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Full Length Research Paper

Demand elasticities of oil in the kingdom of Saudi Arabia using autoregressive and error correction procedures

Hamad M. H. Al-Sheikh and Bukhari M. S. Sillah*

Department of Economics, College of Business Administration, King Saud University, Riyadh, K.S.A.

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This paper investigates the short-run and the long-run oil demand elasticities in Saudi Arabia for the period 1980-2009, using auto-regressive and co-integration analyses. It finds oil price (the world crude price) insignificant in the short-run and significant in the long-run, and the demand to be price inelastic. The income is significant, and the demand is income inelastic in the short-run and elastic in the long-run. There is a long-run co-movement between the oil consumption and linear summation of the oil price and the income. However, a deviation from this long-run equilibrium takes a long time to correct, as only 0.08% of deviation is corrected annually. The income and the oil consumption have a bi-directional relationship, whereas the domestic oil consumption is found neutral of the world oil price, and the domestic income growth is found to put pressure on the world oil price to rise. The implications of the study are that domestic energy conservation should be cautiously managed as reductions in the domestic oil consumption can have damaging consequences for the economic growth, and the authorities should monitor and evaluate the sustainability of the neutrality of domestic oil consumption market from the world oil market shocks.

Key words: Auto-regressive, co-integration, analyses, domestic, energy, conservation, income, growth, bi-directional, oil consumption, economic growth, inelastic, demand.

INTRODUCTION

Oil demand elasticities are means whereby economic analysts can forecast changing oil consumptions as consumers get richer, or predict oil consumption responses as oil is taxed or subsidized. There are four demand type elasticities of oil that one can study (Dahl, 2010). They are income elasticity, own price elasticity, cross-price elasticity and structural and demographic elasticity, which indicates how oil needs vary as countries industrialize or de-industrialize, or as citizens urbanize, or as the population gets older. The current paper attempts to address the first two demand elasticities in Saudi economy. This is to shed light on the nature of income and own price elasticities in the context of increased economic modernization and the desire to conserve oil. To study the short run and the long run nature of these two elastiticities, the paper will indicate how intensified the oil consumption has been with increased income, and whether the oil consumption is a driving force for the economy. The paper uses the international oil price in the demand model to link the domestic oil market with the international market. This tells how the domestic oil consumption disruptions can feed back to the international markets and it helps the analysts anticipate domestic oil use responses if the oil subsidy is to be reduced

*Corresponding author. E-mail: bsillah73@yahoo.com.

Abbreviations: PPP, Public private partnership; **GDP,** gross domestic product; **OECD,** Organization for Economic Cooperation and Development.

or removed. The paper employs autoregressive, error correction procedures, co-integration and Granger causality tests to analyze the relation between the domestic oil consumption and the GDP in Saudi Arabia using 1980 – 2009 annual observations.

LITERATURE REVIEW

Dahl (2010) has developed a database on energy demand with a collection of 18,000 equations in more than 1,000 studies across more than 41 countries. In this database, the least used estimation technique is autoregressive and error correction methods, they account for less than 5% of the database. Dahl derives general conclusions from the database, which are that income and price elasticities of oil are inelastic, and that the elasticity estimates on static models are lower than those on long run dynamic models. Then he draws three testable hypotheses, which are a) poor countries have higher income elasticities than rich countries, b) cross-sectional data yields higher price elasticity than time series, and c) monthly estimates yield lower long run elasticities than annual estimates. Another testable hypothesis was observed by Tang et al. (1993) in the Chinese data, where it was found that estimates obtained by using public private partnership (PPP) gross domestic product's (GDP's) are higher than those obtained when exchange rates are used to convert GDP's to dollars. The first hypothesis was rejected by the findings of Dargay and Gately (2010). Their findings show that income elasticities for Organization for Economic Cooperation and Development (OECD) countries fall between 0.56 and 1.1, whereas for the oil exporting countries it is between 0.70 and 1.0, and for the rest is below 0.39. The hypothesis that poor countries tend to have income elasticity higher than the developed countries is premised on the observation that energy intensity increases as economies move from agriculture to industry and then decreases as they shift towards services; this was the pattern observed for the developed countries, and it is anticipated that developing countries will repeat it. But with availability of efficient energy technologies, the developing countries may not repeat the pattern. Ghosh (2009) finds India to repeat the pattern, his findings show income elasticity to be 1.97 in India, and that economic growth drives up the energy consumption, and not vice versa. Similar unidirectional causality is found in South Africa by Ziramba (2010), but in South Africa oil is found to be a necessity. Earlier on in India, Paul and Bhattacharya (2004) found the causality relation between energy consumption and economic growth to be bi-directional. These conflicting results could be due to the fact many causality tests involve only an energy and an economic variable, whereas large sample sizes and multivariate models, which are close to economic theory, are often ignored, Zachariadis (2007). The absence of production side, which involves GDP, energy, capital and labor, in the modeling could produce conflicting results as well. Oh and Lee (2010) include the production side in the modeling of demand side of energy, GDP and real energy price and find no causality between energy and GDP in the short run. In the long run, causality is found to run from GDP to energy consumption. This relation is found in 11 oil exporting countries in panel data study by Mehrara (2007). This means, the exporting countries, which often suffer from domestic oil price distortions, can undertake energy conservation without a damaging consequence on their economic growth. In china, it is bi-directional, He et al. (2008); in South Africa, it is bi-directional, Odhiambo (2009); in Gambia, Ghana and Senegal, it is uni-directional running from GDP to energy, Akinbo (2008); in Canada, it is uni-directional running from energy to GDP, Balcilar (2006). In Canada, energy conservation can impede economic growth. This result in Canada is further confirmed by Lee and Chien (2010), who find that energy consumption drives up economic growth in Canada, Italy and UK. They find it neutral in Germany and U.S.A. It is also found neutral in some developing countries such as Cameroon, Cote I Voire, Nigeria and Keyna, Akinbo (2008). This shows that oil consumption has varying patterns with the economic activity across countries, even across countries that are of the same income classification. The current paper contributes to this debate and literature by providing another evidence for the pattern of the relation in an oil exporting country, which has embarked on tremendous industrialization to reduce dependency on oil revenues. It is important to enlighten the policymakers in this country on the pattern and nature of the relationships between domestic oil consumption and the income, and on how domestic consumption responds to changes in the international oil prices. Specifically, the paper attempts to address the following questions:

1. Has energy consumption intensifies with the growth of per capita income?
2. How responsive is the domestic oil consumption to the changes in the international oil markets?
3. Is oil a necessity or a luxury for Saudi consumers?
4. Is there any long relationship between oil consumption and the per capita GDP?
5. What is the nature of Granger causality relation in the short run and the long run between oil consumption and per capita GDP?

ESTIMATION TECHNIQUES AND EMPIRICAL ANALYSIS

Economic theory of demand holds that oil consumption is a function of its own price, the income of the consumers, prices of related goods and other variables that are believed to influence the quantity of oil consumers' demand. This paper argues that own price (international price) and income are the relevant variables that explain variations in the domestic oil demand in Saudi Arabia. The income captures the activity level of industrial and demographic factors and purchasing power of the consumers. The domestic oil price is highly subsidized and seldom changes, the international oil price acts not only as an own price variable, but also as a linkage factor between the domestic market and international markets, and in this way it brings to bear on the domestic market the innovations and changes in the global oil market. Thus, the demand function is specified in a log form as;

$$\ln C_t = \alpha + \beta_1 \ln P_t + \beta_2 \ln Y_t + \varepsilon_t \qquad (1)$$

Where, lnC = log per capita oil consumption, lnP = log oil price, lnY = log per capita real GDP, and □ is the error term.

Autoregressive procedure

Let Equation (1) be a long run relationship between the left side and the right side variables, and that C□ is the equilibrium level of oil consumption that the consumers wish to attain given the oil price and the per capita income. With these assumptions, Equation (1) becomes:

$$\ln C_t^* = \alpha + \beta_1 \ln P_t + \beta_2 \ln Y_t + \varepsilon_t \qquad (2)$$

Equilibrium value of C is unobservable, but at any given time, the consumers adjust their oil consumption towards this target level of oil consumption, employing the partial adjustment process, this behavior of the consumers can be described as

$$\ln(C_t - \ln C_{t-1}) = \lambda(\ln C_t^* - \ln C_{t-1}), \qquad 0 \le \lambda \le 1 \qquad (3)$$

Equation (3) states that the current oil consumption level moves partially from its previous level towards the desired equilibrium level, and the amount of adjustment is $\lambda(\ln C_t^* - \ln C_{t-1})$ and lambda □ indicates the speed of adjustment. By substituting for the value of the equilibrium oil consumption from Equation (2) into Equation (3) and solving for the observed value of the current oil consumption, an autoregressive model appears:

$$\ln C_t = \lambda\alpha + (1-\lambda)\ln C_{t-1} + \lambda\beta_1 \ln P_t + \lambda\beta_2 \ln Y_t + v_t \qquad (4)$$

If there is an adjustment, the short run and long oil demand elasticities of income and own price can be derived by estimating equation (4) as

$$\ln C_t = b_0 + b_1 \ln C_{t-1} + b_2 \ln P_t + b_3 \ln Y_t + v_t \qquad (5)$$

The coefficients of Equation (5) are the short run elasticities. The knowledge of these coefficients helps derive the long run elasticities in Equation (2).

The estimation of Equation (5), (details in appendix A) gives us the following:

$$\ln C_t \;=\; -0.44 + 0.92\ln C_{t-1} - 0.04\ln P_t + 0.18\ln Y_t$$
$$p-values = (0.45) \quad (0.000) \qquad (0.335) \qquad (0.004)$$
$$R^2 - adjusted = 0.966$$

It shows that the international oil price does not have a short run influence on the domestic oil consumption in Saudi Arabia, and the income elasticity of oil consumption is inelastic in the short run. In the long run, oil consumption is income elastic at 2.25, and it is price inelastic at 0.5. The next section discusses the contemporaneous relationship between oil consumption and the income and the price, and explores the existence of equilibrium relation and the adjustment towards it.

Error correction method (ECM)

Another way to look at the long relation in Equation (1) is to assume the gap between the left side variable and the right side variables to be corrected at every particular time to maintain the equilibrium balance between the two sides. This gap is the error term in Equation (1):

$$\ln C_t - \alpha - \beta_1 \ln P_t - \beta_2 \ln Y_t = \varepsilon_t \qquad (6)$$

The adjustment towards the equilibrium depends on the amount of error previously committed, or specifically,

$$(\ln C_t - \ln C_{t-1}) = \delta\varepsilon_{t-1} + e_t$$

$$\Delta \ln C_t = \delta\varepsilon_{t-1} + e_t \qquad (7)$$

The coefficient of the lagged error term in Equation (7) is the amount of error corrected at every particular time towards the equilibrium. For this correction to take place, the lagged error term should be significant and negative. Equation (7) is expanded to include not only the lagged error term of the long relation, but also the lagged adjustments of the dependent variable and the contemporaneous and lagged adjustments of the explanatory variables to capture all the potential adjustment processes in the relation towards the equilibrium.

These adjustments disappear when the equilibrium is attained. Incorporating these potential adjustment processes in Equation (7), result in the error correction procedure as shown in Equation 8:

$$\Delta \ln C_t = a_0 + \sum_{i'=1}^{q} b_i \Delta \ln C_{t-i} + \sum_{i=0}^{n} c_i \Delta \ln P_{t-i} + \sum_{i=0}^{m} d_i \Delta \ln Y_{t-i} + \delta \varepsilon_{t-1} + v_t \qquad (8)$$

When the adjustment processes are complete, the long equilibrium relation of Equation (1) emerges from Equation (8) as the coefficient of the lagged error term becomes negative one. However, the long coefficients of Equation (1) are not easily derived from equation (8), unlike the case of Equation (5). To derive the long coefficients, the value for the lagged error term from equation (6) is to be substituted in Equation (8), which will consequently reduce the degrees of freedom. Given the limited observations, the paper stops at Equation (8) and analyzes the adjustment processes of the model. One lag is introduced to adhere to the data limitation.

Due to limited observations, Equation (8) is estimated with no lagged differences as in ECM below, (details in appendix B):

$$\begin{aligned} \Delta \ln C_t \quad &= \quad 0.043 + 0.004 \Delta \ln P_t + 0.1064 \Delta \ln Y_t - 0.0867 \varepsilon_{t-1} \\ p - values &= (0.0012) \;\; (0.924) \qquad (0.4207) \qquad (0.0809) \end{aligned}$$

The aforementioned ECM results prove no contemporaneous relationship between oil consumption and international oil price, and between oil consumption and the income. But there is evidence for a long run equilibrium relation between the oil consumption and linear summation of the international oil price and the income at 10% significance level. The long run relation does take a long time to reach equilibrium after a shock as only 0.87% of the deviations from the equilibrium are corrected annually. This long adjustment process could be attributed to the presence of the international price in the model, since this variable has no immediate relation with the domestic oil consumption market.

CO-INTEGRATION TEST

If the coefficient of the lagged error term in Equation (8) is significant and negative, and the variables in equation in Equation (1) are integrated of order one, then a co-integration is established between the left side variable and the right side variables in Equation (1). Co-integration is a long run co-movement between variables. The variables do not diverge, but co-move within a relation. This relation here can be identified as an oil consumption demand that co-moves permanently with the per capita GDP and its own price. This relation can be uni-directional or bi-directional depending on whether GDP Granger causes oil consumption, or oil consumption Granger causes GDP, or both Granger cause each other. This feedback process between the variables is tested using the Engle-Granger causality test.

The co-integration test using critical values based on MacKinnon-Haug-Michelis (1999) 5% significance level for a linear model with intercept and no trend, finds one co-integration relation. The previous ECM model does prove the existence of a long run equilibrium, but it does not specify the number of it, or produce the long run co-integrating coefficients. Here the coefficients of this long run relation are estimated, and feedback effects from each variable in the relation are examined. The long run relation as normalized by the coefficient of lnC is presented below, (details in appendix C):

$$\begin{aligned} \ln C_t \quad &= \quad 4.599 - 0.608 \ln P_t + 2.113 \ln Y_t \\ t - statistic &= \qquad\quad (-2.356) \quad (5.1548) \end{aligned}$$

In the long run, the oil consumption in Saudi Arabia is price inelastic and income elastic. No feedback effects are found between oil consumption and the per capita income, or between oil consumption and the oil price. But income and international oil price have bi-directional feedback effects. These feedbacks are further investigated in the Granger causality tests.

GRANGER CAUSALITY TEST

If per capita oil consumption, C, Granger causes per capita GDP, Y, then the present value of per capita GDP can be predicted by using past values of the oil consumption, and vice versa. This test is performed as;

Feedback test from oil consumption and oil price to per capita GDP;

$$Y_t = \beta_0 + \sum_{i=1}^{q} \beta_{1i} \ln C_{t-i} + \sum_{i=1}^{m} \beta_{2i} \ln P_{t-i} + u_t \qquad (9)$$

Feedback test from per capita GDP and oil price to oil consumption;

$$C_t = a_0 + \sum_{i=1}^{q} a_{1i} \ln Y_{t-i} + \sum_{i=1}^{m} a_{2i} \ln P_{t-i} + u_t \quad (10)$$

If the sum coefficients of per capita oil consumption in Equation (9) are significantly different from zero, then the changes in the per capita GDP can be predicted using the past values of the per capita consumption. The feedback will run from per capita GDP to oil consumption if the sum coefficients of per capita GDP in Equation (10) are significantly different from zero. The paper examines lags from 1 to 4 in the test. This means past one to four year values are assumed to hold information about the current value of another variable if there are to be feedback processes. The estimation results for the different lags are found in appendix D.

The pair-wise Granger causality tests with one lag in the model finds no directional relation between the local oil consumption and the international oil price, whereas the local oil consumption and the income have a bi-directional relation. When more lags are included in the model, there exists only a consistent uni-directional relation running from the income to the both the oil consumption and the oil price. It means in the short run, oil conservation can have negative impact on the income, while in the long run it will be the income, which will drive up oil consumption, and hence the oil conservation will have no damaging consequences for the economy. However, a caution is to be taken here as the previous estimation results show that the long run relation takes a long time to be established. The oil conservation will cause a shock to the equilibrium relation, causing the economy to undergo a long painful adjustment period to reach equilibrium and gain the benefits of the uni-directional relation from the income to the oil consumption.

CONCLUSIONS AND POLICY IMPLICATIONS

This paper finds the oil price (the world crude oil price) insignificant in the short-run and significant in the long-run, and the oil consumption demand in Saudi Arabia to be price inelastic. The income is significant, and the demand is income inelastic in the short-run and elastic in the long-run. There is a long-run co-movement between the oil consumption and linear summation of the oil price and the income. However, a deviation from this long-run equilibrium takes a long time to correct, as only 0.08% of deviation is corrected annually. The income and the oil consumption have a bi-directional relationship in the short run; and in the long run there exists a uni-directional relation running from the income to the oil consumption.

The domestic oil consumption is found neutral of the world oil price, and the domestic income growth does put pressure on the world oil price to rise. The implications of the study are that domestic energy conservation should be cautiously managed as reductions in oil consumption can have damaging consequences for the economic growth, and the authorities should monitor and evaluate the sustainability of the neutrality of domestic oil consumption market from the world oil market shocks.

REFERENCES

Akinbo AE (2008). Energy consumption and economic growth: Evidence from 11 Sub-Saharan African countries. Energy Econ., 30(5): 2391-2400.

Balcilar M, Ozdemir Z, Arslauturk Y (2010). Economic growth and energy consumption causal nexus viewed through boostrap rolling window. Energy Econ., 32(6): 1398-1410.

Dahl C, Duggan TE (1998). Survey of price elasticities from economic exploration models of US oil and gas supply. J. Energy Financ. Dev., 3(2): 129-169.

Ghosh S (2009). Import demand of crude oil and economic growth: evidence from India. Energy Pol., 37(2): 699-702.

Lee CC, Chien MS (2010). Dynamic modelling of energy consumption, capital stock, and real income in G-7 countries. Energy Econ., 32(3): 564-581.

Mehrara M (2007). Energy consumption and economic growth: the case of oil exporting countries. Energy Pol., 35(5): 2939-2945.

Odhiambo NM (2009). Electricity consumption and economic growth in South Africa: a bi-variate causality test. Energy Econ., 31(5): 635-640.

Odhiambo NM (2010). Energy consumption, prices, and economic growth in three SSA countries: a comparative study. Energy Pol., 38(5): 2463-2469.

Oh W, Lee K (2004). Energy consumption and economic growth in South Korea: Testing the causality relation. J. Pol. Model., 26 (8-9: 973-981.

Paul S, Bhattacharya RM (2004). Causality between energy consumption and economic growth in India: a note on conflicting results. Energy Econ., 26(26): 977-983.

Tang C, La C, Summer J (1993). Energy consumption and economic activity in China. Energy J., 14(4): 21-36

Zachariadis T (2007). Exploring the relationship between energy use and economic growth with bi-variate models: New evidence from G-7 countries. Energy Econ., 29(6): 233-1253.

Ziramba E (2010). Price and income elasticities of crude oil import demand in South Africa: a co-integration analysis. Energy Pol., 38(12): 7844-7849.

APPENDIX

Appendix A. Autoregressive model equation (5).

Dependent variable: LC				
Included observations: 29 after adjustments				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	-0.44499	0.582838	-0.76349	0.4523
LC(-1)	0.918878	0.036778	24.98443	0
LP	-0.03783	0.038486	-0.98284	0.3351
LY	0.179637	0.06042	2.973159	0.0064
R-squared	0.970108	Mean dependent var		12.83257
Adjusted R-squared	0.966521	S.D. dependent var		0.287233
S.E. of regression	0.052556	Akaike info criterion		-2.92644
Sum squared resid	0.069053	Schwarz criterion		-2.73784
Log likelihood	46.43333	F-statistic		270.4465
Durbin-Watson stat	2.886363	Prob(F-statistic)		0

Appendix B. ECM, Equation (8).

Dependent variable: D(LC)				
Included observations: 29 after adjustments				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	0.042886	0.011713	3.661292	0.0012
D(LP)	0.003935	0.040873	0.096268	0.9241
D(LY)	0.106413	0.129987	0.818643	0.4207
ER(-1)	-0.08666	0.047633	-1.81932	0.0809
R-squared	0.135505	Mean dependent var		0.044234
Adjusted R-squared	0.031766	S.D. dependent var		0.063949
S.E. of regression	0.062925	Akaike info criterion		-2.56629
Sum squared resid	0.09899	Schwarz criterion		-2.3777
Log likelihood	41.21121	F-statistic		1.306206
Durbin-Watson stat	1.979916	Prob(F-statistic)		0.294412

Appendix C. Co-integration test.

Vector error correction estimates	
Sample (adjusted): 1982 2009	
Included observations: 28 after adjustments	
Standard errors in ( ) and t-statistics in [ ]	
Cointegrating Eq:	CointEq1
LC(-1)	1.000000
LP(-1)	0.608441
	(0.25825)
	[2.35600]
LY(-1)	-2.11263
	(0.40984)
	[-5.15479]
C	4.599069

Appendix C. Contd.

Error correction:	D(LC)	D(LP)	D(LY)
CointEq1	-0.09636	-0.23927	0.120690
	(0.02908)	(0.17923)	(0.05723)
	[-3.31375]	[-1.33495]	[2.10889]
D(LC(-1))	-0.38938	-0.2869	0.000995
	(0.18912)	(1.16574)	(0.37222)
	[-2.05888]	[-0.24611]	[0.00267]
D(LP(-1))	0.003629	-0.6853	-0.16491
	(0.03626)	(0.22351)	(0.07137)
	[0.10008]	[-3.06609]	[-2.31071]
D(LY(-1))	0.066315	1.657225	0.614831
	(0.09800)	(0.60409)	(0.19289)
	[0.67667]	[2.74336]	[3.18754]
C	0.055782	0.034815	-0.00185
	(0.01282)	(0.07904)	(0.02524)
	[4.35043]	[0.44049]	[-0.07341]

Appendix D. Granger causality tests.

Pairwise Granger causality tests			
Lags: 1			
Null hypothesis:	**Observe**	**F-Statistic**	**Probability**
LP does not Granger cause LC	29	2.37749	0.13518
LC does not Granger cause LP		0.56451	0.45920
LY does not Granger cause LC	29	9.55813	0.00471
LC does not Granger cause LY		4.27477	0.04877
LY does not Granger cause LP	29	12.7542	0.00141
LP does not Granger cause LY		3.61641	0.06835
Pairwise Granger causality tests			
Lags: 2			
Null hypothesis:	**Observe**	**F-Statistic**	**Probability**
LP does not Granger cause LC	28	0.98298	0.38937
LC does not Granger cause LP		1.32789	0.28460
LY does not Granger cause LC	28	4.94810	0.01632
LC does not Granger cause LY		2.85149	0.07829
LY does not Granger cause LP	28	7.21568	0.00370
LP does not Granger cause LY		1.44816	0.25564
Pairwise Granger causality tests			
Lags: 3			
Null hypothesis:	**Observe**	**F-Statistic**	**Probability**
LP does not Granger cause LC	27	0.79952	0.50865
LC does not Granger cause LP		1.01930	0.40502

Appendix D. Contd.

LY does not Granger cause LC	27	2.96414	0.05675
LC does not Granger cause LY		1.18563	0.34036
LY does not Granger cause LP	27	5.90112	0.00469
LP does not Granger cause LY		1.61029	0.21852
Pairwise Granger causality tests			
Lags: 4			
Null hypothesis:	**Observe**	**F-Statistic**	**Probability**
LP does not Granger cause LC	26	0.73389	0.58140
LC does not Granger cause LP		0.88352	0.49457
LY does not Granger cause LC	26	6.32636	0.00262
LC does not Granger cause LY		0.63958	0.64145
LY does not Granger cause LP	26	3.89675	0.02007
LP does not Granger cause LY		1.23177	0.33448