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Energy consumption and Economic Growth: Assessing the Evidence from Sri Lanka

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Abstract*-- This study attempts to shed light into the empirical relationship between energy consumption and economic growth in Sri Lanka (1981-2012) employing the vector error-correction model estimation (VECM). The vector specification includes energy consumption, real GDP and price developments, and the latter was taken to represent a measure of economic efficiency. The empirical evidence suggests that there is a long-run relationship among the three variables, supporting the endogeneity of energy consumption and real output. These findings suggest important policy implications, since the adoption of suitable structural policies aiming at improving economic efficiency can induce energy consumption without impeding economic growth.

Keywords— Keywords: Energy consumption, Economic growth and Vector error-correction model (VECM).

I. *Introduction*

The energy crises in the 1970s and the unprecedented high levels of energy price, especially oil, which had a detrimental effect on growth, called for the implementation of energy conservation processes. Indeed, most of the industrialized countries managed to have gradually curtailed energy requirements.

Since the end of the 1970s, there has been fairly extensive empirical research interest on the temporal causality between energy consumption and economic growth of Sri Lanka, with neither conclusive results not persuasive explanations. The research effort, very much facilitated by the 'newly' development statistical techniques (e.g. Sim's test), aimed at investigating whether economic growth takes precedence over energy consumption or if energy consumption can boost economic growth. The advance of econometric techniques in recent years stimulated further empirical research on the energy consumption-economic growth debate, still with elusive results. As regards to policy issues, the question is whether the adoption of energy saving processes is a stimulus to growth or the opposite, the relevant literature referring to the possibility or feasibility for the adoption of energy saving processes. In this paper, we take a fresh look at the empirical evidence on the relationship between economic growth and energy consumption with a view of offering suggestions about how the issue may be addressed in future. We feel that the question of energy growth is more usefully analyzed and it is placed in a broader perspective, rather than within the partial consideration of energy conservation issues. The case of Sri Lanka, a small size country, serves as an example in our empirical investigation and the conclusions drawn could be useful for the analysis of other medium-sized economies.

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The paper evaluates empirically the dynamic interaction between energy consumption, real output and the price level and test for the endogeneity of these three variables included in the vector, utilizing the vector error-correction models (VECM) technique. The relevance of endogenous energy consumption is investigated and its dynamic response to structural shocks is estimated. Furthermore, the empirical analysis distinguishes between three categories of energy consumption: total; residential; and industrial energy consumption, all treated independently.

The empirical results showed that total energy consumption is an endogenous variable also affecting economic growth. In addition, economic efficiency, as reflected in price developments, is a determining factor of both energy consumption and income behavior. The same applies to industrial energy consumption, while energy consumption for residential uses behaves independently of price and income developments. As regards to policy implications, policies aiming at improving economic efficiency via structural reforms (implementation of adjustment policies, enforcement of endogenous growth mechanisms) boost economic growth and result in lower energy requirements. At the same time, these policies induce energy conservation, positively affecting economic growth. Hence, structural policies are a stimulus to both economic growth and energy saving. This being the case, energy conservation does not impede economic growth.

The paper proceeds as follows. Section 2 briefly reviews previous empirical work on the relationship between energy requirements and growth, also considering the developments in Sri Lanka. Section 3 deals with methodological issues and the data used in the empirical analysis, while in Section 4, the empirical evidence is presented. Finally, in Section 5, the conclusions of the analysis are summarized and policy implications are discussed.

II. Energy Consumption and Economic Growth

A. Empirical evidence

The bulk of the literature has so far offered conflicting and inconsistent results concerning the causal relationship between energy consumption and economic growth. The pioneer work in this area was by Kraft and Kraft (1978), who found a unidirectional causality running only from Gross National Product (GNP) to energy consumption from 1947-1974 in the United States. The results implied that energy consumption policies could be implemented without affecting GNP growth.

However, Akarca and Long (1980) failed to obtain similar results when they shortened the data sample of Kraft and Kraft (1978) implying that the time period chosen might have influenced the results. Yu and Hwang (1984) updated the US data for the period 1947-1970 and found causal relationship between energy consumption and Gross Domestic Product (GDP). Yu and Chio (1985), using data from five countries, confirmed the absence of causality between GNP and total energy consumption.

Although the empirical evidence seems to support the neutrality hypothesis for the post-war US data, the evidence on other countries is mixed. Hwang and Gum (1992) found bi-directional causality in Taiwan. Recently, Masih and Masih (1996) in a multivariate framework examined the relationship between total energy consumption and real income of Asian Economies. Energy consumption was found to be neutral with respect to income for Malaysia, Singapore and Philippines, unidirectional causality existed from energy consumption to GNP for India, exactly the reverse for Indonesia and mutual causality was present for Pakistan.

Recently, Yu and Jin (1992) used the 'Engle-Granger' testing procedure to study whether energy consumption and income are co-integrated and to determine the presence of a long-run relationship between these two variables for the United States over the period 1974-1990. Stern (1993) used a VAR model of four variables and performed standard causality tests. Although there was no evidence that gross energy consumption to Granger caused GDP, a measure of final energy consumption adjusted for changing fuel composition was found to Granger caused GDP. Recent advances in Juselius maximum likelihood approach (1990-1992), have allowed testing for the presence of all long-run relationship that the Engle-Granger tests might have failed to unveil. Furthermore, besides shot-run causality an additional channel of Granger causality emerges from any long-run co-movements that the variables may share, that was ignored by the standard causality test (Granger, 1988).

Empirical studies on Sri Lankan economy have investigated that energy consumption and association energy output and their prices. However, these studies have not addressed the problem of the possible interdependence of output and energy consumption and its policy implications.

In particular, Kalman filter techniques supported the view that elasticities behave as a cluster against energy demand. Donatos and Mergos (1989) estimated energy demand and price equations for the period 1963-1984 and came to the conclusion that energy demand is rather inelastic with respect to price. Similar results for energy demand in Sri Lanka has been researched by Dissanayaka (1997) analyzing the recent time period

B. Energy and Economic growth

The pattern of development of energy consumption in Sri Lanka is closely related to the output. In particular, over the 1970s and until the first energy crisis in 1973, the economy of Sri Lanka had experienced medium rates of economic growth (4.1% on average) as a result of the industrialization process, with the industrial sector gaining an increasing share in GDP. At the same time, the average rate of increase of the total energy consumption (7.7%) and especially industrial sector energy consumption (14.3%) exceeded the output considerably. Further, in early 1970s closed economic policies used trade restrictions for the development of their own productivity and with economic growth. Also, World Bank and other development institutes keep mentioning that closed economic policy means in fact of show low rate of the economic growth on the above period.

TABLE I. ENERGY CONSUMPTION, ECONOMIC GROWTH AND INFLATION IN SRI LANKA

Year	*Energy Consumption**	*Economic Growth rate*	*Inflation rate*
1981	7815.06	5.8	21. 4
1982	7889.69	5.1	13.7
1983	7901.31	4.9	18.9
1984	7992.17	5.1	09.5
1985	7705.54	5.0	11.5
1986	7789.98	4.3	12.9
1987	7801.06	1.5	18. 4
1988	7897.13	2.7	29.1
1989	7995.09	2.3	09.1
1990	8085.12	6.2	12.8
1991	8501. 44	4.6	09.0
1992	9036.92	4. 4	13.8
1993	10142.31	7.7	11.7
1994	11051.57	5.3	08. 4
1995	12136.94	6.0	07.7
1996	11594.76	3.2	15.9
1997	12520.93	6.8	09.6
1998	13877.91	4.6	09. 4
1999	14013.62	5.0	09.1
2000	14637.32	5.8	10.1
2001	14933.21	5.6	11.0
2002	15135.75	4.1	10.2
2003	15323.56	6.6	02.6
2004	15636.76	5.3	07.9
2005	15987.13	6.0	11.0
2006	16156.27	7.5	10.0
2007	16352.76	7.1	18.8
2008	16628.87	4.6	14.4
2009	16903.65	4.8	04.8
2010	17012.32	7.9	06.9
2011	17237.08	8.4	06.7
2012	17526.73	5.3	07.6

a. *million of kWh

Sources: Central Bank of Sri Lanka Annual Reports. (1981 to 2010).Example of a figure caption. *(figure caption)*

Early in the 1980s and until the hydro electricity supply increased the pace of increase of GDP, so did energy consumption. Over the 1980s and the early 1990s, the economic activity in Sri Lanka registered normal average growth rate 5.6% and industrial output increased 11%. During the same time pattern of the energy consumption has changed. Since the mid-1980s, rise of the energy consumption in transport and residential. According to Dissanayaka (2006), as a result uses the total energy consumption mostly related to a general improvement of the standard of living in Sri Lanka.

Consequently, price index in Sri Lanka closely follows energy prices. In particular, over the second half of the 1980s, the GDP deflator increased with average annual rates of 40%, and by 70% during the 1990s, while the Consumer Price Index

rose by 21% and 30%, the price of electricity by 45% and 60% and the price of oil by 40% and 65% respectively over the corresponding periods. Besides, empirical evidence strongly suggests that price development in Sri Lanka have been closely associated with the macroeconomic and microeconomic policy stance (Dissanayaka, 2000). The persistence of macroeconomic imbalances and the inefficient functional both of the economy over the period of 1990-2002, allowed for undesirable high inflation rates and increased income distribution disparity. On the contrary, the successful stabilization and liberalization efforts initiated in the early 2000, managed to reduce economic imbalances, improve social welfare network, increase wage rates by 200% in public sector and substantially decrease of the inflation rate. As a result, during that period, the overall debt service ratio are decreased. Year 2010 debt service ratio is 11.2%, this ratio still indicate a very low levels of total country risk with respect to its vulnerability and exposure to external debts (Central Bank of Sri Lanka, 2012).

III. Methodology

The empirical analysis tests for the endogeneity of energy consumption and economic growth. Price are included in the specification for two reasons. Firstly, because they play a crucial role in affecting energy consumption, since the Sri Lanka economy is highly dependent on energy and energy imports (Dissanayaka, 2006). Secondly, and most importantly, as a proxy for the degree of the efficient functioning of the economy. In other words, we assign a broader interpretation to the role of prices, so far not explicitly recognized in the related body of literature. An improvement in economic efficiency through structural measures is reflected to price developments and to economic growth. At the same time the implementation of energy conservation policies cannot be disassociated from improvements in economic efficiency and technological progress.

Also, the analysis distinguishes between different categories of energy consumption: total; industrial; and residential consumption, in order to investigate for any difference in behavior of the energy-income relationship among various sectors of economic activity.

In addition, we examine the responses of the levels of these variables to their rates of change (changes in energy consumption, changes in output and inflation), in order to capture their short-run dynamics of the variables. Testing for the existence of a statistical relationship among the three variables is carried out in three steps.

The first step is to verify the order of integration of the variables since the causality tests are valid if the variables have the same order of integration. Standard tests for the presence of a unit root based on the work of: Dickey and Fuller (1997), (ADF); Perron (1988) and Phillips (1997), Kwiatkowski et al. (1992); (KPSS); are used to investigate the degree of integration of the variables used in the empirical analysis (The combined use of the three tests employed to investigate the degree of integration of the series may result in four possible outcomes: (a) rejection by the ADF and PP statistics and nonrejection by the KPSS test offers strong evidence of stationarity; (b) Nonrejection both ADF and PP and rejection by the KPSS is a strong indication of I (1); (c) Nonrejection by all tests suggests that the data are not sufficiently informative on the long-run characteristics of the series and (d) Rejection by all tests indicates that the series is neither an I (1) nor and I (0) process.

The second step involves testing for co integration using the Johansen (1998), maximum likelihood approach Johansen and Juselius (1990). The Johansen-Juselius (1992), estimation method is based on the error correction representation of the Vactor Error Adjustment (VRA) model with Gaussian errors (Engle and Granger, 1987).

Evidence of co-integration rules out the possibility of the estimated relationship being 'spurious' so long as the four variable have common trend, causality in the Granger sense and not in the structural sense, must exist in at least one direction. Although co-integration implies the presence of Granger causality, it does not necessarily identify the direction of causality between variables. This temporal Granger causality can be captured through the vector error-correction model derived from the long-run co-integration vectors (Granger and Granger, 1988).

Thus, the third step involves utilization of the vector error-correction modeling and testing for exogeneity of variables. Engle and Granger (1987) show that in the presence of co-integration, there always exists a corresponding error-correction representation, which implies that change in the dependent variable are a function of the level of disequilibrium in the co-integrating relationship, captured by the error-correction term (ECT), as well as changes in other explanatory variables. Thus, through ECT, the VECM modeling establishes an additional way to examine the Granger causality ignored initially from the Granger-Sims tests. The Wald test applied to the joint significance of the sum of the lags of each explanatory variable and the t-test of the lagged error-correction term will imply statistically the Granger exogeneity or endogeneity of the dependent variables. The nonsignificance of ECT is referred as a long-run noncausality. Which is equivalent to that the variable is weakly exogenous with respect to long-run parameters. The absence of short-run causality (Granger causality in the strict sense) is established from the nonsignificance of the sums of the lags of each explanatory variable. Finally, the nonsignificance of the explanatory variables including the ECT term in the VECM indicates the econometric strong exugeneity of the dependent variable, which is the absence of Granger causality.

The empirical analysis has been carried out using annual data for the period 1981-2012 for Sri Lanka. The energy consumption variables, namely total energy (ENT), residential (ENH) and industry (ENI) are in Mtoe, real output is the real GDP (RGDP) at 2006/07 market prices, the price variables are expressed in logarithms (LENT, LENH, LENI, LRGDP and LPRICE). Data for the energy variables are obtained by the Organization for Economic Co-operation and Development (OECD). The Consumer Price Index is taken from the 2006/07 Consumers and Finance Surveys Report of the Central Bank

of Sri Lanka, while real GDP is obtained from the Annual Central Bank Reports of Sri Lanka.

IV. Empirical results

The results of the PB, PP and KPSS tests for the variables used in the analysis in level and in first differences (total, residential and industrial energy consumption, real output and prices; does not present the results of ADF tests. However, the results are available upon request). The relevant tests are derived from the OLS estimation of the following auto-regression for the variable involved.

tm is the t-statistics for testing the significance of d2 when a time trend is not included in equation (1) and tt is the t-statistic for testing the significance of d2 when a time trend is included in equation (1). The calculated statistics are those reported in Dickey and Fuller (1981). The critical values at 5% and 1% for n=50 are -2.93 and -3.58 for tm and -3.5 and -4.15 for tt, respectively. The lag length structure of fi of the dependent variable xt is determined using a recursive procedure in the light of a Lagrange multiplier (LM) autocorrelation test (for orders up to 4) which is asymptotically distributed as c2 distribution and the value of t-statistic of the coefficient associated with the last lag in the estimated auto-regression. The critical values for the Phillips-Perron unit root tests are obtained from Dickey and Fuller (1991), ta denotes the t-statistics for testing the significance of d2 included, with an exogenous break in 1993. The calculated statistics are those reported in Perron (1999). Specifically, the critical values at 5% and 1% for 1=0.4 are -3.72 and -4.34, respectively. hm and ht are the KPSS statistics for testing the null hypothesis that the series are I (0) when the residuals are computed from a regression equation with only an intercept and intercept time trend, respectively. The critical values for hm and ht at 5% are 0. 463 and 0.146, and at 1% are 0.739 and 0.216, respectively (Kwiatkowski et al. ,1992). (Full results are not reported in order to conserve space and all statistical results are available from the www.iss.ui.no/d-180.ep-sd-EconNet).

The ADF statistic suggests that all variables are integrated of order one, I (1), whereas for the first differences, the results indicate that all variables except price are integrated of order zero, I (0). Therefore, the hypothesis that the time series except price contain an autoregressive unit root is accepted in all cases. Although, employing the Phillips-Perron test give different lag profiles for the various time series and sometimes lowered the level of significance, the main conclusion is qualitatively the same as reported above by the Dickey-Fuller tests. In particular, the Phillips-Perron test based on the 5% and 1% critical values support the hypothesis that all series except price contain a unit root. Thus both tests are in favor of the unit root hypothesis in all time series except for prices.

The KPSS statistics test for lag-truncation parameters one and four (1=1 and L=4; The KPSS statistics are known to be sensitive to the choice of truncation parameter one, and tend to decline monotonically as one increases) since it is unknown how many lagged residuals should be used to construct a the null hypothesis of level and trend stationarity for both lag truncation parameters. The KPSS statistics does not reject the I (0) hypothesis for the first differences of the most of the series at different levels of significance. Therefore, the combined results of all tests suggest that all the series except price appear to be I (1) processes.

Contrary, the ADF, PP and KPSS statistics suggest that the price level variable is integrated of order 2, I (2), whereas the first differences (inflation) is integrated of order 1, I (1). However, since for all the variables under consideration, there is a structural shock in 1980 due to the oil crisis we employed the PB test to perform a unit root test with a trend break in 1980. The empirical results suggest that all the variables, including price, are integrated of order 1 I (1).

It summarizes the results of cointegration analysis among the three categories of energy consumption, real output and prices. To test for cointegration we use the Johansen maximum likelihood approach employing both the maximum eigenvalue and trace statistic. For the determination of the length of the VRA, three versions of system were initially estimated: a four, a three and a two-lag version. Then, an Akaike Information Criterion (AIC), a Schwarz Bayesian Criterion (SBC), and a likelihood ratio test (Sims' test) were used rejected the null hypothesis that all the specification are equivalent. In particular, the tests suggested that VAR=3 should be used in the estimation procedure of cointegration to avoid over-parameterization of the estimated models. Finally, a log-likelihood ratio test is used to test for the deletion of a dummy variable (for the 1980 energy crisis) and the trend from the VAR model. All tests reject the null hypothesis of the deletion of the dummy variable and trend from the VAR model.

V. Summary and conclusions

In this paper, interrelationship among economic growth, energy consumption and the price level is analyzed. Various categories of energy consumption changes, and economic development, such as income and prices, are explained in a temporal Granger causal framework, employing data for Sri Lanka. In the short-run dynamics (Granger causality in the strict sense), the empirical results indicate that there is no relationship among energy Consumption, real output and prices, with the exception of a short-run relationship between total output and total energy consumption. In particular, the results suggest that in the short-run, real output is affected by changes in total energy consumption and inflation.

Moreover, the use of strong exogeneity reveals the Granger endogeneity of energy consumption (with the exception of residential energy consumption) and economic growth. This analysis indicates that in the case of Sri Lanka, both the total and industrial energy consumption is closely related to economic growth. On the contrary, residential energy consumption is exogenous to economic growth.

The adoption of stop-go-policies in the 1990s led to a sluggish development of economic activity, high inflation rates and relatively high-energy requirements (The annual growth rate of GDP increased to 5.5% in the 1980s, to around 5.0% in the second half of the 1990s, while inflation dropped

from 19% in the 1980s and early 1990s to 11% in 1998. Also, the rate of growth of per capita energy consumption decreased from 2.7% in the 1980s to around 1.6% in the 1990s). Finally, the results of this analysis have important implications relating to the regional trade blocs convergence processes. The implements of micro-macro structural policies by the Sri Lanka government, aiming at achieving convergence towards and the variants regional trading agencies states through the acceleration of GDP growth. This gives rise to efficient energy consumption reducing the high dependence of the economic on energy imports.

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No substantial economic growth can be expected without prudent increase in energy consumption.