A CO-INTEGRATION ANALYSIS OF THE PRICE AND INCOME ELASTICITY OF ENERGY DEMAND

by

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ABSTRACT

Only two studies by Cox (1978) and Durant (1991) have endeavoured to conduct an empirical investigation of energy demand in Barbados. Research in the area is useful, especially in the current environment of soaring oil prices and relatively high current account deficits. This paper examines the price and income elasticity of Barbados' demand for energy[1], using a simple demand function and data spanning the period 1960-2005. Co-integration analysis is utilized to estimate the demand model and the results of the Engle and Granger (1997) Error Correction and the Johansen (1992) Vector Error Correction techniques are compared. The study finds that the demand for energy is fairly income elastic and price inelastic in the long run. Energy demand is responsive to lagged demand and to a lesser extent, prices, in the short-run.

Keywords: Energy Demand, Elasticity and Co-integration.
JEL Classification: Q4, C2

[1] Consumption of petroleum energy is used here as a proxy for total energy due to the unavailability of data on total energy consumption.

Introduction

It is rather surprising that there has been no attempt to analyze the impact of a change in oil prices on the demand for energy in Barbados, considering the importance of energy and the usefulness of price elasticity of demand. To the author's knowledge only two studies have endeavoured to conduct an empirical investigation of energy demand in Barbados. After the first oil shock in 1973, Cox (1978) investigated the relationship between energy demand and economic growth. Following his research, Durant (1991) conducted a study on the residential demand for electricity. Since then no research on the topic was published.

However, as is widely known, research in the area is extremely helpful, especially in the current environment of soaring oil prices and worsening current account deficits. A first hand knowledge of the price elasticity of energy demand would allow for an analysis and forecast of the impact of changes in oil prices on energy demand. This type of research is critical for Barbados, particularly now that the country is faced with the difficult task of finding alternative strategies for reducing its fuel import bill and dependence on petroleum consumption.

This paper makes a first attempt to examine the price and income elasticity of Barbados' demand for energy[2] using a simple demand function and data spanning the period 1960 to 2005. The objective is two fold (1) to determine the responsiveness of energy consumption to changes in oil prices and (2) to determine whether an oil price increase would be effective in reducing Barbados' energy demand. To estimate the energy demand model, the Engle and Granger (1997) error correction and Johansen (1990) vector error correction techniques are utilised, the first time that co-integration analysis has been applied. Thus, the paper adds to the literature and promises to be instrumental as it has the potential to inform the conduct of Barbados' energy demand policy and the management of Barbados' energy resources.

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[2] Consumption of petroleum energy is used here as a proxy for total energy due to the unavailability of data on total energy consumption.

The paper is divided into six sections. Section II continues with a short history on energy demand in Barbados. This is followed by a brief review of the literature in section III. The theoretical background of the selected energy demand model and the data are discussed in section V and section VI presents the empirical method and results. Section VII provides a summary and conclusion.

SECTION. II

A Primer to Energy Demand in Barbados (1960-2005)

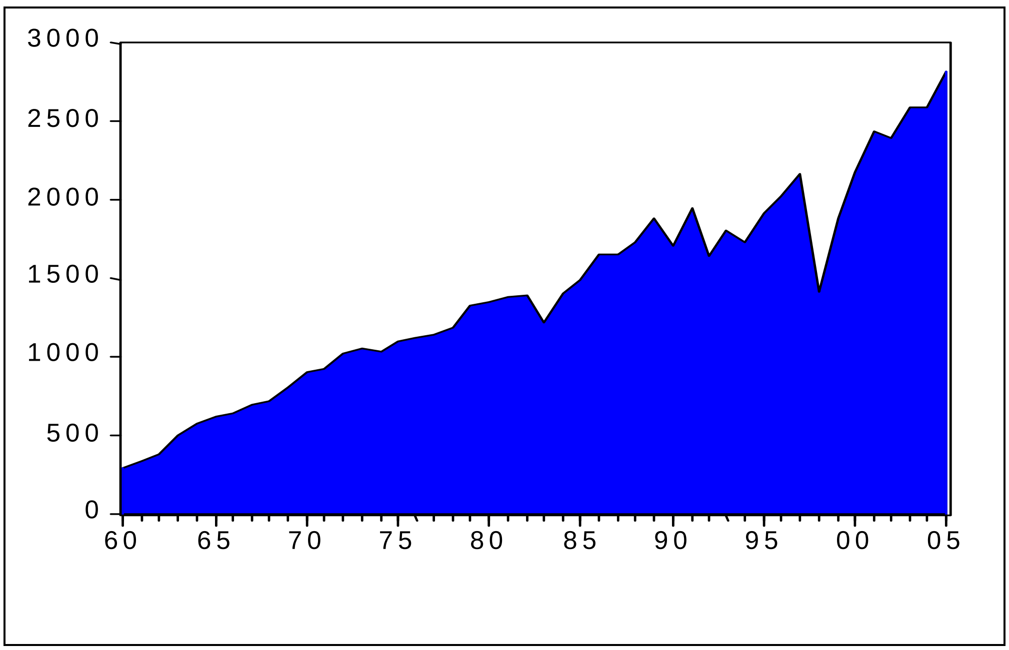
Barbados is usually characterised as a small open economy with a fixed exchange rate and a large propensity to import. Today the country imports about twice as much petroleum products as it did back in the early twentieth century. This change in energy consumption can be traced as far back as the 1960's. According to Cox (1980) the change in the pattern of energy consumption in Barbados was mainly attributed to the switch from non-commercial to commercial energy sources.

After the rise of the tourism and manufacturing industries, and the decline in sugar cane production, the consumption of commercial energy increased rapidly in Barbados. The consumption of bagasse and kerosene oil fell significantly between 1960 and 1978 as sugar cane production declined and households moved from cooking with kerosene to natural gas. At the same time, as the level of incomes rose and lifestyles continued to change, households demand for electricity increased, primarily for lighting and the powering of electrical appliances. Excluding the fall in energy consumption during 1974 (oil shock 1973) and the Gulf War in 1991, energy consumption in Barbados has maintained an upward trend ever since, reflecting the country's unwavering demand for commercial energy.

In the nineties, petroleum consumption and the imports of petroleum products continued to increase, especially after the shut down of the Mobil Oil Company in 1998 and the sharp increase in gasoline consumption following the influx of motor vehicles thereafter. Prior to the closedown of the Mobil oil refinery, Barbados mined and produced its own petroleum products, specifically diesel, gasoline and fuel oil. However, following the shut down of the Mobil Company, the Barbados Government exported crude oil to the Petro Trin refinery in Trinidad and Tobago, in an agreement to repurchase the refined crude oil at a market based reduced price. As a result, the value of fuel imports to Barbados increased by approximately 43.6% in 1998 and then by 27.5% in 1999. During this same period, however, petroleum consumption fell by almost 34.7% but grew by nearly the same amount in the following year. Subsequently, buoyed by consecutive increases in economic activity, petroleum energy consumption increased on average by more than 10.0% between 1999 and 2005.

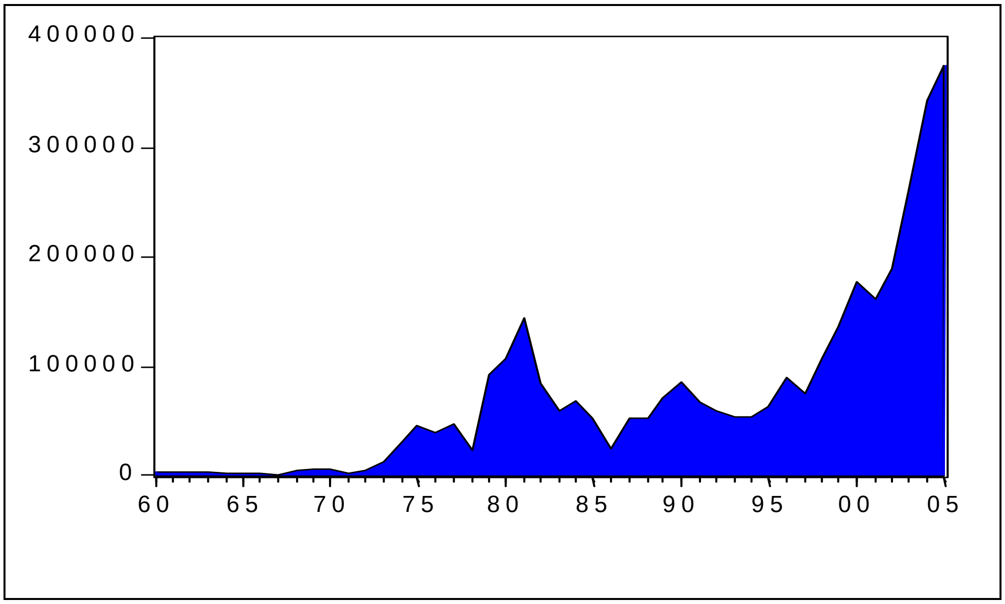
Consumption of Petroleum Products
(000'Barrels)

Graph 1.0



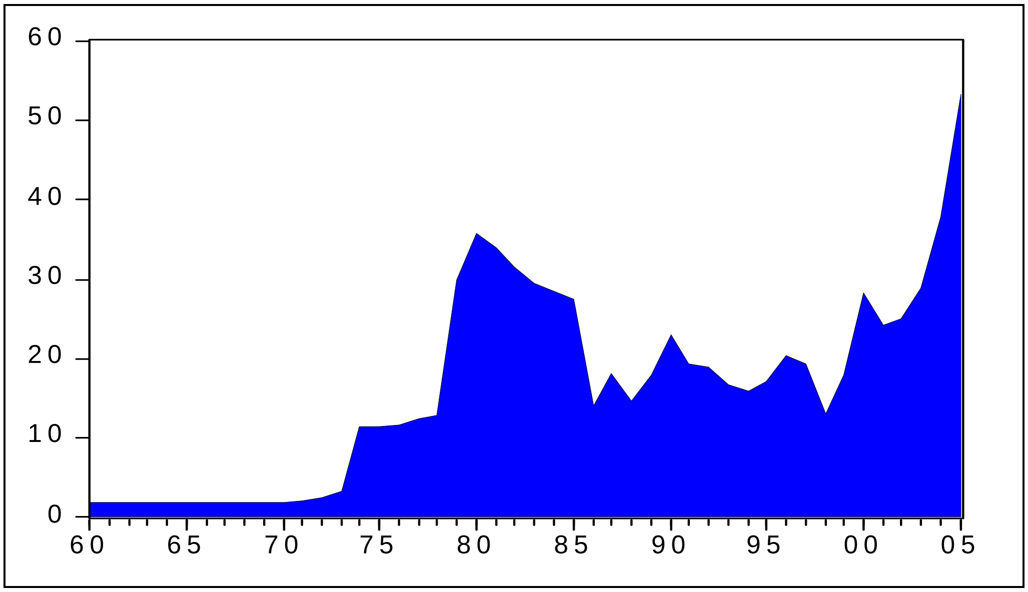
Fuel Imports
(Bds $Million)

Graph 2.0



International Crude Oil Prices
(U.S dollars Per Barrel)

Graph 3.0



SECTION. III

A Brief Review of the Literature

Empirical Models of Energy Demand

Overtime the empirical methods used to investigate the determinants of energy demand have changed substantially, but the modelling technique has generally remained the same. In the majority of studies the energy demand model comprises a price variable and an income variable, regressed on some measure of energy consumption.

Hodge (1999) used a demand function based on utility maximizing theory to model the demand for energy in the U.S economy. The function was made up of the quantity of energy demanded (E_t) on income ($Y_{t)}$, energy prices (P_t) and energy efficiency (F_t), which were measured by energy consumption, an energy price index, per capita GDP and average miles per gallon, respectively. A similar model was employed by Al-Azzam and Hawdon (1997) to estimate the demand for energy in Jordan. However, their model included a construction variable and a dummy, capturing changes in the political climate in Jordan. The authors argued that construction activity is a good indicator of the development process, and therefore it has a substantial impact on other economic activities, which are also users of energy. Both papers applied co-integration analysis to estimate the demand model. Hodge used the popular Johansen (1990) approach, and Hawdon employed the Stock and Watson (1993) Dynamic OLS approach.

Price and Income Elasticities of Energy Demand

As mentioned earlier, only a few studies have endeavoured to conduct an empirical analysis of energy demand in Barbados, and this has generally been the case in the Caribbean as well. In the literature, most of the studies are conducted by developed countries, which mention vaguely the impact of oil prices on energy demand for Non-OECD and developing countries. Moreover, the studies are typically based on cross section analysis and therefore, offer only a representative measure or benchmark for price and income elasticity of energy demand in the region.

Gately and Huntington (2001) found that the long-run income elasticity of energy and oil demand for Non-OECD oil importers with slow and uneven income growth was about 0.5, or half the elasticity estimate for Non-OECD countries with steadily growing incomes. The authors also found that energy demand responded more to increases than to decreases in price both in the OECD and Non-OECD countries and that in all cases, the speed of adjustment of energy demand to changes in price were slower than to changes in income. In a survey of energy demand elasticities for the developing world, Dahl (1992) provides estimates for price and income elasticities of energy demand. According to the survey, the average price elasticity of demand for developing countries is about –0.33 and average income elasticity is approximately 1.27. Hodge (1999) notes that Dahl's income elasticity figure is consistent with the results derived from a co-integration analysis of energy demand in the U.S economy, which reported an income elasticity of 0.806. Both results support the view that energy demand is very responsive to changes in income. However, Hodge found no relationship between prices and energy demand in the short-run.

SECTION. IV

Theoretical Model and Data

Model

At the most basic level, the demand for a good is dependent on the price of that commodity and available income. Of course, they are many other factors that may influence a consumer's demand, such as, taste, the price of available substitutes and technological innovation, etc. but it is not possible to account for the effect of each variable. Therefore, to facilitate a practical analysis of energy demand, studies have generally used a simple demand function, while allowing for the effect of changes in technology etc., *ceteris paribus* (Hodge 1999). The energy demand model in this paper is defined as follows:

$$\ln E_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln I_t + \beta_3 \ln F_t \qquad (1)$$

Where,

$\ln E_t$, is the log quantity of energy demanded

$\ln P_t$, is the log price of energy

$\ln I_t$, is the log of available income

$\ln F_t$, is energy intensity

In accordance with consumer theory, the quantity of energy demanded (E_t) should be inversely related to the price of energy, and positively related to the level of available income. Additionally, the relationship between energy intensity and the quantity of energy demanded is also expected to be positive. Estimates of the long-run own price and income elasticity of demand are derived by running the model in log form, where ln is the natural logarithm.

In the majority of studies, energy demand is measured by the total amount of energy consumed in the economy. However, in the absence of sufficient data on energy consumption, the energy variable (E_t) in this paper is measured by the consumption of petroleum products, or the total barrels of diesel, gasoline and fuel oil consumed within a year. This is believed to be an adequate proxy for primary energy consumption- the main focus of the paper, since energy services such as electricity and transportation, are derived from the consumption of petroleum products. The price of energy (P_t) is captured by the international price per barrel of crude oil and available income (I_t) is represented by Gross Domestic Product (GDP) per capita, mainly to eliminate the effects of changes in population size. Energy intensity (F_t)- a measure of efficiency, is approximated by the ratio of fuel imports to nominal GDP and describes the amount of energy per unit of GDP used up in the economy. Other studies have employed more conventional measures, such as a simple trend, or a ratio of total energy consumption to total GNP, but these are not included in this particular model, mainly because (1) The latter variable could introduce the problem of multicollinearity in the regression and the aforementioned might be too simple for a meaningful interpretation of the results and (2) within the context of Barbados, the ratio of fuel imports to nominal GDP is possibly one of the most reliable estimates of changes in energy efficiency, primarily because the ratio is essentially a reflection of

Barbados' reliance on imported energy. A smaller ratio of fuel imports to GDP would imply lower energy intensity and a reduction in energy demand.

Data

The model is estimated using data spanning the period 1960 to 2005. Data for the consumption of petroleum products and GDP per capita is obtained from the Central Bank of Barbados Annual Statistical Digest (2005). Fuel imports are gathered from The Central Bank of Barbados Economic and Financial Statistics (March 2006) publication and the international price per barrel of crude oil is sourced from the IMF International Financial Statistics (March 2006) CD ROM. For some of the earlier years, data on GDP per capita is taken from various publications of the Barbados economic survey report and the national income of Barbados. Additionally, between 1998 and 2005 data on the consumption of petroleum products is obtained from Barbados National Terminal Company Limited (BNTCL).

SECTION. V

Methodology and Empirical Results

Econometric methods

The model described in equation (1) is rather simple and seems relatively easy to estimate using a normal ordinary least squares (OLS) procedure, as was done in the earlier study by Cox (1978). However, before estimating any relationship between economic variables it is best to test for the presence of unit roots to see whether the variables are stationary or non-stationary in their level form. Variables that are stationary in the level are said to be I(0), while those that are non-stationary are said to be integrated of order 1 or I(1). Research has shown that the use of I (1) variables to estimate long-run relationships may lead to spurious or non-sense regressions if the non-stationary variables are not themselves co-integrated (Granger *et al*. 1987). Hence, numerous methods for detecting unit roots and the presence of co-integration have been developed. One of the most popular tests for stationarity is the Augmented Dickey Fuller test for unit roots. In this technique, the ADF test statistic is compared to a set of critical values with a null hypothesis of a unit a root. If the ADF statistic exceeds the critical values, the hypothesis of non-stationarity is rejected and it is said that one can safely use the normal OLS procedure to estimate the long-run relationship in level form. However, if the test determines that all variables are non-stationary, one must check to see if a long-run relationship exist (if the variables are collectively stationary) before moving on to estimation.

Co-integration theory suggests that although a set of variables may be individually integrated or I (1), they may exist a linear combination of these variables that is stationary or co-integrated. Based on this concept, the Engle and Granger (1997) vector error correction approach was developed. The method provides a framework to test for co-integration, and allows for the estimation of long run and short-run dynamics, using a simple linear equation transformed into a dynamic Error Correction Model (ECM)[3].

Another technique, which has gained considerable popularity, is the Johansen and Juselius (1990) vector error correction approach (VECM). This method has several advantages over the ECM: (1) unlike the two-step procedure by Engle and Granger, the model does not assume one co-integrating relationship (2) it does not impose any exogeneity restrictions (all variables are treated as endogenous) and (3) it uses a system of equations framework to estimate the model. The Johansen Vector Error Correction Model (VECM) is as follows:

$$\Delta y_t = \eta + \sum_{i=1}^{p-1} \Pi_i \Delta y_{t-i} + \varphi Z_t + \Pi y_{t-1} + \varepsilon_t \qquad (2)$$

where Δ is the first difference operator, y is a (n x 1) vector of variables and η is a (n x 1) vector of deterministic variables. Π_i and Π are (n x n) coefficient matrices, φ is a (n x m) matrix of coefficients, while Z is a (m x 1) matrix of exogenous I(0) variables. The term ε is a (n x 1) vector of disturbances *iid* $(0, \sigma^2)$.

[3] $\Delta Y_t = \gamma_0 \Delta X_t - (1-\alpha)[Y_{t-1} - \beta_0 - \beta_1 X_{t-1}] + \mu_t$
The ECM incorporates both long run and short run effects. When equilibrium holds, $[Y_{t-1} - \beta_0 - \beta_1 X_{t-1}]$ =0. But in the short run, when disequilibrium exists, this term is non-zero and measures the distance that the system is away from equilibrium at time t. Thus $(1-\alpha)$ provides an estimate of the speed of adjustment of the variable Y_t.

The rank of the coefficient matrix Π identifies the number of linearly independent vectors or co-integrating relationships. If the rank of Π is zero then no long-run relationship exists between the variables. On the other hand, if Π is of full rank (n) then the relationship is stationary and a VAR in levels is considered appropriate. In a third case, if Π is less than full rank then there exists two (n x r) matrices, α (matrix of adjustment terms) and β (matrix of co-integrating vectors) such that $\Pi = \alpha \beta'$. Hence α must be negative and significant to achieve long-run equilibrium, since disequilibrium in β' must be corrected by an opposite shock in α. Thus, α tells us about the speed of adjustment to long-run equilibrium.

Empirical Results

The ADF test for unit roots reveals that all variables except for petroleum energy demand are non-stationary in the level (see Table 1.). However, a further test for unit roots, using the ADF test[4] for structural breaks (Joyeux 2001 and Perron 1989,1990) suggests that the variable is indeed non-stationary. The results from the ADF test are as follows:

$$\ln E_t = 1.84 + 0.01 Trend + 0.714 \ln E_t(-1) - 0.473 Dum \quad (3)$$

[5.545245] [4.458568] [13.26862] [-6.911367]

Where *Dum* is a dummy variable representing the shutdown of the Mobil oil company in 1998 and the figures in parenthesis are the t-statistics. As equation 3 shows, the structural break is significant, along with the coefficient on lagged energy demand and the trend. Hence, petroleum consumption is non-stationary, but with a structural break in the unit root. Given this result, it is plausible to test for co-integration among the variables. The Johansen co-integration test and the ADF co-integration test are utilised. As seen in Table 2, the trace statistic indicates one co-integrating equation at the five percent level. Moreover, the residual test in table 4 suggests that the long run residuals are stationary, which also indicates one co-integration equation- that is according to the ECM approach. Therefore, with verification of one co-integrating equation, the results of the ECM and VECM are compared.

[4] If a series is stationary around a deterministic trend with a structural break we are likely to accept the null of a unit root even if we include a trend in the ADF regression. There is a similar lost of power in the unit root tests if the series present a shift in the intercept. If the breaks are known the ADF tests can be adjusted by including dummy variables in the ADF regression (Perron (1989,1990), Zivot and Andrews (1992) among others).

The results for the long run and short-run under the ECM and VECM are reported in Table 4. All diagnostic tests were favourable for both models. There were no signs of autocorrelation or heteroscedasticity, and the disturbance terms appeared to satisfy the normality assumption.

The long-run results for the ECM and VECM have the same signs and the coefficients are of similar magnitude and significance. The variable-International Crude price- is significant at the five percent level and the coefficient is small, implying that the demand for petroleum energy is relatively price inelastic. Under the ECM the own price elasticity of petroleum energy demand is approximately -0.16, which is slightly lower than the elasticity of -0.28 reported by the VECM. The long run income elasticity of demand, according to the ECM and VECM are 0.57 and 0.42, respectively. As for energy intensity, the ECM results suggests that there is no relationship between energy intensity and energy demand, however, the VECM indicates that the variable is significant and has a positive relationship with petroleum energy demand. The elasticity estimate for energy intensity, according to the VECM approach is 0.14.

In the short run, both approaches find that lagged energy demand is significant to the current demand for energy. In fact, the results obtained by each method are quite similar. For the ECM the short-run elasticity of lagged energy demand is –0.21 and for the VECM it is –0.19. Income was also found to be significant in the ECM during the short-run. The coefficient obtained is 0.36, which suggests that a one percent increase in income during the short-run could raise the demand for petroleum energy by as much as 36%. However, the energy intensity variable was not significant in the short run under both models. This is not surprising since the implementation of new technology to create cheaper energy or finding alternative energy resources take time. Research and planning could take as long as ten years. The error correction coefficients for both approaches were acceptable, and confirmed the presence of a long-run relationship. In the ECM the co-integrating parameter had a coefficient of –0.31, while the VECM short-run parameter had a coefficient of –0.33. These coefficients indicate a relatively slow adjustment to long run equilibrium. The reported R squared for the two models were 0.58 for the ECM and 0.72 for the VECM, and hence, the results of the VECM are considered to be superior since the model accounts for most of the variation in energy demand.

SECTION. VI

Conclusion

This study attempts to examine the price and income elasticity of the demand for petroleum energy in Barbados. Using the ECM and VECM approaches to co-integration the results suggest that the demand for petroleum energy is fairly price inelastic and relatively income elastic in the long run. However, there appears to be no relationship between prices and energy demand in the short run. Only income is found to be a factor, at least under the ECM approach. Lagged petroleum energy demand is also significant in the short-run and this is consistent with the results obtained in other studies.

In summary, the study finds that the own price elasticity of demand for petroleum energy in Barbados ranges between –0.16 and –0.28, and the income elasticity of demand ranges between 0.57 and 0.42. Hence, an increase in the price of crude oil could reduce the demand for petroleum energy by at least 20% in the long run, while a rise in the level of income could boost petroleum consumption by a much as 50% on average. The results are fairly consistent with those obtained in the literature, except for income elasticity of demand, which appears to be fairly low. Most of the studies on developing countries have found that the income elasticity for energy demand is around unity (Dahl 1992).

Taking into account the fact that gasoline prices are subsidised by the Barbados Government, these estimates seem to suggest that a full pass through of crude oil price increases to the domestic market would reduce energy consumption by a larger percentage and by extension, curb the impact on the energy import bill. However, considering the wide spread effects of rising energy prices on total economic activity a policy aimed at reducing subsidies for fuel prices may not be a best option.

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APPENDIX

Table 1.0: Growth Trends 1960-2005

Period	Petroleum Consumption	Fuel Imports	Crude Prices	Real GDP
1960-1965	13.8	7.4	0.6	4.7
1966-1971	7.1	25.2	3.7	11.4
1972-1977	3.5	96.3	51	20.6
1978-1983	1.5	37.8	22.8	15.1
1984-1989	7.6	14.1	-4.1	7
1990-1995	0.9	-0.9	0.3	1
1996-2001	6.5	20	10.3	4.02
2002-2005	3.8	23.9	22.6	4.6

Table 2: Augmented Dickey Fuller Test for Unit Roots (ADF)

Variables	*ADF Statistics*	*Critical Values*
$\ln P_t$	-5.913315	-3.515523*
$\ln I_t$	-3.603667	-2.929734*
$\ln F_t$	-7.144953	-3.515523*
$\ln E_t$	-3.651447	-3.513075

Note: * indicates significance at the five percent level. Although the test statistic for $\ln E_t$ is not significant, a further test for structural breaks reveal that the variable is non-stationary.

Table 2: Johansen Test for Co-integration- Rank Test (Trace)

Co-integrating Equations	Eigen value	Trace Statistic	5% Critical Value	P-Value
$r = 0$	0.635426	79.21468	55.24578	0.0001
$r \leq 1$	0.424067	34.81756	35.01090	0.0524
$r \leq 2$	0.173719	10.53996	18.39771	0.4299
$r \leq 3$	0.047556	2.143872	3.841466	0.1431

Note: The trace test indicates one co-integrating equation at the five percent level of significance.

Table 4: Estimated Long-run and Short-run Elasticities

Equation	*Long-Run ECM*	*Short-Run ECM*	*Long-Run VECM*	*Short-Run VECM*
$\ln P_t$	-0.166 [-2.09]		0.289 [2.77]	
$\ln I_t$	0.575 [8.838]		-0.43 [-2.69]	
$\ln F_t$	0.039 [0.685]		-0.148 [-2.19]	
$\Delta \ln P_t$				
$\Delta \ln I_t$		0.357 [2.156]		
$\Delta \ln F_t$				
$\Delta \ln E_t$ (-1)		-0.214 [-2.104]		-0.196 [-2.167]
$\Delta \ln P_t$ (-1)				0.078 [1.857]
$\Delta \ln I_t$ (-1)				0.075 [0.480]
$\Delta \ln F_t$ (-1)				-0.035 [-1.341]
Dummy [Mobil Shutdown]		-0.479 [-6.324]		-0.455 [-6.910]
Residual ($\hat{\mu}$)	-0.286 [-3.514]			
		Diagnostics		
R^2		0.589		0.728
Error-Correction Mechanisms		-0.318 [-3.229]		-0.335 [-5.462]
S.E of equation		0.075		0.064
L.M Statistic (Autocorrelation)		18.959		12.027
Jarque-Bera (Normality)		2.141		11.077
Chi-Square statistic (Heteroscedasticity)		8.744		137.889

Note: The figures in parenthesis are t-statistics and represent significance at the five percent level. The test for autocorrelation, normality and heteroscedasticity under the VECM are joint tests.