ESTIMATING THE DEMAND FOR ENERGY IN JORDAN: A STOCK-WATSON DYNAMIC OLS (DOLS) APPROACH

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ABSTRACT

Recent developments in econometrics provide robust estimators for cointegrated series where sample sizes are small. We estimate the demand for energy in Jordan over the period 1968-1997 using the dynamic OLS method developed by Stock and Watson, and compare the results with conventional forms of cointegration and error correction estimation. Results are found to be robust to various departures from standard regression assumptions and to be stable in spite of the rapid structural changes in the Jordanian economy over the period of the study. Income, construction activity, and political instability are found to impact significantly on consumption, while real price has only a neutral or weak effect. Changes to energy prices on their own are unlikely to achieve current goals for energy conservation.

1.INTRODUCTION

Econometric modelling of energy demand is widely undertaken to provide information on income and price elasticities. Such information is, however, flawed if proper account is not taken of the time series properties of the variables used in the investigation, and the size and nature of the samples from which the data is obtained. Early demand studies for industrialised countries such as (Pindyck, 1980) or (Bohi, 1981) appeared before these issues were raised, while more recent work has addressed the problem of cointegration among variables using primarily error correction methods. (Bentzen, 1993,1994). Few studies have been directed towards investigating the demand for energy in the developing countries; see for example (Munasinghe, 1990), (Dahl, 1994), (Eltony, 1995, 1996a, 1996b), (Masih and Masih ,1996a,1996b) and (Balabanoff,1994).

Obtaining reliable estimates of energy demand models is made difficult by the limitations of existing techniques. Non stationarity of the economic variables involved in the analysis of energy demand leads to violation of the classical assumptions of standard regression methods, and to spurious estimates. The possible endogeneity of regressors is another problem not well handled by OLS. Finally the sample sizes available for data analysis are usually small leading to small sample bias in estimates. This is particularly relevant to the developing countries where statistical data is of recent origin. The purpose of this study is to use the most recent advances in modelling long run or co-integrated relationships, in order to take into account the above problems of demand modelling. Jordan was chosen because of its developing country status, its almost total dependence *on* imported oil as a source of energy and, not insignificantly, because of one of the authors' first hand experience of Jordan (Al-Azzam, 1995).

This study is divided into five sections. Section two contains a brief overview of the energy position in Jordan. The theoretical model and econometric methodologies are discussed in section three. The data and empirical results are discussed in section four. Finally, conclusions and policy implications are made in section five.

2.ENERGY POSITION IN JORDAN

Jordan, as a small developing country, has been characterised by a high import/GDP ratio; accompanied with a weak productive sector and a relatively stagnant export sector. In addition to this, during the last few years, the development process in Jordan has been constrained by increased foreign debt servicing and declining foreign exchange resources due to the decline in the inflow of Arab aid and workers remittances. Jordan's recoverable local sources of energy are very modest. Since the second half of the 1970s, however, Jordan has witnessed a remarkable growth in energy demand. This growth has given rise to an increase in energy cost whether expressed in terms of burden on balance of payments or of increase in financial burden on the budget as a result of subsidising domestic energy prices.

The growth in various economic sectors, developments in socio-economic activities, population growth and improvement in standard of living in Jordan, will all contribute to continued increase in energy demand. It should be noted, that energy imports amounted to approximately JD300 million in 1997, which is equivalent to 34% of total exports and 6.5% of net domestic production. This sharp increase in energy cost also raises the question of what alternatives Jordan should choose in directing its development process and energy structure, within the limits of a policy aimed at rationalising utilisation of its resources.

3. MODEL AND ECONOMETRIC APPROACH

A log linear specification is used to represent the long-run demand for energy both because it yields elasticities in a convenient form and because it has been found to work well in previous studies using error correction methods. It is consistent with a conventional maximising approach when constrained to satisfy the usual homogeneity and adding up restrictions. In addition to relative prices and incomes, construction activity is included amongst the independent variables. Construction activity is a good indicator of the development process involving resettlement and urbanisation, and has a substantial impact on other economic activities which are themselves users of energy. The model allows for changes in the political climate facing Jordan by incorporating dummy variables representing the level of conflict in the region.

The long run demand model used here is: -

$$Log(Q_t) = {}_0 + {}_1Log(P_t) + {}_2Log(Y_t) + {}_3Log(A_t) + {}_{4i}Di + {}_t \qquad (1)$$

where Q_t is aggregate energy consumption, P_t is the real price of energy; Y_t represents real income (GDP). A_t represents the total area constructed in square meters. *Di* is dummy variables for conflict and political instability. ${}_0$ is a constant, ${}_{1,}$ ${}_{2,}$ ${}_{3,}$and ${}_4$ are total energy demand elasticities. ${}_t$ is an error term assumed to be *iid* $(0,\sigma^2)$.

3-1. Integration and cointegration tests

We follow current time series econometric practice in recognising that classical regression properties hold only for cases where variables are stationary (integrated of order 0), that by contrast most economic variables are integrated of order 1 or higher (and hence do not satisfy these assumptions), but that where error correction mechanisms or long run relationships exists, certain combinations of I(1) variables are likely to be I(0) and hence amenable to OLS estimation. Where this is so, the variables are said to be cointegrated and OLS estimates of such cointegrated variables may be superconsistent in the sense of collapsing to their true values more quickly than if the variables had been stationary. The first step is to determine the degree of integration of the individual series under investigation. This we do using standard Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests on a series of regressions of original values, first differences in the series, second differences and so on where the null hypothesis to be tested is that the series is non-stationary.

A large number of methods are also available for testing whether a model has appropriate cointegration properties. We will briefly mention two of these methods before going on to describe our preferred approach. In the first place, residuals from OLS estimates of the supposed long run relationship can be used to detect the presence of cointegration. Providing that the residuals are I(0), or stationary, the model can be considered to be cointegrated and a valid long run relationship exists between the variables. In the DF and ADF cointegration tests, the appropriate null hypothesis is that the residuals possess a unit root against the alternative hypothesis that the residuals are stationary. Where a cointegrating relationship cannot be found, no long run relationship among the variables can be demonstrated and we have the case of spurious regression.

The OLS approach, while simple to implement, is not without problems. Parameter estimates can be biased in small samples as well as in the presence of dynamic effects, and this bias varies inversely with the size of the sample and the calculated R^2. Secondly, when the number of regressors exceeds two there can be more than one cointegrating relationship or vector and it is difficult to give economic meaning to this finding. Then there is the problem caused by the likely endogeneity of the regressors, which would prevent OLS estimating the true values of the parameters. These difficulties associated with the OLS approach have led to the development of alternative procedures, the most well known of which is that of (Johansen, 1991). Johansen developed a maximum likelihood procedure, which improves on OLS in various ways. Firstly, the existence of at most one cointegrating vector is not assumed a prori, but is tested for in the procedure. Next, the Johansen procedure takes the regressors to be endogenous and applies appropriate methods. Finally, a more powerful set of tests are provided which enable the number of cointegrating vectors to be identified and the effect of various restrictions to be evaluated. Implementing the method involves identifying the rank of the matrix P in the following equation:

$$D X_t = d + \sum_{i=1}^{k-1} G_i D X_{t-i} + P \ X_{t-k} + e_t \qquad \textbf{(2)}$$

where *Xt*. is a column vector of the m variables , and represent coefficient matrices, is a difference operator, *k* denotes the lag length and is constant.

This can be done using methods described in (Pesaran and Pesaran 1997). The rank r provides the number of cointegrating vectors, so that if the rank is 1 for example, a single stationary relationship exists which can be taken as the long run relationship. The parameters of the cointegrating relationship itself and the adjustment coefficients of an error correction model can be obtained by further decomposition of the matrix P.

3-2 The Stock Watson dynamic OLS (DOLS) approach

An alternative approach, which has certain advantages over both the OLS and the maximum likelihood procedures, has been proposed by (Stock and Watson, 1993). Their method improves on OLS by coping with small sample and dynamic sources of bias. The Johansen method, being a full information technique, is exposed to the problem that parameter estimates in one equation are affected by any mispecification in other equations. The Stock Watson method is, by contrast, a robust single equation approach which corrects for regressor endogeneity by the inclusion of leads and lags of first differences of the regressors, and for serially correlated errors by a GLS procedure. In addition it has the same asymptotic optimality properties as the Johansen distribution. The method has been applied to the estimation of Chinese coal demand by (Masih and Masih, 1996a), and we adapt and extend their approach here.

We model the demand for energy in Jordan as

$$Q_t = X_t M' + \sum_{i=-m}^{i=m} f_i \Delta P_{t-i} + \sum_{i=-n}^{i=n} y_i \Delta Y_{t-i} + \sum_{i=-l}^{i=l} q_i \Delta A_{t-i} + e_t \qquad (3)$$

where

$M = [c, a, b, g]$, $X = [1, P_t, Y_t A_t]$

and *m, n* and *l* are the lengths of leads and lags of the regressors.

Suppose that *Q* has been found to be I(1) and at least some of the RHS variables I(1) or I(0), then DOLS estimates are obtained by regression analysis of the above equation.

4. DATA AND EMPIRICAL RESULTS

4-1. Data

Data used in this study relate to the period 1968 to 1997 and were obtained from various sources. Annual data on consumption of energy are from reports issued by the Ministry of Energy and Mineral Resources. GDP, the consumer price index CPI, the consumer price of fuel and utilities index and construction activity are all from statistical series issued by the Central Bank of Jordan.

4-2. Integration and cointegration tests

Dicky-Fuller and augmented Dicky-Fuller tests were used to test for unit roots and the results are presented in table1. Schwarz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) were both used for selecting the order of augmentation. It is clear that none of the variables included in the analysis are stationary in levels. The first difference of the variables LP, LY and LA are stationary. The first difference of LQ is stationary when DF tests are applied.

Table 1. T-tests for Stationarity (1968 – 1997)

Series	**DF Levels ***	**ADF Levels ***	**DF first difference ****	**ADF first difference ****	**Augmen-tation Order**
LP	-1.619	-2.209	-2.570	-3.020	1
LY	-1.647	-2.123	-4.096	-3.880	1

LA	-1.824	-1.847	-4.4977	-4.096	1
LQ	-1.137	-1.113	-3.052	-1.624	1

*95% critical value for the Dickey-Fuller statistic = -3.603
**95% critical value for the Dickey-Fuller statistic = -2.991

The possibility of cointegration between the variables included in the models is examined by estimating the cointegrating regression initially by OLS. The results are reported in table 2. Although the DF test is inconclusive, the ADF test of the residuals clearly indicates cointegration. The long-run income elasticity is 0.76, the long-run price elasticity is –0.35,the long run elasticity with respect to construction activity is 0.33 and the coefficient of the dummy is 0.17. All long-run elasticities have the predicted sign and, it is clear that all the estimates are highly significant and that they pass the diagnostic tests. We will compare these results later with the Stock Watson results in an attempt to assess their significance for policy making.

The presence of rapid structural changes in the Jordanian economy makes it necessary to check the stability of the demand model, if the model is unstable this will make it very difficult to interpret regression results. Since a parametric econometric model is completely described by its parameters, model stability is equivalent to parameter stability (see Chan and Lee, 1997). The cumulative Sum of Recursive Residual *CUSM* and the cumulative Sum of Squares of Recursive Residual *CUSUMSQ* tests are conducted to investigate the stability of the model parameters. In general if the *CUSM* or *CUSUMSQ* move out side the critical lines of 5% significance level, the null hypothesis will be rejected, meaning that the model is unstable. The tests are presented in Figures 1 and 2 and it is clear that the demand equation is stable over the period of the study.

Table 2. OLS estimation of the total energy demand

Regressor	**Coefficient (S.E.)**		**Diagnostic Tests(LM version) [p:value]**
C	-0.500 (0.354)		Serial Correlation ^{2}(2) 0.0781 [.780]
LP	-0.347 (0.086)		Functional Form ^{2}(1) 2.317 [0.128]
LY	0.762 (0.084)		Normality ^{2}(2) 0.134 [0.935]
LA	0.332 (0.045)		Heteroscedasticity ^{2}(1) 2.896 [0.089]
D1	0.171 (0.034)		
R^2	0.993		
^{2}	0.991		
DW-statistic	1.948		
DF	-4.560*		
ADF(1)	-6.689*		* 95% critical value for the DF statistic = -5.024

Figure1

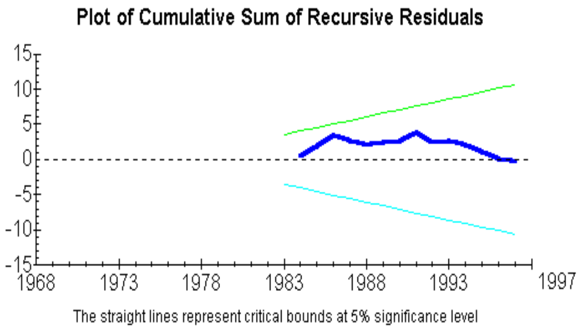
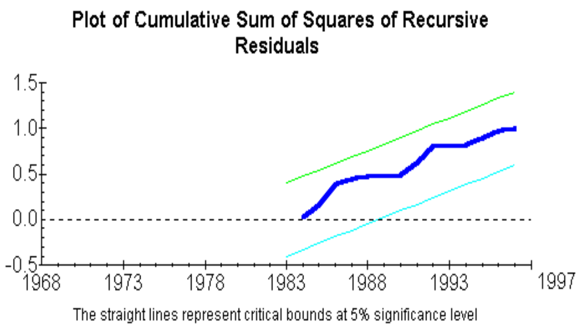


Figure2



Further evidence on cointegration is found from applying the Johansen procedure to estimate total energy demand and results are reported in Table 3. Unrestricted intercepts and trends in the VAR are assumed for this analysis .The order of the VAR is chosen to be 2 based on (SBC) and (AIC) criterion taking into account the size of the sample. Cointegration LR tests based on both the maximal eigenvalue and the trace of the stochastic matrix shows the presence of one cointegrating vector at 5% level of significance; this means that there exist long-run relationship between the variables (LQ, LY, LP, LA) included in the cointegrating vector.

The ML estimate of the cointegrating vector gives a long–run income elasticity of 0.95 and long-run price elasticity of –0.22 and long–run elasticity of demand with respect to the area constructed 0.37. The elasticities are all correctly signed and of reasonable magnitude (table.4). Tests for unit income elasticity and zero price elasticity are performed giving $\chi^2(2)$=1.03[0.597], which is not significant, and suggest that the restrictions imposed can not be rejected.

Table 3. Johansen tests for cointegration

Hypothesis		**L_{max}**		**L_{trace}**	
Null	Alternative	Statistic	95%CV	Statistic	95% CV
r = 0	r = 1	33.911	31.000	65.424	58.930
r<= 1	r = 2	17.612	24.350	31.514	39.330
r<= 2	r = 3	13.810	18.330	13.902	23.830
r<= 3	r = 4	0.092	11.540	0.092	11.540

r is the number of cointegrating vectors

Table 4. Johansen estimates of the cointegrating vectors

Variable	**Unrestricted estimate (S.E)**	**Restricted estimate (S.E)**
LQ	1.000 (NONE)	1.000 (NONE)
LP	0.218 (0.207)	0.000 (NONE)
LY	-0. 952 (0.315)	-1.000 (NONE)
LA	-0. 369 (0.080)	-0.361 (0.091)

4-3. Stock-Watson (DOLS) results

The Stock-Watson DOLS estimates for total energy appear in Table5.The demand equations were estimated including up to j=±3 leads and lags, the insignificant lags and leads were dropped. Long run income elasticity is found to be 0.98, price elasticity -0.082, construction activity elasticity 0.30, and the coefficient of the dummy variable 0.13. Apart from the energy long-run price elasticity, which has the expected sign but is insignificant, all other elasticities have the predicted sign and are highly significant. The DOLS for the demand is robust to various departures from standard regression assumptions in terms of residual correlation, hetroscedasticity, misspecification of functional form and non-normality of residuals. Stability tests conducted by plotting *CUSM* and *CUSMSQ* where they both suggest that estimated models are stable over the sample period see figures 2 and3.

Table 5. Stock-Watson Dynamic OLS estimates of total energy demand

Regressor	***Coefficient (S.E.)***		***Diagnostic Tests(LM Version)*** **[P:value]**
C	-1.871 (0.426)		Serial Correlation ^{2} (1) 0.151 [0.697]
LP	-0.082 (0.091)		Functional Form ^{2} (1) 3.656 [0.056]
LY	0.978 (0.090)		Normality ^{2} (2) 5.068 [0.079]
LA	0.303 (0.043)		Heteroscedast.ity ^{2} (1) 1.851 [0.174]
D1	0.127 (0.032)		
DLP	-0.300 (0.174)		
DLY(+1)	0.432 (0.129)		
DLY(+2)	0.457 (0.136)		
DLA(+1)	0.137 (0.047)		
R^2	0.997		
^{2}	0.996		

Figure 3

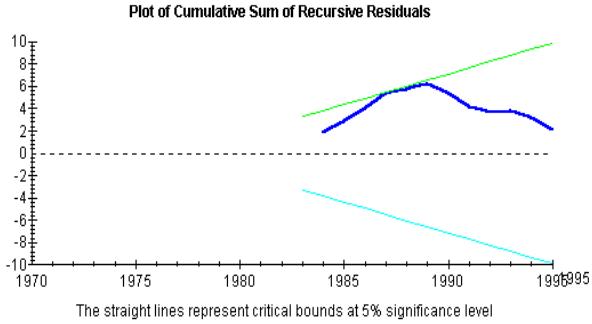
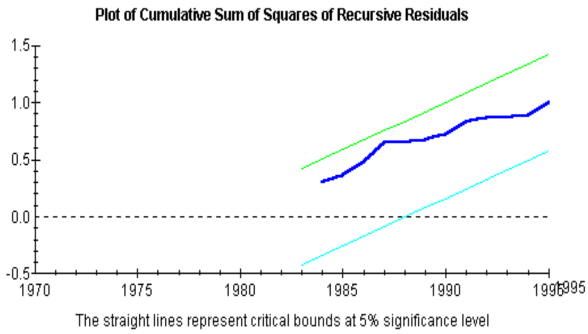


Figure 4



4-4 Comparison with simple ECM

It is interesting to compare the DOLS and Johansen results with those that would have been obtained from the popular error correction model (ECM). Since the ECM uses lagged residuals from the long-run OLS model as one of its regressors, we can see from the OLS results reported above the extent of the long-run bias, which would result from using this method. In the first place applying the ECM would lead us to infer that price has a significant, although small, effect on demand. This would be mistaken in view of the DOLS finding that, taking bias into account, the long-run price elasticity is not significantly different from zero. Again the ECM model suggests that as income rises, demand rise less than proportionately so that it might be mistakenly inferred that energy growth will moderate as the economy develops. In fact as the DOLS results show, there is unlikely to be any moderation of the link between income growth and growth in energy use. Thus on two counts, reliance on the simple ECM model would lead to policy conclusions which might well prove detrimental to the achievement of conservation or environmental goals. The Johansen results are sufficiently close to the DOLS results as to lend strength to this argument.

5.CONCLUSIONS AND POLICY IMPLICATION

The purpose of this study was to estimate the elasticities of demand for energy in Jordan using annual data from 1968-1997. Recent developments in time series econometrics modelling including Johansen (VAR), Stock-Watson (DOLS) and OLS methods were employed to estimate the elasticities. These were then compared with results from a simple error -correction model and serious problems are identified which are avoided using DOLS.

The income elasticity for total energy demand is found to be close to unity implying that economic growth is likely to be accompanied by proportional increases in energy demand and hence environmental degradation. The lack of responsiveness of demand to price changes suggest that taxes on their own are unlikely to achieve government goals for energy conservation or environmental improvement, although they may well be efficient for revenue raising.

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