition to visual analysis by the above graph we also ran the Johansen test to check for cointegration of the variables. This test allows for the testing various variables at once, which is why we decided to use this method over continuing with the augmented Dickey Fuller for he residuals. The Johansen test breaks down into two separate tests: trace or with eigenvalue. “The null hypothesis for the trace test is that the number of cointegration vectors is r=r*<k, vs. the alternative that r=k” (Johansen test, 2016). While the “null hypothesis for the "maximum eigenvalue" test is as for the trace test but the alternative is r=r*+1 and, again, testing proceeds sequentially for r*=1,2,etc., with the first non-rejection used as an estimator for r”(Johansen test, 2016). So running to the code R to confirm that Price cointegrates with Days, Quota, Cheat we get the following results: Both the values for Trace and Eigen test statistic reject the null at r = 0 , r=1, and both fail to reject null at r=2.Therefore we are going to pick r=2 for our vecm model, which also means that there are two cointegrations. Additionally, the confirmation that variables

are cointegrate means that have long run relationship and we can therefore run the error correction model and the vector error correction model.

6.2 Cointergrating: OLS Residuals

The results of OSL test show that the following variables: Days, Cheat, Caputil, Quota, are individually significant at .05 level. The results for ANOVA test or F-statistic is 12.95 and P value is less than .05. The dummies variables were not significant. Our assumption being that the spikes during those periods did not greatly affect the data, and could be omitted.



6.2 Cointergrating: DOLS with Error Correction Model

The equation for the Error Correction Model for short run with one lag is as follows:

$$\Delta Price_t = \alpha\mu_{t-1} + \sum_{i=1}^{s} \lambda_{1i}\, \Delta Days_{t-1} + \sum_{i=1}^{s} \lambda_{2i}\, \Delta Quota_{t-1} + \sum_{i=1}^{s} \lambda_{3i}\, \Delta Cheat_{t-1}$$

$$+ \sum_{i=1}^{s} \lambda_{4i}\, \Delta Caputil_{t-1} * + \sum_{i=1}^{s} \lambda_{1i}\, \Delta price_{t-1} + \xi_t$$

	Dependent variable:
##	Dprice
## ect1	-0.046
##	(0.106)
## L(ect1, 1)	-0.198*
##	(0.102)
## Ddays	0.210
##	(0.173)
## L(Ddays, 1)	0.140
##	(0.181)
## Dcheat	3.248**
##	(1.293)
## L(Dcheat, 1)	1.337
##	(1.303)
## Dcaputil	-28.169
##	(27.905)
## L(Dcaputil, 1)	-26.758
##	(28.235)
## Dquota	4.544***
##	(1.399)
## L(Dquota, 1)	1.604
##	(1.358)
## Constant	-0.376
##	(0.580)
## --	
## Observations	95
## R2	0.317
## Adjusted R2	0.235
## Residual Std. Error	5.343 (df = 84)
## F Statistic	3.894*** (df = 10; 84)
##	
==	

```
## Note:        *p<0.1; **p<0.05; ***p<0.01
```

The Error Correction model shows that increase in days, cheat and quota tend to increase price, while an increase in caputil tends to decrease price.

6.3 Cointergrating: Long run VECM

For the Long run VECM we use r=2 per the results of the Johansen Cointegration Test that show two cointegration variables that are non-stationary I(0) and one lag per AIC results. The Cointegrating vectors, as estimated by ML, are as follows:

```
## Call:
## lm(formula = substitute(form1), data = data.mat)
##
## Coefficients:
##              Price.d     Days.d      Cheat.d     Quota.d     Caputil.d
## ect1         -1.930e-01   2.926e-02  -2.075e-04   1.204e-02   7.288e-04
## ect2          4.112e-01  -6.146e-02   3.264e-03  -2.895e-02  -1.562e-03
## constant     -5.664e+01   5.554e+00   1.830e+00   1.034e+00   1.947e-01
## Q1            2.239e+00   1.395e+00  -1.977e-01   8.969e-02  -2.027e-02
## Q2            6.569e+00   7.629e+00   5.596e-01  -2.264e-01   6.246e-03
## Q3            5.305e+00   3.511e+00   3.291e-01   1.795e-01   2.188e-02
## War1          1.032e+01  -5.855e-01  -2.964e-01   3.852e-01   3.693e-03
## War2         -1.279e+00   1.092e+00   6.592e-01  -4.100e-01   1.126e-02
## Price.dl1     1.633e-02   1.088e-03  -4.702e-02   5.864e-02   4.907e-04
## Days.dl1     -9.778e-02  -1.056e-01  -4.357e-02  -3.850e-02  -4.078e-03
## Cheat.dl1     1.974e+00  -8.946e-01   1.016e-01   5.360e-02   3.085e-03
## Quota.dl1     1.464e+00  -4.832e-01   4.059e-01  -3.721e-01  -2.257e-03
## Caputil.dl1  -8.086e+00   8.831e+00  -1.047e+01   6.424e+00  -1.995e-01
##
##
## $beta
```

```
##                    ect1          ect2
## Price.l2       1.0000 -2.220446e-16
## Days.l2        0.0000  1.000000e+00
## Cheat.l2    -113.4222 -5.009923e+01
## Quota.l2     197.7200  9.414920e+01
## Caputil.l2 -6858.4892 -3.202874e+03
```

```
#the Vector error correction model is approximate my maximum likelihood estim
ator
#the VECM with 1 lag and 2 cointegration.


#The error correction coefficents1 is Price.d,Days.d, Cheat.d, Quota.d, and C
aputil.d
#are 1.930e-01, 2.926e-02, -2.075e-04, 1.204e-02, 7.288e-04


#The error correction coefficents1 is Price.d,Days.d, Cheat.d, Quota.d, and C
aputil.d
#are -1.930e-01,   2.926e-02,  -2.075e-04,   1.204e-02,   7.288e-04


#the cointegrating vector
#$beta
#ect1          ect2
#Price.l2       1.0000 -2.220446e-16
#Days.l2        0.0000  1.000000e+00
#Cheat.l2    -113.4222 -5.009923e+01
#Quota.l2     197.7200  9.414920e+01
#Caputil.l2 -6858.4892 -3.202874e+03
```

7. Causal Order among Variables

We also decided to tested the hypothesis proposed by Kaufman and his colleagues that Prices Granger-cause Days, Cheat, Quota, Caputil. Running a test for this in R we find that the P value is smaller than .05, and we therefore reject the null and conclude that Price does not Granger-cause Days Cheat Quota Caputil at 5% level.

8. Results

Similarly to the results proposed by Robert K. Kaufmann, Stephane Dees, Pavlos Karadeloglou and Marcelo Sánchez we find the Dickey Fuller test and HEGY reject the null and that the residuals for equation number 1 demonstrate an annual or stochastic trends. OLS results for the equation demonstrate a cointegrating vector that is different from zero. Also, we found that all the variables in the equations cointegrate by the Johansen Cointegration Test. In conjunction with previous findings we see that coefficient for Caputil is non-negative indicating that increases in the capacity would also raise prices. It is our conclusion that there is a significant relationship between oil prices, OPEC capacity, OPEC quotas, and that the results described above indicate that: (1) there is a statistically significant relationship among real oil prices, OPEC capacity utilization, OPEC quotas. Our results indicate that OPEC continues to have the ability to set prices by making decisions about quotas, production and capacity into 2010. In information could be interpreted about OPEC's behavior as a cartel from our data.

References:

Kaufmann, Robert K., et al. “Does OPEC Matter? An Econometric Analysis of Oil Prices.” The Energy Journal, vol. 25, no. 4, 2004, pp. 67–90. JSTOR, JSTOR, www.jstor.org/stable/41323358.

Ayed Al-Qahtani, Edward Balistreri, Carol Dahl (2008). Literature Review on Oil Market Modeling and OPEC’s Behavior Retrieved from http://dahl.mines.edu/LitReviewOPEC.pdf
Belton, B. (1998). OPEC can no longer make "people quake" USA Today.

Gately, D. (1995). Strategies for OPEC's Pricing and Output Decisions. The Energy Journal, 16(3), 1-38. Retrieved from http://www.jstor.org/stable/41322604

Griffin, J. (1985). OPEC Behavior: A Test of Alternative Hypotheses. The American Economic Review,75(5), 954-963. Retrieved from http://www.jstor.org/stable/1818638

Johansen, Søren (1991). "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models". Econometrica. 59 (6): 1551–1580. JSTOR 2938278

Johansen test. (2016). In Wikipedia, The Free Encyclopedia. Retrieved from https://en.wikipedia.org/w/index.php?title=Johansen_test&oldid=753937196

Koenker, R. (n.d.). E-TA 3: Introduction to Dynamic Models. Retrieved December 20, 2016, from http://www.econ.uiuc.edu/~econ508/R/e-ta3_R.html

O’Neal, Lydia (2016). How Do Oil Prices Affect the US. International Business Times. Retrieved from http://www.ibtimes.com/how-do-oil-prices-affect-us-economy-opec-cuts-production-12-million-barrels-day-2451802

Pfaf, B. (2007, July). Analysis of Integrated and Cointegrated Time Series. Retrieved from https://www.rmetrics.org/files/Meielisalp2007/Presentations/Pfaff.pdf

Stock, J. H., & Watson, M. W. (2007). Introduction to econometrics. Boston: Pearson/Addison Wesley.

Tapia, Joan (2006). OPEC Returns for Now. The Corner. Retrieved from http://thecorner.eu/world-economy/opec-returns-for-now/59949/

Hamilton, J.D. (1994). Time Series Analysis. Princeton University Press