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## Demand elasticity of imported crude oil in USA

*ABSTRACT : Demand side management is key to policy maker there this paper looks at demand for imported crude oil as a function of real price for crude oil and real income in US between 1965-2014. A dynamic model including a lagged dependant variable as a regressor is estimate to establish elasticities using OLS. Results show that both prices and income are negatively price inelastic in the short run while prices are elastic in the long run and income is positively inelastic in the long run. Some coefficient signs were unexpected. . There is general acceptance real world crude oil prices and the real GDP do not influence the importation of crude oil. US can explore policies related to demand side management, energy efficiency, strengthen environmental policies and also boost domestic oil production.*

Presented to: Dr. Rafael MACATANGAY

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## LIST OF ABBREVIATION

ADF	Augmented Dickey-Fuller test
EIA	Energy Information Administration
GDP	Gross Domestic Product
LN	Logarithm
LNG	liquefied natural gas
OLS	Ordinary Least Square
UECM	Unrestricted Error Correction Model
US	United States

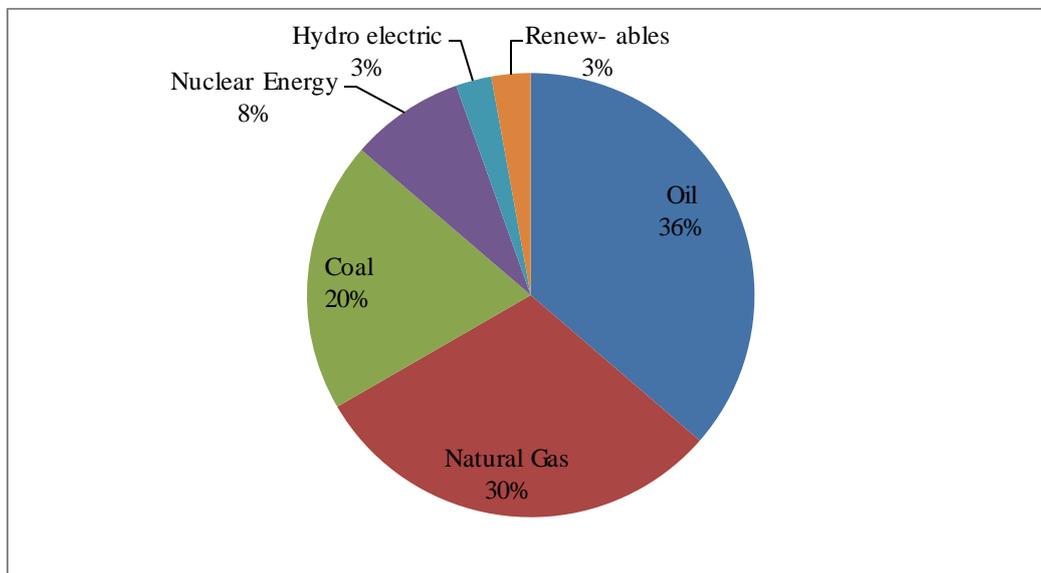
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## CHAPTER 1: INTRODUCTION

The World Bank estimates the United States of America's (US) at 318.9 million people making it the third largest populated country in the world after India and China. Whereas it's amongst the most populated countries, its economy has continued to grow. This growth goes along with heavy consumption of energy making it the second largest consumer of energy in the world utilizing about 16.1% of total world energy consumption (Enerdata, 2015).US's primary energy mix in 2014 comprised of 36% Oil, 30% Natural Gas, 20% Coal,8% Nuclear Energy ,3% Hydro and 3% Renewables as illustrated in the figure below:

**Figure 1: Primary Energy mix for 2014**



Source BP Statistical Review of World Energy June 2015

As seen in the mix, oil takes up the biggest composition and EIA reported US as largest importer of oil in the world and spent about \$427 billion on oil imports. However over the past five years the domestic crude production has increased while importation of the same has reduced. US imports most of its crude oil from Canada, Saudi Arabia, Venezuela, Mexico and Iraq. Whereas domestic production has increased overtime, the exportation of crude oil is still restrictive in the US and this may lead to over surplus in the domestic market.

Taking a glance at 2014, EIA reports that about 80% of the total petroleum imports in the US were crude oil and about 46% of it was processed in refineries while 27% of the net crude oil imports accounted for the petroleum consumed in US. This was

termed as the lowest annual average since 1985. Its net oil imports dropped by 1.1Mb/d to 5.1Mb/d still the lowest since 1985 (BP statistical review, 2015). Further, EIA reported a reduction in the importation of crude oil due to the reduced importation of crude oil type that was present in the USA such as the light and medium crude oil.

With the falling oil prices US would be expected to import more compared and increase production from the imported crude oil other factors kept constant but this is not the case over the past years. EIA forecasts a further decrease in crude oil importation in the coming years. Though recently China is claimed to have taken up as the world's largest importer of crude oil, there is still a reason for US to be concerned since the emerging economies of China and India have also increased their demand for crude oil and hence competition for the scarce resource. From that note, there is need for a demand analysis to ascertain if the prices of crude oil and Income determine the importation of crude oil holding other factors

This paper therefore aims at estimating the demand elasticity of imported crude oil in US mainly looking at price and income elasticities and also taking into the consideration the theoretical relationship between the concerned variables. The empirical analysis is for the period 1965-2014, using annual data. A demand trend for imported crude oil is first applied followed by an estimation of an econometric model using the Ordinary Least Square (OLS) method to establish price and income elasticities. Also a lagged dependant variable is introduced in the model as an explanatory variable. Many studies have previously been focusing on the demand of crude oil products than crude oil itself.

## CHAPTER 2: LITERATURE REVIEW

Many scholars and planners have analysed elasticity of demand using different approaches. Overtime the literature has improved in terms of model specification, Variable choices and estimation techniques. But the core is to use the normal demand function and add some other explanatory variables.

Andrea and Sylvian (2013) analysed elasticities of gasoline demand in Switzerland using quarterly data from 1970 to 2008 using Engle and Granger's cointegration approach in order to establish a long and short run relationship. They obtained weak price elasticity of 0.09 in the short run and 0.034 in the long run. They recognised an additional impact of oil shocks and mineral oil tax as an additional impact on gasoline and fuel demand.

While Economist Moore (2011) in estimating the demand elasticities for oil in Barbados also used the single equation cointegration approach of the Unrestricted Error Correction Model (UECM). He estimated the model with the barrels of oil consumed as the dependent variable and price of oil, number of vehicles, real gdp, electricity consumption and imported household appliances as explanatory variables. The model is estimated using monthly data over the period 1998–2009. He concluded that demand for 'oil imports is price inelastic in the long run but the consumption of oil is responsive to past consumption, prices, income, electricity consumption and the number of appliances imported in the short-run.' Ziramba (2010) used the same approach while estimating the income and price elasticities of crude oil imported in South (1980-2006), he concluded that price and income were inelastic.

Narayan and Wong (2009) also based on the classical economic theory that demand is a function of price and income to draw conclusions on the determinants of oil consumption in six Australian states and one territory. Using a panel data approach; the estimated long-run elasticities indicated that oil prices have a statistically insignificant impact on oil consumption while income has a positive and statistically significant.

Whereas the above studies centred more on the use of cointegration approach and UECM, dynamic models have also gained a trend in energy estimation. This involves the inclusion of a lagged dependent variable as one of the explanatory variables to enable us analyse how the current demand depends on the previous

demand and also find the long run elasticities. Bhattacharyya and Blake (2009) in estimating the demand for petroleum in the Middle East and North Africa included a lagged variable on the per capita consumption of petroleum products. Bhattacharyya (2011) also emphasised that this is kind of model is suitable when dealing with demand analysis at macro and sectorial level and it explains better than the static equation. However due to its assumption of constant elasticity of demand, it may not be in agreement with the demand theory though it is a better model.

## CHAPTER 3: METHODOLOGY

### 3.1 Model specification

To investigate the elasticities, this study relies on the same concept like other scholars that demand is a function of price and income other factors kept constant. Emphasis is also drawn from Altinay's (2007) submission that what to be included in the model depends on the characteristic of energy demand type and that will determine if it should be extended. Hence since crude oil is not a final product but rather oil products such as LPG, kerosene, gasoline etc. can be got from it; and also it can be used in other sectors such electricity production then the model will be straight forward considering the determinants of demand for imported crude oil. Therefore the US quantity demanded for imported crude oil in this case will be directly a function of real prices of crude oil ( $P$ ) and Real GDP of US.

$$QI=f(P,Y).....(i)$$

A lagged variable is introduced to establish if demand in period  $t$  depends on the past periods.

$$QI_t = \alpha_1 + \alpha_2 P_t + \alpha_3 RGDP_t + \alpha_4 QI_{t-1} + \mu_t.....(ii)$$

$QI_t$  is the quantity of crude oil imported in the USA.  $P_t$  is the real price of oil,  $RGDP_t$  is the real GDP.  $QI_{t-1}$  is a onetime lagged variable on  $QI_t$  implying that importation also depends on the previous period rather than real prices and real GDP only.  $\mu_t$  is the error term; it is assumed to be independent and normal.  $t$  is the time period and  $\alpha_{1,2,3,4}$  are coefficients. It is expected that quantities of imported crude oil are positively related to GDP and its lagged variable and negatively real prices.

This model is transformed in to log-linear form because this gives a direct estimation of price and income and best when dealing with this sort of energy demand.

$$\ln QI_t = \alpha_1 + \alpha_2 \ln P_t + \alpha_3 \ln RGDP_t + \alpha_4 \ln QI_{t-1} + \mu_t ..... (iii)$$

I will use the ordinary least square method for estimation expecting the obvious short run elasticities and the level of significance will be 5%. Afterwards I will compute the long run by dividing a specific coefficients with one minus the lagged variable ( $\alpha_4$ ) as shown in the table below (Bhattacharyya , 2011).

Elasticities	Short run	Long run
Price	$\alpha_2$	$\alpha_2 / (1 - \alpha_4)$
income	$\alpha_3$	$\alpha_3 / (1 - \alpha_4)$

$\alpha_2$ ,  $\alpha_3$  and  $\alpha_4$  are all parameters

If elasticity less than 1 then demand is inelastic, if its greater than 1 then demand is elastic and if it is exactly 1 then then it is unitary (Varian,2003).

### 3.2 Data and source

Annual data is used in this study from 1965 to 2014. This data was retrieved from different sources because a one single source could not give all the data for the years needed. The quantity of imported crude oil in thousands of barrels per day was obtained from United States Energy Information Administration. Real Prices of crude oil were got from the BP Statistical Review of World Energy of June, 2015 and it's measured in us dollar per barrels. Real GDP in billions of current dollars was got from US Bureau of Economic Analysis expressed in 2015 prices. The reason for the use of real GDP and prices it's because they are adjusted for inflation and also past studies have done the same.

**Table 1: Summary of descriptive statistics**

	LOG QI	LOGPRICES	LOG REALGDP
Mean	8.529255	3.691817	8.461886
Median	8.735204	3.658245	8.668441
Maximum	9.222862	4.762943	9.761238
Minimum	7.028201	2.395164	6.611638
Std. Dev.	0.663740	0.708107	0.974422
Skewness	-1.014239	-0.251143	-0.418560
Kurtosis	2.895790	2.024404	1.894728

Source: EIA, BP and US Bureau of Economic Analysis

### 3.3 Testing for Unit Root

The unit root is formal way for testing if the series are stationary though there are other tests like the graphical analysis and correlogram. Stationarity is a critical assumption while estimating time series models; it assumes constant mean and variance on time series overtime. Inclusion of non- stationary variables may result into spurious regression and the analysis may only be valid for the period data is available but also forecasting may be a problem. In this study I apply the Augmented Dickey-Fuller test (ADF) to test for the presence of a unit root. The advantage of the ADF is the capability to include enough terms so that the correlated error terms are

uncorrelated unlike the Dickey –Fuller that assumes that the error terms are already uncorrelated. A phillip –perron test will be used to confirm the test

The model is augmented with p lags of the dependent variable, in order to try to make residuals completely random

$$\Delta X = \beta_1 + \beta_2 t + \delta X_{t-1} + \sum_{i=1}^p \alpha_i \Delta X_{t-1} + U_t$$

Where

$\Delta =$  First Difference Operator       $t =$  Time index

$\beta =$  Coefficient on a time trend       $\delta =$  the process root coefficient

The test will take the Null hypothesis that  $H_0: \delta = 0$  and the Alternative hypothesis that  $H_1: \delta < 0$

In case there is any non-stationary series at all level then, I will difference the series to correct it/them so that they are all for stationary. Hence I will run the normal OLS regression and consult the ADF test statistics and P values instead of the t statistics.

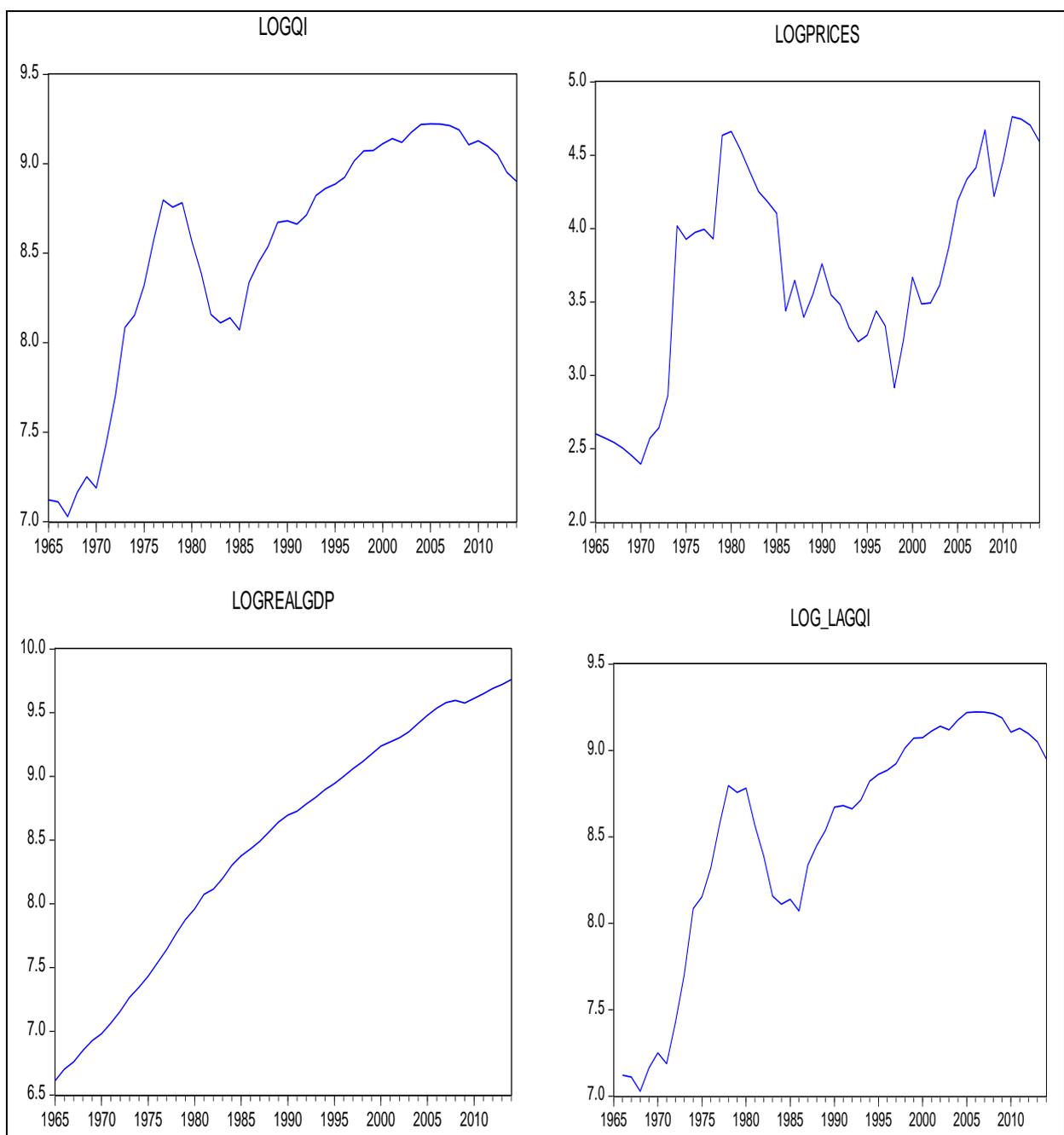
## CHAPTER 4: EMPIRICAL RESULTS

The chapter presents the results of the study.

### 4.1 Graphical time series

The four individual time series of the data used are plotted in their natural logarithms. The quantity of imported crude oil (LOG Q1 ), its lagged variable (LOG-LAGQI) and real GDP ( LOGREALGDP) have generally an upward movement. The real price of crude oil (LOGPRICES) was unstable and does not show any specific trend.

**Figure 2: LOGQI, LOGPRICES, LOGREAL GDP and LOGLAGQI**



## 4.2 Tests for unit root

The results below

**Table 2: Results of unit root test**

<b>Augmented Dickey Fuller Unit Root Test at level</b>				
<b>Variables</b>	<b>ADF Statistics</b>	<b>ADF Critical (5%)</b>	<b>P-Values</b>	<b>Stationarity status</b>
<b>LOGCONS</b>	-2.441350	-2.923780	0.1362	Non stationary
<b>LOGPRICES</b>	-1.548820	-2.922449	0.5008	Non stationary
<b>LOGREALGDP</b>	-6.531478	-2.922449	0.0000	Stationary
<b>LOG_LAGQI</b>	-2.407004	-2.925169	0.1453	Non Stationary
<b>First difference ; order of integration I(1)</b>				
<b>LOGCONS</b>	-3.824630	-2.923780	0.0050	Stationary
<b>LOGPRICES</b>	-6.862110	-2.923780	0.0000	Stationary
<b>LOGREALGDP</b>	-6.531478	-2.922449	0.0000	Stationary
<b>LOG_LAGQI</b>	-3.761651	-2.925169	0.0061	Stationary

From the table above and relating to the hypothesis stated in 3.2, the null hypothesis of non-stationary cannot be rejected in all the variables expect Real GDP at 5% level of significance. Looking at the probability values (P-Values) of Quantities of crude oil imported, the realprices and the Lagged Variable are all above 5% and also in those three the ADF statistic is less than the ADF critical a more emphasis that that we cannot reject the null. So from that point I conclude that all series are non-stationary besides real Gdp.

After differencing once all the series became stationary and also the P –Values became less than 5%.The ADF test statistics are greater than the critical values also This is referred to as integrated of order one Or I(1)

The Phillips –Perron test was used as a confirmatory test, it gave the same results as the ADF test in all the variables and within the same rage of the statistics and p-values.

## 4.3 Results of the elasticities

$$\ln QI_t = 0.317 - 0.079 \ln P_t - 0.023 \ln RGDP_t + 1.024 \ln QI_{t-1} + \mu_t$$

Using the OLS method, the parameters are estimated and are indicated in the table below;

**Table 3: Results of price and income elasticities of imported crude oil in the USA**

Short run		Long run		Lagged demand coefficient $\alpha_4$	Adjusted R square
Price elasticity $\alpha_2$	Income elasticity $\alpha_3$	Price elasticity $\alpha_2 / (1 - \alpha_4)$	Income elasticity $\alpha_3 / (1 - \alpha_4)$		
-0.079 (-2.571)* (0.0135)* *	-0.023 (-0.565)* (0.5748)**	3.29	0.95	1.024 (15.988)* (0.000)**	0.970

\*in brackets are t statistic while\*\* in brackets are the probability value

From the table above, it is shown that crude oil imports are price and income are inelastic in the short run. The short run price elasticity is significant at 5% level of significance evidenced with a lower p-value and it holds the expected sign. On the other hand the short run income elasticity is insignificant at 5% level of significance basing on the higher p-values and does not have the expected sign. A 1% increase in prices of crude oil leads to a 0.1% decrease in demand of crude oil. A 1% increase in the income (GDP) of the nation leads to a 0.02% decrease in the demand of imported crude oil. In the long run, 1% increase in crude oil prices leads to 3.3% increase in quantity demand of imported crude oil. This is not an expected sign but it is logical as will be explained below. A 1% increase in income lead to a 0.95% increase in the quantity demand of crude oil and this is the expected sign though it tends to unitary elasticity implying a an equal proportionate increase. The lag is significant with p values less than 5% however this coefficient being equal to 1 could be statistically questionable.

The results may be different from what was expected however other researchers have experienced the same. When Bhattacharyya and Blake (2009) investigated on domestic demand for MENA countries they found out that Algeria and Saudi Arabia had unexpected signs in the short run on price elasticity of gasoline while Libya had an expected sign for gasoline in the long run. UAE also had unexpected sign on the short and long price elasticity for demand of diesel oil while Qatar had on short run income elasticity for the same. Chakravolty et al. (2000) in estimating the Domestic demand for petroleum products in OPEC countries also found unexpected signs on the income elasticity of LPG for Saudi Arabia and Venezuela.

Whereas the studies quoted are basically on domestic demand for the final products of crude oil and cite subsidies and data problem as the possible cause. In this case at a macro level, crude oil is an intermediate good and therefore a possible risk of double

counting in terms of GDP and the added value is possible or even other issues. Further, Achen (2000) emphasised the issue of a lagged variable in the regression, that lagged variables on explanatory variables can destroy the true impact of other variables and even produce significant coefficients( see in table3).He added that a model without a lag normally produce meaningful theoretical results. However, if data is enough and stationary then this may not be an issue of wrong signs. Given that all data used here was stationary then there is a possibility of inadequate data since annual data was used instead of weekly or monthly data and also when testing for autocorrelation I obtained negative sign on the coefficient of the lag which prompted me to ignore the auto-correlated adjusted model in favour of the presented one.

Still other factors can come to play for the case of US .The negative inelastic prices is true for oil products due to the absence of an immediate substitute. However in the long run prices are elastic where by an increase in the price leads to more demand for imported crude. This could be so because US has commitments to consume from specific countries and also it has refineries domestically which are specialised to process heavier crude oil from Venezuela and Mexico which cannot be changed or closed easily in case world crude prices go high (Bushele, 2014). So the already established infrastructure for refining oil comes into play characterised with high capital costs to construct them.

Further, the negative income elasticity for crude oil imported in the short run might indicate that crude oil is becoming an ‘inferior good’ in the US though it turns out a normal good in the long run but still inelastic. This could be true because the current world prices of crude oil, has influenced US to increase its domestic oil and gas production from unconventional oil reserves using hydraulic fracturing or fracking techniques. In 2014 its oil production was 11.6Mb/d way above its 1970 record of 11.3Mb/d (BP statistical review, 2015).

## CHAPTER 5: CONCLUSION AND POLICY IMPLICATION

This paper attempts to establish the elasticities of demand for crude oil in the US using annual data and also using a dynamic model by introducing in a lagged dependant variable as an explanatory variable. Unit root test was carried out to test for stationary and all data was made stationary. Generally the results show that both price and income are inelastic in the short run while price is elastic in the long run and income is positively inelastic respectively with the right sign. Whereas some signs were not expected various explanations under lie beneath them as explained above.

This study has policy implication. The price elasticities depict that US still has a high reliance on imported crude oil .It also suggests that the real GDP is not affected with quantity of crude oil imported in the short run. This suggests that generally real world crude oil prices and the real GDP do not influence the importation of crude oil. Like recommended by Ziramba (2010), the application of demand side management and energy efficiency policies can be a solution to control the quantity of crude oil imported.

Also continuing the control of imported crude oil will improve its trade deficit while at the same time continuing to support its domestic oil production though great conscious about over production should be taken care of given the current tight policy on the exportation of crude oil from US. On that note US may need to free up its oil exportation policy. This will not only benefit the domestic oil producers but also other countries will benefit from the surplus.

This price and income inelasticity for crude oil could also contribute to increased Carbon dioxide emissions therefore the need for US to strengthen its policies for negative externalities such as pollution. This can be done encouraging substitutes that are environmentally friendly and putting up much higher environmental standards for bigger industries.

Also a more robust technique that combines dependent lagged variables and serial correlation can be used to obtain better results.

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