Energy Consumption- Growth Nexus in Saarc Countries: Using Cointegration and Error Correction Model

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Abstract

The paper explores the nexus between energy consumption (oil and electricity) and economic growth in the five SAARC countries over the period 1970-2006. Using cointegration and Error Correction Model (ECM), the paper finds a unidirectional short run and long run causality from oil consumption to economic growth in Bangladesh and Nepal, a unidirectional short run and long run causality from electricity consumption to economic growth in Pakistan and Sri Lanka, a unidirectional short run and long run causality from economic growth to oil consumption in India and Sri Lanka, and a unidirectional causality from economic growth to electricity consumption in India and Nepal. It also finds the bidirectional causality between electricity consumption and economic growth in Bangladesh and between oil consumption and economic growth in Pakistan. The paper at the end suggests that energy and environmental policies should recognize the differences in the energy consumption-growth nexus in order to maintain sustainable economic growth in the region.

Keywords: Energy Consumption, Economic Growth, ECM

1. Introduction

Economic growth of a nation is closely related to its energy consumption. Several studies on energy economics have examined this relationship. Methodologically, there are two approaches to trace the nexus between energy consumption and economic growth. First, regression approach (Pachauri, 1977; Tyner, 1978), where there is little attention to direction of causality and second, causality approach (Odhiambo, 2009; Bowden and Payne, 2009; Yuan et al. 2008), where there is high stress on the direction of causality. The present paper, however, focuses the causality approach only. The causal relationship between economic growth and energy consumption has been the prime focus of economists and policy analysts since the seminal work of Kraft and Kraft (1978). The central issue of this causality approach is whether economic growth stimulates energy consumption or is energy consumption itself a stimulus for economic growth via indirect channels of effective aggregate demand, improved overall efficiency and technological progress (Ghosh and Basu, 2006). There are two related hypotheses on the nexus between energy consumption and economic growth: energy - led- growth hypothesis and growth- led- energy hypothesis. The investigation of these two hypotheses is well established in the development literature, yet the outcomes remain inconsistent and controversial (see Table 1). This may be due to various structural frameworks and policies followed by different countries under different conditions and time periods. The controversies are also due to differences in methodology, various proxies for energy consumption and growth, presence of omitted variables, varying energy consumption patterns, etc. (Apergis and Payne, 2009; Balat, 2008; Chiou-Wei et al., 2008; Lee and Chang, 2008; Mahadevan and Asafu- Adjaye, 2007; Lee and Chang, 2007; Hatemi-J and Irandoust, 2005). The conflicts are usually on the direction of causality and its long term verses short term impact on energy policy. The literature provides four possible relationships between energy consumption and economic growth: unidirectional causality form energy consumption to economic growth (i.e. growth hypothesis), unidirectional causality form economic growth to energy consumption (i.e. conservation hypothesis), bi-directional causality form energy consumption to economic growth (i.e. feedback hypothesis) and no causality between energy consumption and economic growth (i.e. neutrality hypothesis).

The study on the direction of causality between energy consumption and economic growth has many policy implications. It not only provides insights with respect to the role of energy consumption in economic growth but also provides a basis for discussion of energy and environmental policies. For instance, a unidirectional causality running from energy consumption to economic growth implies that economic growth is dependent on energy consumption and a decrease in energy consumption may restrain economic growth (Yuan et al., 2010; Zhang and Cheng, 2009; Narayan and Singh, 2007). A number of explanations may be set forth, if an increase in energy consumption has a negative impact on economic growth. For instance, the situation could be one in which growing economy requires a decreasing amount of energy consumption as production shifts towards less energy intensive service sectors. Moreover, the negative impact of energy consumption on real GDP could be attributed to either excessive energy consumption in unproductive sectors of the economy, capacity constraints, or an efficient energy supply. A unidirectional causality form economic growth to energy consumption, on the other hand, implies that the country is not entirely dependent on energy consumption for its economic growth. Hence, energy conservation policies can be implemented with little or no adverse effects on economic growth. That means the conservation hypothesis is supported if an increase in economic growth causes an increase in energy consumption. However, it is possible that a growing economy constrained by political, infrastructural, or mismanagement of resources could generate inefficiencies and the reduction in the demand for goods and services, including energy consumption (Squalli, 2007). In this case, an increase in economic growth would have an adverse impact on energy consumption.

The bidirectional causality between energy consumption and economic growth implies that a high level of economic growth leads to high level of energy demand and vice versa. That means they are interrelated and may very well serve as complements to each other (Apergis and Payne, 2009). In such a case, an energy policy oriented towards improvements in energy consumption efficiency would not adversely affect real GDP. For instance, energy consumption policies aimed at declining energy use must look for some channels to reduce consumer demand in order to impede unfavorable effects on economic growth. Such an attempt could be achieved through an appropriate combination of energy taxes and subsidies. Policy makers should also encourage industries to adopt technology that reduces pollution (Hatemi-J and Irandoust, 2005). Finally, the finding of no causality between energy consumption and economic growth, so called neutrality hypothesis, implies that energy conservation policies do not affect economic growth (Asafu-Adjaye, 2000; Paul and Bhattacharya, 2004).

In the light of above backdrop, present paper seeks to investigate the causality between economic growth and energy consumption in the five SAARC countries, namely Bangladesh, India, Nepal, Pakistan and Sri Lanka, during 1970-2006. The residual of the paper is organized as follows: Section II describes data set and econometric modelling. Section III follows empirical results and its discussion thereof. The final section offers conclusion and policy implications.

2. Data Set and Econometric Modelling

Data used in this analysis are annual time series on economic growth (GDP) and energy consumption [i.e. per capita electricity consumption (EC) and per capita oil consumption (OC)] for the five SAARC countries [Bangladesh, India, Nepal, Pakistan and Sri Lanka]. The data are obtained from World Economic Outlook Database, International Monetary Fund, Washington. The Table 1 provides the summary statistics for each of the variables across the five SAARC countries. It is to be noted that all these variables (GDP, EC and PC) are in natural logarithms so that their first differences approach the growth rates.

The test for the energy-led-growth hypothesis and growth-led-energy hypothesis in the SAARC countries has been undertaken by Granger causality test. Engle and Granger (1987) showed that, if two variables (say X and Y) are individually integrated of order one [i.e. I (I)] and cointegrated then there is possibility of a causal relationship in at least one direction. That means cointegration with I (1) variables indicate the presence and absence of Granger causality but it does not indicate the direction of causality. The vector error correction model is used to detect the direction of causality of long-run cointegrating vectors. Moreover, Granger Representation Theorem indicates how to model a cointegrated series in a Vector Auto Regressive (VAR) format. VAR can be constructed either in terms of level data or in terms of their first differences [I (0)] with the addition of an error correction to capture the short run dynamics. If the series are I (I) but not cointegrated, the causality test may give some misleading results unless data are transformed to induce stationarity.

The whole process of causality between economic growth and energy consumption can be performed in three steps.

Step 1: Test for unit root (i.e. for order of integration) in the per capita electricity consumption, per capita oil consumption and GDP to know the level of stationarity.

Step 2: Test for cointegration to know the existence of long run equilibrium relationship between energy consumption and economic growth.

Step 3: Granger causality test to assess the short run cointegration and the direction of causality between the two variables.

2.1 Test for Order of Integration

The Augmented Dickey Fuller (ADF) and Phillips and Peron (PP) unit root test have been applied to know the order of integration of variables. The estimation procedure of these two tests is described below:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_t \qquad \text{(1)}$$

Where Y is the variable of choice; Δ is the first- difference operator; α_i (for i = 0 & 1) and β_i (for i = 1, 2… *p*) are constant parameters; and ε_t is a stationary stochastic process. To determine the order of integration of a particular time series variable, the equation has to be modified by including second differences on lagged first and *p* lags of second differences. This is as follows:

$$\Delta^2 Y_t = \eta_1 \Delta Y_{t-1} + \sum_{i=1}^{p} \mu_i \Delta^2 Y_{t-i} + \xi_t \qquad \text{(2)}$$

Where Δ^2 is the second- difference operator; η_1 and μ_i (for i = 1, 2… *p*) are constant parameters; and ζ_t is a stationary stochastic process. The p lagged difference terms are included so that the error terms (ε_t and ζ_t) in the respective equations are serially independent. For stationarity, the ADF test (Dickey and Fuller, 1981) and PP test (Phillips and Perron, 1988) are applied to equations 1 and 2 respectively. The null hypothesis are H_0: $\alpha_1 = 0$ against H_0: $\alpha_1 \neq 0$ for equation 1 and H_0: $\eta_1 = 0$ against H_0: $\eta_1 \neq 0$ for equation 2 respectively. Let *'d'* represents the number of times that a variable needs to be differenced in order to reach the stationarity. In this case, such a variable is said to be integrated of order *'d'* and denoted by I (d). For example, if the variable is stationary at the level data then it is said to be integrated of order zero [I (0)]. Similarly, if the variable is stationary at the first difference then it is said to be integrated of order one [I (I)] and if the variable is stationary at the second difference then it is said to be integrated of order two [I (2)] and so on.

2.2 Testing for Cointegration

The Cointegration technique is applied to know the existence of long run equilibrium relationship between the two variables. For the statistical point of view, a long run equilibrium relationship means the variables move together over time so that short term disturbances from the long term trend will be corrected. A lack of cointegration suggests that such variable have no long run equilibrium relationship and in principle, they can wander arbitrarily far away from each other (Dickey et al., 1991). Note that regression among integrated series is meaningful, if and only if they involve cointegrated variables.

The cointegration test was first introduced by Engel and Granger (1987) and then developed and modified by Johansen (1988) and Johansen and Juselius (1990). The paper used Johansen maximum likelihood (ML) approach to test the existence of cointegration between energy consumption and economic growth. The technique is used for two specific reasons. First, the technique is usually most reliable one and is very useful for small sample properties. Second, several cointegration relationships can be estimated by this technique. The cointegration technique is meant to calculate two statistics: trace (T_r) statistics and the maximum eigenvalue (λ_{max}) statistics. The estimation procedures of these statistics are as follows:

Let X_t be a (n X 1) vector of variables with a sample of t. Assuming X_t follows I (1) process, identifying the number of cointegrating vector involves estimation of the vector error correction representation:

$$\Delta X_t = A_0 + \prod X_{t-p} + \sum_{i=1}^{p-1} A_i \Delta X_{t-i} + \varepsilon_t \qquad \text{(3)}$$

Where, vector ΔX_t and ΔX_{t-1} are I (1) representation. The long run equilibrium relationship among X_t is determined by the rank of Π (say r) is zero, then equation (3) can be transferred to a VAR model of pth order and the variables in level do not have any cointegrating relationship. If 0 < r < n, then there are n X r matrices of α and β such that

$$\Pi = \alpha\beta' \qquad \text{(4)}$$

Where, the strength of cointegration relationship is measured by α, β is cointegrating vector and $\beta' X_t$ is I (0), although X_t are I (I). We have to estimate (A_0, A_1, ….., A_{p-1}, Π) by maximum likelihood method, such that 'Π' can be written as in (3). The estimation of these parameters follows two-step procedures. First, regress ΔX_t on ΔX_{t-1}, ΔX_{t-2}, …., ΔX_{t-p+1} and obtain the residuals $\hat{u}_t$. Second, regress X_{t-1} on ΔX_{t-1}, ΔX_{t-2}, …., ΔX_{t-p+1} and obtain the residuals $\hat{e}_t$. Having obtained the residuals '$\hat{u}_t$' and '$\hat{e}_t$', we can form the variance-covariance matrices. This is as follows:

$$\sum_{uu}^{\wedge} = \left(\frac{1}{T}\right)\sum_{t=1}^{T}\hat{u}_t\hat{u}_t' \quad \text{.............. (5)}$$

$$\sum_{ee}^{\wedge} = \left(\frac{1}{T}\right)\sum_{t=1}^{T}\hat{e}_t\hat{e}_t' \quad \text{.............. (6)}$$

$$\sum_{ue}^{\wedge} = \left(\frac{1}{T}\right)\sum_{t=1}^{T}\hat{u}_t\hat{e}_t' \quad \text{.............. (7)}$$

The maximum likelihood estimator of 'β' can be obtained by solving:

$$\left|\lambda\hat{\Sigma}_{ee} - \hat{\Sigma}_{eu}\, INV(\hat{\Sigma}_{uu})\,\hat{\Sigma}_{ue}\right| = 0 \quad \text{.............. (8)}$$

Where the eigenvalues are $\hat{\lambda}_1 > \hat{\lambda}_2 > .... > \hat{\lambda}_n$ and the normalized cointegrating vectors are $\hat{\beta} = \left(\hat{\beta}_1, \hat{\beta}_2, ..., \hat{\beta}_n\right)$, such that $\hat{\beta}'\hat{\Sigma}_{ee}\hat{\beta} = I$. The null hypothesis can be tested at r = h (for 0 ≤ h < n) against the alternative hypothesis of r = n. This is obtained from the following trace statistics:

$$\lambda_{trac} = L_A - L_0 \quad \text{.............. (9)}$$

Where,

$$L_0 = -\left(\frac{Tn}{2}\right)\log(2\prod) - \left|\frac{Tn}{2}\right| - \left(\frac{T}{2}\right)Log\left|\hat{\Sigma}_{uu}\right| - \left(\frac{T}{2}\right)\sum_{i=1}^{h}Log\left(1-\hat{\lambda}_i\right) \quad \text{.............. (10)}$$

$$L_A = -\left(\frac{Tn}{2}\right)\log(2\prod) - \left|\frac{Tn}{2}\right| - \left(\frac{T}{2}\right)Log\left|\hat{\Sigma}_{uu}\right| - \left(\frac{T}{2}\right)\sum_{i=1}^{n}Log\left(1-\hat{\lambda}_i\right) \quad \text{.............. (11)}$$

$$\text{and } L_A - L_0 = -\left(\frac{T}{2}\right)\sum_{i=h+1}^{n}Log\left(1-\hat{\lambda}_i\right) \quad \text{.............. (12)}$$

This can be further modified to

$$2\left(L_A - L_0\right) = -T\sum_{i=r+1}^{n}Log\left(1-\hat{\lambda}_i\right) \quad \text{.............. (13)}$$

Where, $\hat{\lambda}_{r+1}$, ... $\hat{\lambda}_p$ are the estimated eigenvalues. The null hypothesis to be tested is that there are at most r cointegrating vectors. That is the number of vectors is less than or equal to r, where r = 0, 1, or 2,….,n. In each case, the null hypothesis is tested against the general alternative hypothesis. The maximum eigenvalue (λ_{max}) statistics can be represented as follows:

$$\lambda_{\max} = -TLog\left(1-\hat{\lambda}_{r+1}\right) \quad \text{.............. (14)}$$

The null hypothesis of r cointegrating vectors is tested here against an alternative hypothesis of r +1 cointegrating vectors. Hence the null hypothesis r = 0 is tested against the alternative r = 1, r =1 against the alternative r = 2, and so forth. It is well known that the cointegration tests are very sensitive to choice of lag length. The Schwarz Bayesian Criterion (SBC) is used to select the number of lags required in the cointegration test.

2.3 Granger Causality Test

There are three different models that can be used to detect the direction of causality between energy consumption and economic growth, depending upon the order of integration and the presence/ absence of cointegration.

Model 1: If the two variables (say X and Y) are individually integrated of order one [i.e. I (1)] and cointegrated, then Granger causality test may use I (1) data because of super consistency properties of estimation. The Granger causality model used in this context is as follows:

$$Y_t = \eta + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=1}^{q} \beta_j X_{t-j} + \varepsilon_t \quad \text{……….. (15)}$$

Where H_0: $\beta_j = 0$ for j = 1, ….., q is tested against H_A: $\beta_j \neq 0$ for at least one j.

$$X_t = \mu + \sum_{i=1}^{r} \gamma_i X_{t-i} + \sum_{j=1}^{s} \lambda_j Y_{t-j} + \xi_t \quad \text{……….. (16)}$$

Where H_0: $\lambda_j = 0$ *for j = 1, …..,s* is tested against H_A: $\lambda_j \neq 0$ for at least one j.

The ε and ξ are random terms, which are serially uncorrelated with zero mean and unit variance. And η, μ, α_1, α_2, ….., α_p, β_1, β_2, …, β_q, γ_1, γ_2, …, γ_r, λ_1, λ_2, …, λ_s are the parameters to be estimated.

Model 2: If X and Y are I (1) and cointegrated, the Granger causality test can be applied to I (0) data with an error correction term. The model used in this context is as follows:

$$\Delta Y_t = \eta + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \sum_{j=1}^{q} \beta_j \Delta X_{t-j} + \delta EC_{t-1} + \varepsilon_t \quad \text{……….. (17)}$$

Where H_0: $\beta_j = 0$ *for j = 1, ….., q* is tested against H_A: $\beta_j \neq 0$ for at least one j.

$$\Delta X_t = \mu + \sum_{i=1}^{r} \gamma_i \Delta X_{t-i} + \sum_{j=1}^{s} \lambda_j \Delta Y_{t-j} + \delta EC_{t-1} + \eta_t \quad \text{……….. (18)}$$

Where H_0: $\lambda_j = 0$ *for j = 1, …..,s* is tested against H_A: $\lambda_j \neq 0$ for at least one j.

The EC is error correction term, which combines long run and short run dynamics of cointegrated variables towards the long run equilibrium.

Model 3: If the data are I (1) but not cointegrated, Granger Causality test requires transformation of data to make them I (0). The Granger Causality model in this case is as follows:

$$\Delta Y_t = \eta + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \sum_{j=1}^{q} \beta_j \Delta X_{t-j} + \varepsilon_t \quad \text{……….. (19)}$$

Where H_0: $\beta_j = 0$ *for j = 1, ….., q* is tested against H_A: $\beta_j \neq 0$ for at least one j.

$$\Delta X_t = \mu + \sum_{i=1}^{r} \gamma_i \Delta X_{t-i} + \sum_{j=1}^{s} \lambda_j \Delta Y_{t-j} + \eta_t \quad \text{……….. (20)}$$

Where H_0: $\lambda_j = 0$ *for j = 1, …..,s* is tested against H_A: $\lambda_j \neq 0$ *for at least one j.*

3. Results and Discussion

3.1 Order of Integration Test

The first and prime step of the nexus between energy consumption and economic growth requires that both the variables should be integrated of same order, specifically 1(1). The ADF and PP tests are deployed for investigating the same. The estimated results of these two tests are reported in Table 3. The p-values of ADF test and PP test represents that the series [economic growth (GDP), per capita oil consumption (OC) and per capita electricity consumption (EC)] are non-stationary in their levels but found stationary in the first difference. That means all these three variables that used in this study are 1 (1). This is true for all the five SAARC countries, namely Bangladesh, India, Nepal, Pakistan and Sri Lanka, during 1970-2006.

3.2 Cointegration Test

This section scans the long run equilibrium relationship between [EC, GDP] and [OC, GDP]. That is to test whether two series are cointegrated. The Johansen cointegration test is deployed for the same. The estimated results are reported in Tables 4 and 5. In both the cases {[EC, GDP] and [OC, GDP]}, the cointegration test uses an intercept but no trend. The estimation procedure of Johansen test is very sensitive to the choice of lag length. The Schwarz Bayesian Information criterion (SBC) is used to fix the optimal lag length. The estimated results between per capita electricity consumption and GDP [EC, GDP] indicate that the two series have one cointegrating relationship (see Table 4). This is because the null hypothesis of H_0: r = 0 against r ≤ 1 is rejected at 1% level. This is true for all the five SAARC countries. The Johansen's cointegration results between per capita oil consumption and economic growth [OC, GDP] also shown one cointegrating relationship except Sri Lanka, where there exists two cointegrating relationships (see Table 5). Hence, the superiority of Johansen's approach compared to Engle Granger's residual based approach lies in the fact that Johansen's technique is capable of detecting multiple cointegrating relationships among the variables (Asafu-Adjaye, 2000). The above results confirm that there is long run equilibrium relationship between energy consumption and economic growth in the five SAARC countries.

3.3 Granger Causality Test

Having found that there is a long run equilibrium relationship between energy consumption and economic growth, it gives an indication that there exists Granger causality in at least one direction. To test the direction of causality, the Error Correction Model (ECM) is deployed. The significance of ECM not only provides an indication of the direction of causality but also enable to distinguish between short run and long run Granger causality. It is to be noted that the estimation of ECM is also very lag specific. The paper uses SBC for choosing the lag length in the ECM estimation. The causality in this case is examined through the significance of coefficient of the lagged error correction term and joint significance of the lagged differences of the explanatory variables by using F-test. The estimated results of ECM are reported in Table 6. The results confirmed that there is unidirectional causality from per capita oil consumption to economic growth (OC => GDP) in Bangladesh, both in the short run and long run. The long run causality from per capita oil consumption to economic growth is supported by the coefficient of lagged error correction term. On the contrary, the short run causality from per capita oil consumption to economic growth is supported by the F-statistics in the economic growth function, which is also statistically significant at 1% level. The reverse causality from economic growth to per capita oil consumption is, however, rejected by the lagged error correction term as well as F- statistics in the energy function, which are all statistically insignificant. Moreover, there is also bidirectional causality between per capita electricity consumption to economic growth (EC <=> GDP) in the Bangladesh economy, both in the short run and long run. This is because both the lagged error correction term and F-statistics are statistically significant in the economic growth function and energy function respectively.

The results for India reflect a unidirectional causality from economic growth to per capita oil consumption (GDP => OC) and from economic growth to per capita electricity consumption (GDP => EC), both in the short run and long run. This is highly supported by the coefficients of lagged error correction term and F-statistics in the energy function and economic growth function, which are statistically significant at 10% level. In the case of Nepal, we found a unidirectional causality from economic growth to per capita electricity consumption (GDP => EC) and from per capita oil consumption to economic growth (OC => GDP), both in the short run and long run. The coefficients of lagged error correction and F-statistics are also statistically significant in the energy function and economic growth function respectively.

Coming to Pakistan economy, the results showed the bidirectional causality between per capita oil consumption and economic growth (OC < = > GDP), both in the short run and long run. The results also showed a unidirectional causality from per capita electricity consumption to economic growth (EC => GDP), both in the short run and long run. However, the reverse causality from economic growth to per capita oil consumption is rejected by the lagged error correction term and F-statistics in the energy function, which is all statistically insignificant. The results of Sri Lanka economy reflect a unidirectional causality from per capita electricity consumption to economic growth (EC => GDP) and from economic growth to per capita oil consumption (GDP => OC). This is highly supported by coefficients of lagged error correction and F-statistics, which are statistically significant in the economic growth function and energy function respectively. A summary of the Granger causality between [EC, GDP] and [OC, GDP] is presented in Table 7.

4. Conclusion

Understanding the nexus between energy consumption and economic growth is very vital in the effective design and implementation of energy and environmental policies. In the case of South Asian Association of Regional Cooperation (SAARC), the data receives a great deal of variation across the countries, both at the level of economic development (GDP) and energy consumption [per capita electricity consumption (EC) and per capita oil consumption (OC)]. The SAARC is basically dominated by India and Pakistan, both in terms of GDP and energy consumption. The present study, however, explores the relationship between energy consumption and economic growth in a bivariate framework {[EC, GDP] and [OC, GDP]} by using cointegration and Error Correction Model (ECM). The five SAARC countries namely Bangladesh, India, Nepal, Pakistan and Sri Lanka are choosen for this purpose and that to availability of data during 1970-2006. The empirical results first confirmed the presence of long run equilibrium between [EC, GDP] and [OC, GDP] in all the five countries. The estimated results of ECM found the followings:

1) A unidirectional causality running from per capita oil consumption to economic growth (OC => GDP) in Bangladesh and Nepal for both short run and long run.

2) A unidirectional causality running from per capita electricity consumption to economic growth (EC => GDP) in Pakistan and Sri Lanka, both in the short run and long run.

3) A unidirectional causality running from economic growth to per capita oil consumption (GDP => OC) India and Sri Lanka for both short run and long run.

4) A unidirectional causality running from economic growth to per capita electricity consumption (GDP => EC) India and Nepal for both short run and long run.

5) The bidirectional causality between per capita oil consumption and economic growth (GDP <=> OC) in Pakistan for both short run and long run.

6) The bidirectional causality between per capita electricity consumption and economic growth (GDP <=> EC) in Bangladesh, both in the short run and long run.

Over and above, the paper does not find a definite conclusion on the issue of “energy consumption-growth nexus” in the five SAARC countries. That means the nexus between energy consumption and economic growth is very divergent across the five SAARC countries namely Bangladesh, India, Nepal, Pakistan and Sri Lanka. The empirical results, however, can give various policy implications for the SARRC, particularly for energy and environmental policies. For countries where we found the evidence of a unidirectional causality running from energy consumption to economic growth, reducing energy consumption could lead to a fall in economic growth. Therefore, when any energy conservation measures are undertaken, considerable care should be taken not to adversely affect the economic growth. In countries, where there was economic growth-led energy consumption, reducing energy consumption may be implemented with little or no adverse effect on economic growth. In contrast, for countries where there exists a bidirectional causality between energy consumption and economic growth, energy consumption and economic growth can complement each other and energy conservation measures may negatively affect economic growth (Wolde-Rufael, 2009).

To conclude, the nexus between energy consumption and economic growth provides a suitable framework in the SAARC to boost their energy and environmental policies. Since energy infrastructure is a big deal to economic growth, a suitable energy policy should be maintained to boost economic growth and maintain sustainable economic development in the region. A piecemeal approach to such a vital issue is of serious consequences and may affect economic growth in the long run. Therefore, respective government has to look the same at any cost and with a greater caution.

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Table 1. Brief Empirical Work between Economic growth and Energy Consumption

Studies	Variables	Study Areas	Time Periods	Methods	Results
Kraft and Kraft (1978)	1, 12	2	2	4	19
Akarca and Long (1980)	1, 2	2	7	4	4
Yu and Hwang (1984)	1, 2	2	3	4	4
Erol and Yu (1988)	1, 2	9, 10, 11, 12, 13, 14	8, 9	2	1, 2, 3, 4
Abosedra and Baghestani (1989)	1, 2	2	1, 2, 3, 4	1, 2	1
Hwang and Gum 1991)	1, 2	7	20	1, 2	3
Yu and Jin (1992)	2, 16	2	29	1, 2	3
Stern (1993)	4, 14, 15	2	5	2	28, 29
Cheng (1995)	1, 2	2	5	1, 2	4
Masih and Masih (1996)	1, 2	1, 3, 4, 6, 8, 18	13, 14, 16	1, 2, 6	1, 2, 3, 4
Cheng and Lai (1997)	2, 4	7	11	2	5
Glasure and Lee (1997)	2, 4	8, 15	20	1, 2	5, 8
Cheng (1999)	2, 4	1	10	1, 2	5
Asafu-Adjaye (2000)	1, 2, 3	1, 3, 4, 5	25, 28	1, 2, 3	2, 3
Yang (2000)	4, 11	7	12	2	30
Aqeel and Butt (2001)	2, 4	6	15	1, 2	5
Cheng and Wong (2001)	2, 4	8	30	1, 2	5
Fatai et al. (2002)	2, 4, 5	19	18	2, 5	5, 8
Glasure (2002)	2, 4, 6, 7, 8	15	20	1, 3, 6	6, 7, 11, 12, 13, 14, 15
Ghali and El-Sakka (2004)	2, 4	11	21	1, 2	3
Jumbe (2004)	4, 9, 10, 11	16	22	1, 2, 3	16, 17, 18
Morimoto and Hope (2004)	4, 13	25	17	2	27
Oh and Lee (2004)	4, 11	15	22	2, 3	30
Al-Iriani (2006)	1, 2	23	26	1, 2	5
Ghosh and Basu (2006)	4, 22, 23	1	23	2	35, 36
Erdal et al. (2008)	1, 2	22	24	1, 2	3
Narayan and Smyth (2008)	1, 2	24	27	1, 2	3
Ya-qun et al. (2008)	1, 2	26	32	1, 2	3
Bowden and Payne (2009)	2, 4, 5, 17	2	6	2, 3	5
Apergis and Payne (2009)	1, 2	2	31	1, 3	2
Halicioglu (2009)	1, 2,	22	19	1, 2	31, 32

Notes to Table 1:

Variable

1: Gross National Product (V_1)
2: Energy Consumption (V_2)
3: Energy Price (V_3)
4: Gross Domestic Product (V_4)
5: Employment (V_5)
6: Government expenditure (V_6)
7: Money Supply (V_7)
8: Oil Price (V_8)
9: Agricultural GDP (V_9)
10: Non-agricultural GDP (V_{10})
11: Electricity Consumption (V_{11})
12: Gross Energy Income (V_{12})
13: Electricity Production (V_{13})
14: Gross Energy Use (V_{14})
15: Adjusted Final Energy Use (V_{15})
16: Industrial Production Index of Manufacturing (V_{16})
17: Real Gross Fixed Capital Formation (V_{17})
18: CO_2 Emissions (V_{18})
19: Foreign Trade (V_{19})
20: Residential Primary Energy Consumption (V_{20})
21: Industrial Primary Energy Consumption (V_{21})
22: Coal Consumption (V_{22})
23: Gas Consumption (V_{23})

Time Periods

1: 1947- 1972	2: 1947- 1974
3: 1947-1979	4: 1947-1987
5: 1947-1990	6:1949-2006
7: 1950-1970	8: 1952-1980
9: 1952-1982	10: 1952-1995
11: 1954-1993	12: 1954-1997
13: 1955-1990	14: 1955-1991
15: 1955-1996	16: 1960-1990
17: 1960-1998	18: 1960-1999
19: 1960-2005	20: 1961-1990
21: 1961-1997	22: 1970-1999
23: 1970-2001	24: 1970-2006
25: 1971-1995	26: 1971-2002
27: 1972-2002	28: 1973-1995
29: 1974-1990	30: 1975-1995
31: 1980-2004	32: 1980-2006

Countries

1: India	2: US
3: Indonesia	4: Philippines
5: Thailand	6: Pakistan
7: Taiwan	8: Singapore
9: Wes Germany	10: Italy
11: Canada	12: France
13: UK	14: Japan
15: South Korea	16: Malawi
17: Pakistan	18: Malaysia
19: New Zealand	20: Argentina
21: Italy	22: Turkey
23: GCC Countries	24: G7
25: Sri Lanka	26: China

Methods

1: Cointegration
2: Granger Causality
3: Error Correction Model
4: Sim's Technique
5: ARDL
6: Variance Decomposition
7: Impulse Response Function

Results

1: $V_1 => V_2$	2: $V_2 => V_1$
3: $V_1 <=> V_2$	4: $V_1 <\neq> V_2$
5: $V_4 => V_2$	6: $V_2 => V_4$
7: $V_4 <=> V_2$	8: $V_4 <\neq> V_2$
9: $V_2 <=> V_6$	10: $V_4 <=> V_6$
11: $V_4 <=> V_7$	12: $V_4 <=> V_8$
13: $V_6 <=> V_7$	14: $V_6 <=> V_8$
15: $V_7 <=> V_8$	16: $V_4 <=> V_{11}$
17: $V_9 <=> V_{11}$	18: $V_{10} <=> V_{11}$
19: $V_1 => V_{12}$	20: $V_2 => V_3$
21: $V_3 => V_2$	22: $V_1 => V_3$
23: $V_1 <\neq> V_3$	24: $V_3 <\neq> V_2$
25: $V_3 <=> V_2$	26: $V_1 <=> V_3$
27: $V_{13} => V_4$	28: $V_4 <\neq> V_{14}$
29: $V_{15} => V_4$	30: $V_{11} => V_4$
31: $V_{18} <=> V_4$	32: $V_{18} <=> V_2$
33: $V_{20} <=> V_4$	34: $V_{21} => V_4$
35: $V_{22} => V_4$	36: $V_{23} <=> V_4$

Table 2. Summary of Univariate Statistics

Countries	Variables	Mean	Median	Max	Min	SD	Skew	Kurt	JB
Bangladesh	GDP	2.94E+10	2.68E+10	6.19 E+10	6.29E+09	1.57E+10	0.421	2.13	2.266
	EC	54	45.4	146	9.67	39.56	0.806	2.52	4.365
	OC	111.9	109	160	80	23	0.550	2.24	2.730
India	GDP	3.11 E+11	2.76 E+11	9.15 E+11	6.63 E+10	2.02 E+10	1.223	4.28	11.74
	EC	265	266	503	99	126	0.225	1.68	2.999
	OC	371	369	510	280	69.2	0.311	1.84	2.666
Nepal	GDP	3.6 E+10	3.49 E+10	9.04 E+10	8.83 E+09	2.05 E+10	0.796	3.10	3.920
	EC	33.7	32.3	79.7	5.71	22.7	0.528	2.21	2.696
	OC	310	305	340	295	14.3	1.070	2.68	7.223
Pakistan	GDP	4.49 E+10	4.0 E+10	1.27 E+10	6.32 E+10	2.93 E+10	0.876	3.41	4.995
	EC	253	253	480	86.5	122	0.083	1.635	2.915
	OC	382	384	499	277	73.6	-0.04	1.535	3.320
Sri Lanka	GDP	9.72 E+09	6.99 E+09	2.83 E+09	2.37 E+08	6.64 E+09	0.956	3.184	5.689
	EC	174	143	400	58.3	97.5	0.780	2.540	4.050
	OC	348	323	487	289	56.3	1.147	3.070	8.120

Note: GDP: Gross Domestic Product ($); EC: Per Capita Electricity Consumption (kWh); OC: Per Capita Oil Consumption (kg); Max: Maximum; Min: Minimum; SD: Standard Deviation; Skew: Skewness; Kurt: Kurtosis.

Table 3. Results of Unit Root Test

Country	Variables	ADF Test		PP Test		Conclusion
		LD	FD	LD	FD	
Bangladesh	**GDP**	-3.23	-6.013*	-0.863	-8.369*	**$U_t \sim I(1)$**
	EC	0.153	-4.809*	-1.527	-8.554*	**$U_t \sim I(1)$**
	OC	0.786	-8.652*	1.895	-10.21*	**$U_t \sim I(1)$**
India	**GDP**	-0.547	-4.141*	-0.547	-4.179*	**$U_t \sim I(1)$**
	EC	-1.066	-4.238*	-0.917	-4.283*	**$U_t \sim I(1)$**
	OC	1.577	-5.641*	1.697	-5.636*	**$U_t \sim I(1)$**
Nepal	**GDP**	-0.977	-6.333*	-1.430	-6.885*	**$U_t \sim I(1)$**
	EC	-2.333	-9.437*	-2.622	-9.336*	**$U_t \sim I(1)$**
	OC	0.682	-5.038*	0.941	-5.002*	**$U_t \sim I(1)$**
Pakistan	**GDP**	-0.246	-5.098*	-0.218	-5.105*	**$U_t \sim I(1)$**
	EC	-0.984	5.283*	-0.958	-5.295*	**$U_t \sim I(1)$**
	OC	-0.410	-5.208*	-0.410	-5.208*	**$U_t \sim I(1)$**
Sri Lanka	**GDP**	-0.046	-6.753*	0.606	-6.760*	**$U_t \sim I(1)$**
	EC	0.136	-6.979*	0.285	-7.097*	**$U_t \sim I(1)$**
	OC	2.587	-5.867*	1.201	-6.067*	**$U_t \sim I(1)$**
Critical Values						

Note: ADF: Augmented Dickey Fuller Test; PP Test: Philips and Perron Test; LD: Level Data; FD: First Difference; GDP: Gross Domestic Product; EC: Per Capita Electricity Consumption; OC: Per Capita Oil Consumption *: Statistically Significant; and $U_t \sim I(1)$: Integrated of Order One.

Table 4. Results of Johansen's Cointegration Likelihood Ratio Test (Between GDP and EC)

Hypothesized Cointegrating H_0	Number of Relationships H_A	Test Statistics			
		λ- Tra	CV	λ- Max	CV
		Bangladesh			
r = 0	r > 0	28.96*	11.2	30.46*	12.32
r ≤ 1	r > 1	1.497	4.13	1.497	4.130
		India			
r = 0	r > 0	14.21*	11.2	14.25*	12.32
r ≤ 1	r > 1	0.221	4.13	0.222	4.130
		Nepal			
r = 0	r > 0	28.98*	11.2	29.05*	12.32
r ≤ 1	r > 1	0.078	4.13	0.078	4.130
		Pakistan			
r = 0	r > 0	18.87*	11.2	18.96*	12.32
r ≤ 1	r > 1	0.087	4.13	0.088	4.130
		Sri Lanka			
r = 0	r > 0	25.11*	11.2	25.22*	12.32
r ≤ 1	r > 1	0.117	4.13	0.117	4.130

Note: r indicates the number of cointegrating relationships; CV: Critical values, which are taken from MacKinnon- Haug- Michelis, 1999. *: Indicates level of Statistical Significance.

Table 5. Johansen's Cointegration Likelihood Ratio Test (Between GDP and PC)

Hypothesized Cointegrating H_o	Number of Relationships H_A	Test Statistics			
		λ- Tra	CV	λ- Max	CV
		Bangladesh			
r = 0	r > 0	22.52*	11.2	23.05*	12.32
r ≤ 1	r > 1	0.533	4.13	0.533	4.130
		India			
r = 0	r > 0	19.77*	11.2	21.17*	12.32
r ≤ 1	r > 1	1.401	4.13	1.401	4.130
		Nepal			
r = 0	r > 0	15.44*	11.2	18.19*	12.32
r ≤ 1	r > 1	2.742	4.13	2.742	4.130
		Pakistan			
r = 0	r > 0	17.19*	11.2	20.33*	12.32
r ≤ 1	r > 1	3.136	4.13	3.136	4.130
		Sri Lanka			
r = 0	r > 0	15.11*	11.2	25.22*	12.32
r ≤ 1	r > 1	7.668*	4.13	7.668*	4.130

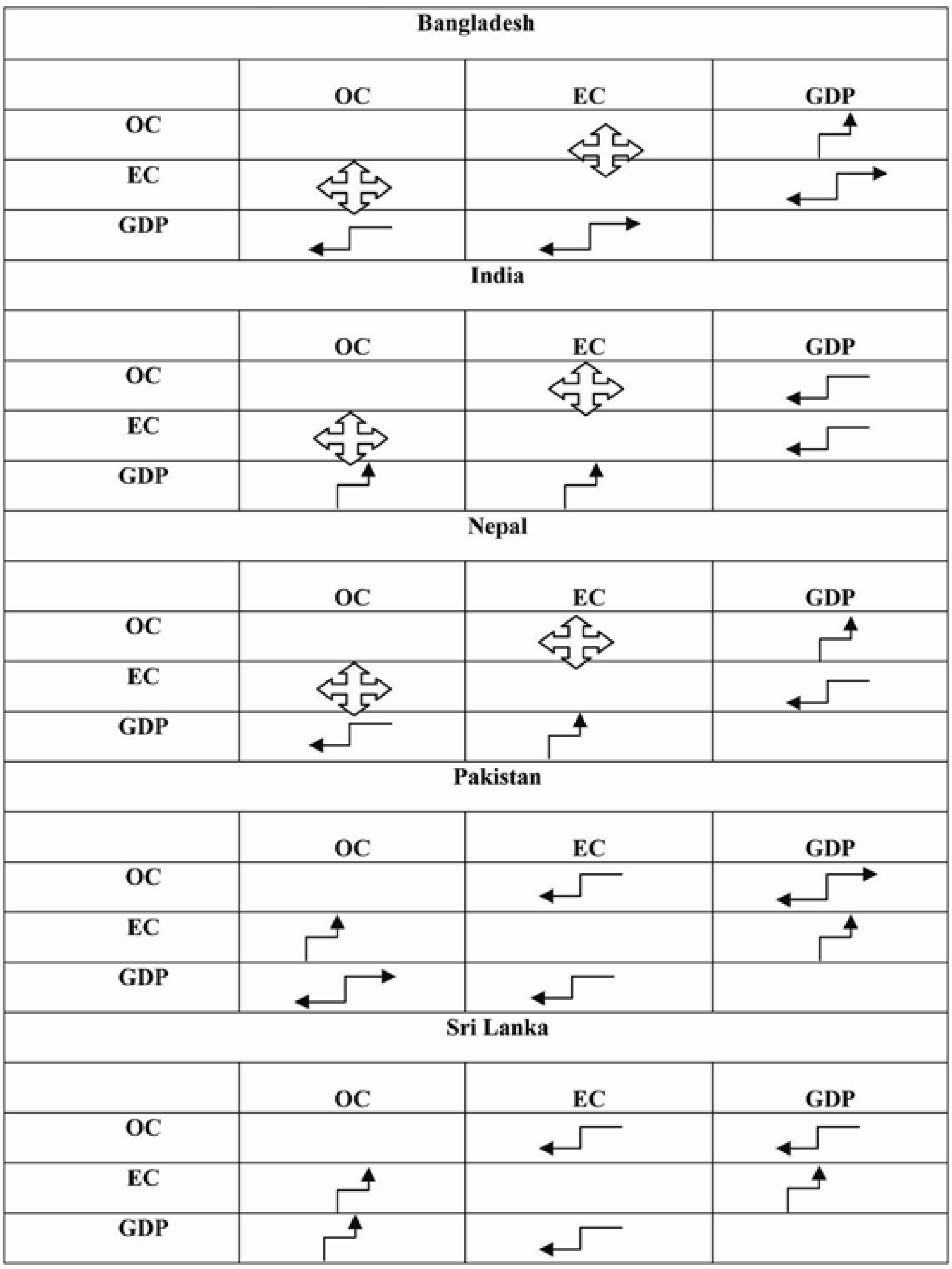
Note: All notations are defined earlier.

Table 6. Results of ECM Estimation

Country	Models	Variables	Error Correction	R^2	F
Bangladesh	**Model 1**	**EC**	-2.42*	0.466	4.71*
		GDP	3.72*	0.615	8.62*
	Model 2	**OC**	-1.60	0.252	1.815
		GDP	3.05*	0.525	5.98*
India	**Model 1**	**EC**	-2.61*	0.331	2.67*
		GDP	0.660	0.158	1.011
	Model 2	**OC**	-2.5*	0.287	2.172
		GDP	0.287	0.171	1.117
Nepal	**Model 1**	**EC**	-3.35*	0.474	4.86*
		GDP	-0.410	0.167	1.079
	Model 2	**OC**	-1.377	0.124	0.767
		GDP	3.347*	0.393	3.49*
Pakistan	**Model 1**	**EC**	-2.028	0.177	1.613
		GDP	2.62*	0.333	2.70*
	Model 2	**OC**	-2.64*	0.267	1.962
		GDP	2.61*	0.333	2.70*
Sri Lanka	**Model 1**	**EC**	-0.799	0.083	0.485
		GDP	2.62*	0.290	2.25*
	Model 2	**OC**	-3.90*	0.454	1.815
		GDP	0.648	0.119	5.96*

Note: All notations are defined earlier.

Table 7. The Direction of Granger Causality Test



Note: : No causality; : Uni-directional causality; : Uni-directional causality; : Bi-directional causality; other notations are defined earlier.