Dynamic Modeling of Energy and Growth in South Asia

By
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Abstract: This study empirically examines the link between real GDP, energy consumption, capital and labour for four South Asian countries including Bangladesh, India, Pakistan and Sri Lanka over the period 1972-2005. Applying bound testing approach to cointegration, we find a strong cointegration between real GDP, energy consumption, capital and labour for each country. The study mainly focuses on the role played by energy in enhancing productivity in the South Asian region. Based on unrestricted error-correction modeling procedure, the study finds supportive evidence in favour of long-as well as short-run causality running from energy consumption to real GDP for each country. The study suggests that the economies of South Asian region are energy dependent economies. Hence the policies of energy conservation are formulated in such a way that these policies would not any produce adverse effects on economic growth in the region.

Introduction

Energy plays an important role both on the demand and the supply sides of the economy. On the demand side, energy is one of the products a consumer decides to buy to maximize his utility. On the supply side, energy is the key factor of production in addition to labour, capital, and other raw materials. Energy is considered to be the key element in the socio-economic development of a country. It also helps to improve the living standards of the society through the increase in economic growth. This implies that there is a causal link running from energy consumption to economic growth.

If causality runs from energy consumption to GDP then it implies that an economy is energy dependent and hence energy is a stimulus to economic growth (Jumbe, 2004). Shortage of energy may negatively affect economic growth or may cause poor economic performance leading to a reduction of income and employment. On the other hand, if causality runs from GDP to energy consumption, this implies that economy is not energy dependent, and hence energy conservation policies may be implemented without adverse effects on economic growth and employment (Masih and Masih, 1997). If there is no

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causality between energy consumption and GDP, it implies that energy conservation policies may be pursued without affecting the economy (Jumbe, 2004).

Based on the above arguments, it is necessary to analyze the link between energy consumption and economic growth because it is argued that the increased availability of energy services act as key stimulus of the process of economic development. The relationship between energy consumption and economic growth has been studies extensively, but the issue associated to the direction of causality between energy consumption and economic growth still remained unsettled. Kraft and Kraft (1978) in their pioneering study, found unidirectional causality running from GNP to energy consumption for United States utilizing annual data over the period 1947-1974. Their results indicates that the low level of energy dependence of US economy on energy enable US to pursue energy conservation policies which have no adverse effects on income (Jumbe, 2004). Akarca and Long (1980) has pointed out that Kraft and Kraft results were spurious by changing the time period by 2 years. The *neutrality hypothesis*[1] was also found by Yu and Hwang (1984), Yu and Choi (1985), Yu and Jin (1992) and Cheng (1995). In the context of developing countries Masih and Masih (1996) found the evidence of Granger causality (Granger, 1988) running from income to energy for Indonesia, but Fatai et al (2004) found unidirectional causality running from energy consumption to income. Asafu-Adjaye (2000) examined the causal relationship between energy consumption, energy prices and economic growth for India, Indonesia, the Philippines and Thailand over the period 1971-95 for India and Indonesia and 1973-1995 for Thailand and Philippines. They find unidirectional causality running from energy to income for India and Indonesia and bidirectional causality running from energy to income for Thailand and Philippines. They further find the evidence of unidirectional causality running from energy and prices to income for India and Indonesia and for Thailand and Philippines energy, income and prices are mutually causal. Aqeel and Butt (2001) investigated the causal relationship between energy consumption and economic growth and energy consumption and employment for Pakistan over the period 1955/56-1995/96. They implemented Hsiao's version of the causality test to determine the

[1] If there is no causality between energy consumption and GDP exist, referred as neutrality hypothesis.

direction of causality. Their results suggest that economic growth causes total energy consumption. The study further suggests that economic growth causes the growth of petroleum production, but no causality observed between growth and gas consumption. The study also explored the causality running from electricity consumption to economic growth without any feedback. Considering the causality issue, Siddiqui (2004) examined the relationship between energy and economic growth for Pakistan over the period 1970-2003 using Autoregressive Distributed Lag (ADL) modeling technique. The results of the study suggest that the impact of all sources of energy were not same on economic growth. The findings of this study were suggested that the impacts of electricity and petroleum products were high and significant on economic growth. However, the study explored reverse causality between petroleum products and economic growth. Paul and Bhattacharya (2004) examined causality between energy consumption and economic growth for India over the period 1950-1996 applying Engle and Granger (1987) and Johansen (1988) cointegration approach. The results were supported the evidence of unidirectional causality energy consumption to economic growth. However, the study does not showed any causal effect from economic growth to energy consumption. The results based on Engle-Granger cointegration test exhibited unidirectional causality running from GDP to energy consumption in the long-run and no causality evidence was found in the short-run. The study has pointed out that when Engle-Granger approach combined with standard Granger causality test, the evidence of bi-directional causality between energy consumption and economic growth was found. The authors concluded that the long-run causal relation running from GDP to energy consumption and the short-run causal relation running from energy consumption to GDP. Same results were found for the Johansen (1988) multivariate cointegration approach.

From the survey of empirical literature we come to the conclusions that although these studies contribute to investigating the relationship between energy consumption and economic growth, but they have not sufficiently shed lights on the dynamics insights of this relationship. We feel that relationship between energy consumption and economic growth may consider together with economic indicators such as labour, capital etc. The complexity of relationship among these variables requires a reexamination of long-term

linkages between energy consumption and real output in Bangladesh, India, Pakistan and Sri Lanka over the period 1972-2004.

The paper is organized as follows: Section 2 shed light on the energy market in South Asia. Model and data is discussed in section 3. Empirical results and their interpretation are given in section 3, while concluding remarks and policy implications are given in the final section.

2. Overview of the Energy Sector in South Asia[2]

Economic and population growth in south Asia resulted in rapid increase in energy consumption in recent years. The Energy Information Administration (EIA) estimates of South Asia's primary energy consumption showed an increase of nearly 64 percent between 1992 and 2002.[3] In 2002 South Asia, accounted for approximately 4.1 percent of the world commercial energy consumption, up from 2.8 percent in 1992. However, despite this energy demand growth South Asia continue to average among the lowest levels of the of per capita energy consumption in the world, but among the highest levels of energy consumption per unit of GDP.

In South Asia the commercial energy mix in 2002 was 46 percent coal, 34 percent petroleum, 12 percent natural gas, 6 percent hydroelectricity, 1 percent nuclear and 0.3 percent others. There are significant variations in the region. For example, Bangladesh energy mix was dominated by natural gas (66.4 percent in 2002), while India relies heavily on coal (54.5 percent in 2002), Sri Lank is overwhelmingly dependent on petroleum (82 percent). Pakistan has diversified among petroleum (42.7 percent), natural gas (42.2 percent), and hydroelectricity (10 percent).

South Asian nations facing rapidly increasing demand for energy coupled with insufficient energy supply. Most of the South Asian countries are already grappling with

[2] This section is heavily based on the "South Asia Regional Overview" available from www.eia.doe.gov
[3] EIA energy statistics include only commercial energy and not animal waste, wood, or other biomass which accounts for more than half of the South Asia's total energy consumption.

energy shortfalls in the form of recurrent, costly, and widespread electricity outages. Because of the economic and political ramifications arising from such shortfalls, improving the supply of energy, particularly the supply of electricity, is an important priority of regional governments. South Asian countries are looking to diversify their traditional energy supplies, produce additional foreign investment for energy infrastructure development, improve energy efficiency, reform and privatize energy sector, and promote and develop regional energy trade and investment.

An important implication of rising energy demand in South Asia is its impact on the regional's level of carbon omissions. In this context South Asia is accounted for 4.8% of global carbon omission as on 2002. The demand for coal in India is projected to increase rapidly in the coming decades from 359 million shot tone (Mmst) in 2002 to 430 million shot tone (Mmst) by the end of 2010. The recent introduction of coal into the fuel mix of other countries in the region leads to a significant increase in omission in the coming future.

The commercial per capita energy consumption in the region continuous to be quite low, indicating the potential for greater energy consumption. The per capita energy consumption pattern of Bangladesh, India, Pakistan and Sri Lanka is reported in table 1.

Table 1: Per capita of Energy Consumption in South Asia (in KGOE)

Year	Bangladesh	India	Pakistan	Sri Lanka	South Asia	World
1990	123.27	425.65	402.17	324.15	394.43	1685.28
1991	118.73	435.24	404.69	324.32	401.73	1676.55
1992	121.9	441.95	419.08	329.74	405.07	1652.61
1993	125.14	445.03	429.97	343.31	408.94	1648.05
1994	127.48	451.1	435.72	325.14	414.1	1635.74
1995	137.37	468.24	443.84	328.08	429.04	1655.52
1996	135.3	475.73	453.15	366.55	436.02	1678.75
1997	138.51	484.62	452.39	375.07	443.17	1671.92
1998	141.66	484.46	450.94	377.12	443.15	1661.31
1999	140.74	499.8	464.72	397.05	456.63	1671.49
2000	145.13	503.96	463.15	417.53	460.46	1686.82
2001	155.39	503.44	461.4	422.7	460.91	1677.28
2002	156.63	508.96	456.96	417.74	464.53	1693.42
2003	160.9	515.47	466.91	448.92	471.3	1730.77
2004	163.7	530.55	489.09	485	485.87	1790.49
Average	139.46	478.28	446.28	378.83	438.36	1681.07

Source: World Development Indicators

This table shows that India has uses highest per capita commercial energy (479.28 KGOE) and Bangladesh has the lowest (139.46 KGOE). The aggregate consumption and production of energy in South Asia can be seen in table 2a-b.

Table 2: (a) Energy Consumption (in Kilo Tone of Oil Equivalent)

Country/Year	1990	1995	2000	2001	2002	2003	2004	Average*
Bangladesh	12826	15997	18710	20428	20993	21981	22789	17090.87
India	361598	436480	511983	519786	533711	548661	572851	4640002.4
Pakistan	43424	54315	63952	65265	66214	69307	74371	57884.67
Sri Lanka	5516	5950	8083	7918	7940	8643	9439	7002.4
South Asia	432790.2	523875	616046	627058.1	642749.4	662887.8	694312.7	557954.8
World	8609872	9118983	9915471	9977883	10193480	10539100	11026260	9507822

(b) Energy Production (in Kilo Tone of oil equivalent)

Country/Year	1990	1995	2000	2001	2002	2003	2004	Average*
Bangladesh	10758	12777	15156	16178	16739	17549	18390	13866.6
India	361598	436480	511983	519786	533711	548661	572851	395969.6
Pakistan	34360	41272	47130	49204	50295	55492	58993	44230.6
Sri Lanka	4191	4022	4530	4462	4240	4840	5161	4376.47
South Asia	391514.9	452380	495097.3	507704.8	519685	540765.3	562185.5	468949.8
World	8798347	9283481	10029940	10164181	10268170	10651420	11171230	9657296

(c) Net Energy Import (% of total energy use)

Country/Year	1990	1995	2000	2001	2002	2003	2004	Average*
Bangladesh	16.2	20.13	19.0	20.8	20.26	20.16	19.3	18.52
India	7.9	11.94	18.55	17.99	18.22	17.88	18.5	14.16
Pakistan	20.87	24.01	26.3	24.61	24.04	19.93	20.68	23.46
Sri Lanka	24.02	32.4	43.96	43.65	46.6	44	45.32	36.30
South Asia	9.54	13.65	19.63	19.03	19.15	18.42	19.03	15.48

(d) GDP per Unit of Energy Use (PPP $ per KOE)

Country/Year	1990	1995	2000	2001	2002	2003	2004	Average*
Bangladesh	9.71	9.65	10.63	10.25	10.42	10.47	10.73	10.23
India	3.89	4.15	4.69	4.86	4.91	5.18	5.37	4.43
Pakistan	4.06	4.07	4.06	4.06	4.13	4.14	4.14	4.08
Sri Lanka	7.27	8.76	8.25	8.29	8.59	8.37	8.08	8.14
South Asia	4.16	4.36	4.85	4.99	5.05	5.27	5.44	4.62
World	3.88	4.14	4.58	4.68	4.72	4.75	4.77	4.32

Source: World Development Indicators

** Average taken from 1990-2004 using World Bank Data

* Average taken from 1990-2003 using World Bank Data

Figure 1: Energy Consumption and Energy Supply in South Asia Since 1990-2004

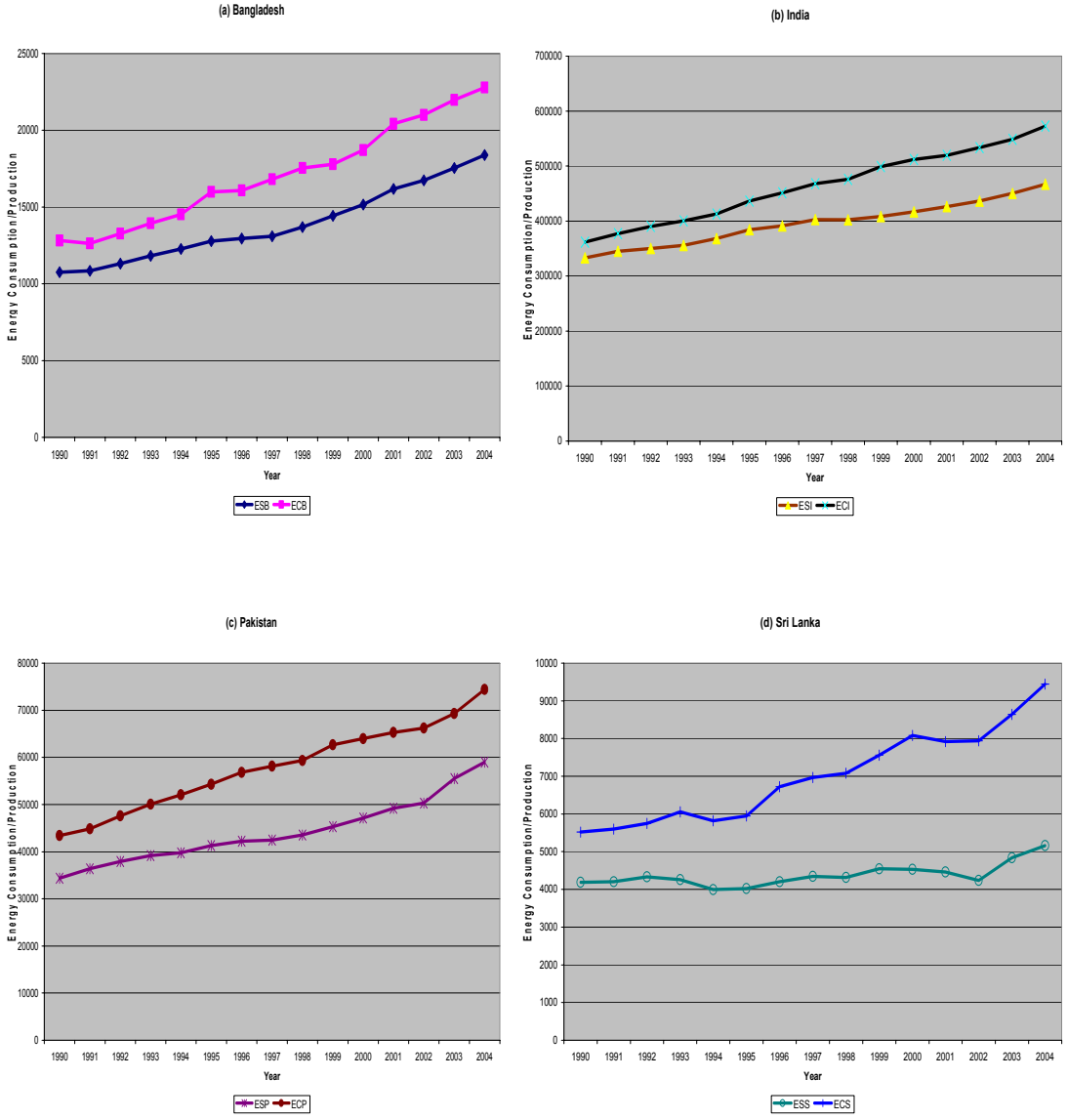


Table 2a-b depicts the trend of energy consumption and the energy production within the region. India is the highest energy user from 1990 to 2004 (464002.4 KTOE on average), and Sri Lanka is the lowest (7004.47 KTOE on average) during the same period, while in terms of production, again India stood the highest producer (395969.6 KTOE), and Sri Lanka has the lowest (4376.47 KTOE). This shows that in South Asia there is wide gap between energy production and energy demand. This can be clearly depicted by figure(s) 1a-1d.

The persistent shortage of energy has been the major factor in keeping low economic growth in South Asia (Wickramasinge, 2001). Poor quality of energy infrastructure has also been one of the major distortions to economic development in the region (Ibid, 2001). South Asia is the net imported of energy. South Asia contains 5.7 billions of oil reserves which is equal to 0.5 percent of the world reserves. The region consumed around 2.72 million barrels of oil per day and produced 0.7 million barrels in 2002, making South Asia net oil importer of around 2.0 million barrels per day. In 2003 production of around 819,000 million barrels of oil per day comes from India, while the remaining around 62,000 barrels of oil per day comes from Pakistan. It is expected that South Asian imports of oil becomes more than double by the end of 2020 and Middle East is expected to remains the primary source of oil imports. The bulk of oil demanded to meet the growing demand from transportation, industry, electricity generation and household sectors. From 1990 to 2000, South Asia consumption of oil grew up about 75 percent. India's oil consumption is expected to grow 33 percent by 2010, and reaching to 2.8 million barrels of oil per day from 2.2 million barrels per day in 2002. Oil is the main source of energy in Sri Lanka and its oil consumption is doubled from 1991 to 2000. In 2002 the oil consumption in Sri Lanka was 75,000 million barrels per day. Sri Lanka imported all its crude oil and uses it largely for electricity generation and transportation. The country has refining capacity is around 50,000 million barrels per day. In the recent years, Sri Lanka has further increased its imports of oil for reduce it's over reliance on hydroelectricity.

Figure 2: Net Import of Energy As Percentage of Total Energy Use

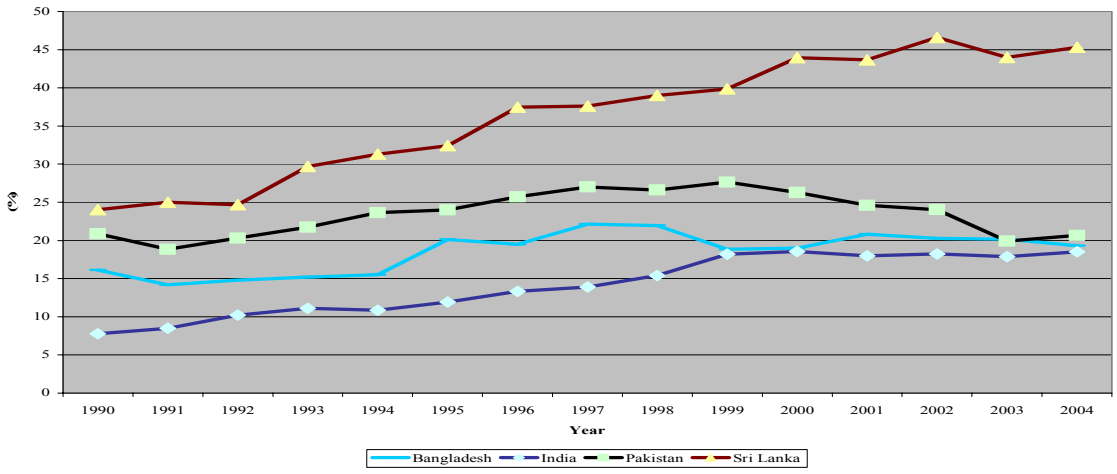
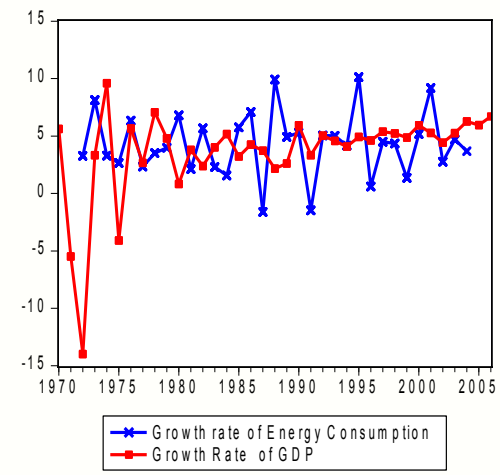


Figure 2 suggest that Sri Lanka is the high energy importer country, while India is the lower net energy importer.

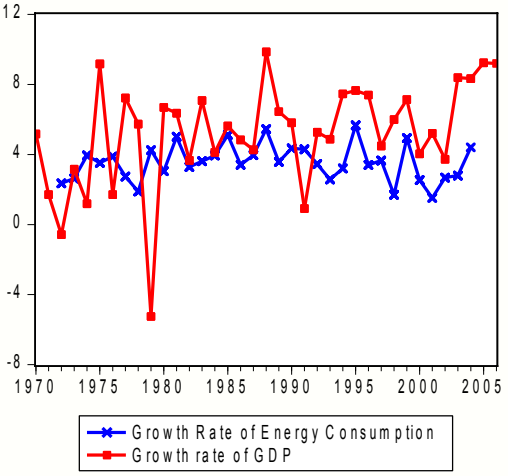
It can be argued that there is strong link between energy consumption and GDP because energy enhances the productivity of capital, labour and other factors of production (Cheng, 1999). The relationship between energy consumption and GDP for each country is depicted in figure 3a-d.

Figure 3: Growth rate of Energy Consumption and GDP

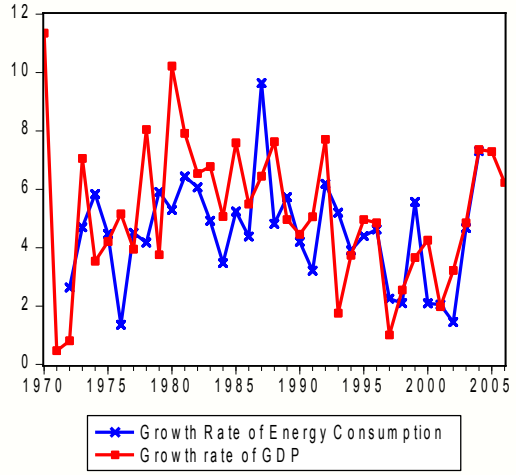
(a) Bangladesh



(b) India



(c) Pakistan



(d) Sri Lanka

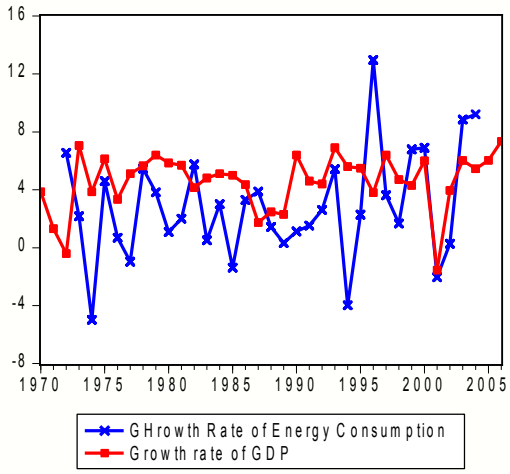


Figure 3a-d depicts the growth rate of energy consumption and growth rate of GDP in South Asia. These figures suggest that the movements in growth of energy consumption are associated with the growth rate of GDP in each country. However, in the case of India, Pakistan and Sri Lanka the growth of energy consumption is less than the growth of GDP, while energy consumption is greater then growth in Bangladesh. The movements of energy consumption and GDP show that there is positive correlation between energy and economic growth. This can be depicted in the following tables of descriptive statistics.

Table 3: Descriptive Statistics of Growth rate in Energy Consumption and Growth rate of GDP

Series	Bangladesh		India		Pakistan		Sri Lanka	
	EC	GDP	EC	GDP	EC	GDP	EC	GDP
Mean	4.32	3.71	3.54	5.09	4.51	5.05	2.86	4.58
Maximum	10.13	9.59	5.67	9.86	9.64	10.22	12.96	7.06
Minimum	1.60	-13.97	1.52	-5.24	1.36	0.81	-4.98	-1.55
Std. Dev	2.79	3.85	1.04	3.02	1.77	2.21	3.76	1.93

Note: EC indicate energy consumption and GDP is gross domestic product.

The statistics presented in table 3 suggest that the average consumption of energy vary between countries. The average growth rate of energy consumption is higher in Bangladesh compared to India, Pakistan and Sri Lanka, while the average GDP growth from 1972-2004 is higher in India and Pakistan as compared to other countries of the region. Similarly the movements in energy consumption are higher in Bangladesh and Sri Lanka as compared to India and Pakistan. Since the per capita consumption of energy is much higher in Bangladesh and Sri Lanka and these countries concentrated much on energy imports (table 2d). A sudden shock in the form of increase in energy prices in the world market brings greater volatility in the energy consumption as compared to other countries.

The correlation between energy consumption and GDP for each country is depicted in table 4 show that there is strong correlation between energy consumption and GDP. This

suggest that for the enhancement of GDP growth energy is pre-requisite besides the other factors of production

Table 4: Correlation between Energy and GDP

Series	Bangladesh		India		Pakistan		Sri Lanka	
	EC	GDP	EC	GDP	EC	GDP	EC	GDP
EC	1.00		1.00		1.00		1.00	
GDP	0.99	10.00	0.95	1.00	0.93	1.00	0.98	1.00

3 Modelling of Energy and Economic Growth

The multivariate model is specified to avoid biased causality inferences due to the omission of relevant variables (Cheng, 1999). Capital and labour and included because these neoclassical theory suggests the potential importance of these two variables along with energy in the growth process. Thus the long-run relationship between real output, energy, capital stock and labour is given by:

$$y_t = a_0 + a_1 enrg_t + a_2 k_t + a_3 l_t + e_t \qquad (1)$$

Where $y, enrg, k$ and l are respectively real output, energy, capital stock and labour. Whereas, e is the error term

The dynamic relationship between energy consumption and economic growth is specified following the modeling approach advanced by Pesaran et al (2001). The variables entering in the model are in logarithmic form. Assume that

$$z_t = (y_t, enrg_t, k_t, l_t)' \quad = \quad (y_t, x_t)' \qquad (2)$$

The conditional unrestricted error-correction model (UECM) for growth-energy nexus is given by

$$\Delta y_t^{\,j} = c_0 + \pi_{yy} y_{t-1}^{j} + \pi_{yx.x} x_{t-1}^{j} + \sum_{i=1}^{k-1} \psi_i' \Delta z_{t-i}^{j} + \gamma' \Delta x_t^{j} + u_t \qquad (3)$$

Where the subscript j is used to represents j th country (Bangladesh, India, Pakistan and Sri Lanka). The coefficients π_{yy} and π_{yx} are the long-run multipliers and c_0 is the drift. Lagged values of Δy and current and lagged values of Δx are used to model the short-run dynamics. The bounds test for the existence of a level relationship between y_t and x_t have the following null hypotheses:

$$H_0^{\pi_{yy}} : \pi_{yy} = 0, \; H_0^{\pi_{yx.x}} : \pi_{yx.x} = 0'$$

and alternative hypotheses are correspondingly given by:

$$H_1^{\pi_{yy}} : \pi_{yy} \neq 0, \; H_1^{\pi_{yx.x}} : \pi_{yx.x} \neq 0'$$

The F -stat has a non-standard distribution, which depends on the unit root properties of the data that is whether variables included in the UECM are I (0) or I (1), and the number of independent variables. The critical values are available in Pesaran and Pesaran (1997) and Pesaran et al (2001). If the calculated F-stat lies above the upper bound, the hypothesis of no cointegration can be rejected and vice versa. If there is an evidence of cointegration between y_t and x_t then one can precede further using autoregressive distributed lag (ARDL) approach to examine the short-run and long-run estimates with the following specification:

$$y_t = \phi_0 + \sum_{i=1}^{k} \phi_1 y_{t-i} + \sum_{i=0}^{k} \phi_2 \, enrg_{t-i} + \sum_{i=0}^{k} \phi_3 k_{t-i} + \sum_{i=0}^{k} \phi_4 l_{t-i} + \eta_t \qquad (4)$$

The study is based on the annual data covering the period 1970-2004. Real GDP (y_t) is used as a proxy for economic growth. Gross fixed capital formulation divided by CPI is used as proxy for capital stock (k_t). Since labour force data are not available for all countries, hence population is used as proxy for labour (l_t).[4] Data on these variables are retrieved from International Financial Statistics (IFS) CD-ROM 2006. Energy consumption (Kilo Tone of Oil Equivalent) divided by consumer price index (CPI) is used to calculate real energy consumption ($enrg_t$). Data on this variable is retrieved from World Bank[5].

[4] See Cheng (1999, p. 41)
[5] http://devdata.worldbank.org/query/default.htm

4 Empirical Results and Their Interpretation

Although bounds testing approach to cointegration does not require any pre-testing of unit roots. However, it is not necessary that all the series are I (0) and I (1), if any of the series are I (2) then autoregressive distributed lag (ARDL) procedure give spurious results. Hence, testing of unit root for each series is important before the implementation of ARDL cointegration method. To examine the time series properties of the data we employ augmented Dickey-Fuller (ADF) unit root test. The results are reported in table 3.

Table 3: Results of the Unit Root Test

Series	level	First Difference	Decision
Bangladesh			
y_t	-0.49 (0)	-7.90(0)*	I (1)
$enrg_t$	-2.18 (1)	-8.67 (0)*	I (1)
k_t	-1.44 (1)	-4.86 (1)*	I (1)
l_t	-4.75 (0)*	-2.45 (0)***	I (0)
India			
y_t	-3.99 (0)*T	-6.01 (0)*T	I (0)
$enrg_t$	-0.93 (1)	-6.58 (0)*	I (1)
k_t	-2.06 (1)	-4.48 (0)*	I (1)
l_t	-7.12 (0)*	2.36 (0)	I (0)
Pakistan			
y_t	-2.34 (1)T	-4.72 (1)*T	I (1)
$enrg_t$	-2.91 (0)***	-3.64 (1)**	I (1)
k_t	-2.06 (1)	-4.62 (0)*	I (1)
l_t	-5.04 (0)*	-1.71 (0)	I (0)
Sri Lanka			
y_t	-3.26 (1)**	-4.92 (1)*	I (0)
$enrg_t$	-1.55 (0)	-4.10 (0)*	I (1)
k_t	-2.80 (0)	-3.37 (1)**	I (1)
l_t	-0.17 (2)	-3.42 (3)***	I (1)

Note: 95% critical value with constant is -2.9472 and with trend are 3.5426 respectively. Number of lags is given in parentheses and Akaike Information Criterion is used for lag selection. ** and ** indicate significant at the 1% and 5% level of significance respectively. T stands for intercept and trend.

The results reported in table 3 suggest that except labour, other series in the case of Bangladesh are non-stationary in their level and stationary at the first difference. Labour

is stationary at its level. Thus for the case of Bangladesh labour is I (0) and other series are I (1). In the case of India real GDP and labour is stationary at level, while energy and capital are nonstationary at their level and stationsry at their first difference. Hence, in the case of India real GDP and labour are I (0) and all other series are I (1). In the case of Pakistan we have obtained mixed results. Energy and labour are I (0), while real output and capital are I (1). For the Sri Lanka, real GDP is I (0) and all other series are I (1) because the hypothesis of stationarity is rejected at their first difference.

Since we obtained mixed unit root results for Bangladesh, India, Pakistan and Sri Lanka. For these countries some series contains I (0) order and some I (1). However, for the case of Sri Lanka all the series are integrated of same order i.e. I (1). Thus we implement bound testing approach in order to examine the cointegration relationship between the variables entering in equation (1) by estimating equation (3) for each country. The results of the bound test are reported in table 4.

Table 4: Results of the Bound Test to Cointegration

Country	Variables Included	Number of Lags	F-Statistic	Decision
Bangladesh	$(y_t \setminus enrg_t, k_t, l_t)$a	1	6.00	Cointegration
India	$(y_t \setminus enrg_t, k_t)$b	2	8.74	Cointegration
Pakistan	$(y_t \setminus enrg_t, k_t, l_t)$c	1	8.41	Cointegration
Sri Lanka	$(y_t \setminus enrg_t, k_t, l_t)$d	2	4.54	Cointegration

Note: The number of lags is selected on the basis of Akaike Information Criterion (AIC). The critical values are given by Pesaran et al (2001).
a= no constant, unrestricted trend and k=3.
b= no intercept, unrestricted trend and k=2.
c= unrestricted intercept, unrestricted trend and k=3.
D= no intercept, unrestricted trend and k=3.

The bound test results reported in table 4 suggest that for all countries the hypothesis of no cointegration is rejected at the 5 percent level of significance. The existence of cointegration suggests that energy, capital and labour plays an important role in enhancing output in these countries.

Given the existence of cointegration between real output, energy consumption, capital and labour, we now implementing autoregressive distributed lag (ARDL) method to examine the long-run and short-run relationship between real output, energy consumption, capital and labour by estimating equation (4). The estimated long-run and short-run results for each country are reported in table 5.

I Bangladesh

The results reported in the case of Bangladesh suggest that energy, capital and labour exerted positive impact on real out put. However, the relative impact of labour and capital is more in the output. The magnitude of energy is equal to 0.12 which is low as compared to the magnitude of labour (0.29) but higher than the magnitude of capital (0. 04) in the long-run. The short-run impact of energy growth is significant and more in terms of size as compared to capital, while the short-run impact of energy is less than that of labour. This implies that in the short-run labour and energy are the key factors playing a dominant role in enhancing economic growth in Bangladesh. The error-correction coefficient is -0.70 which is highly significant suggesting the existence of long-run causality running from energy to economic growth. Furthermore, in the short-run the coefficient of energy is positive and significant indicating the presence of causality running from energy to economic growth. This result has important policy implications that Bangladesh's economy is energy dependent economy and the shortage of energy adversely affect its economic growth and employment. Presently, Bangladesh faces shortage of energy. In the year 2004 its demand for energy is equal to 22789 (KTOE) while supply is equal to 18390 (KTOE) and the shorted is 4399 (KTOE). To meet this shortfall in energy, Bangladesh's net imports of energy is equal to 19.3 percent of total energy use (table 2 a-d).

Table 5: Long-run and Short-run Estimates of Energy and Real Output

Bangladesh	Long-Run Estimates $y_t = 0.12\,enrg_t + 0.04k_t + 0.29l_t + 0.04trend$ $(5.05)^*$ (1.56) $(8.43)^*$ $(11.33)^*$ Short-Run Estimates $\Delta y_t = 0.08\,\Delta enrg_t + 0.03\Delta k_t + 0.21\Delta l_t + 0.03\Delta trend - 0.70\,Ecm_{t-1}$ $(4.31)^*$ (1.53) $(4.69)^*$ $(5.29)^*$ $(-6.01)^*$ $\overline{R}^2 = 0.55$ $F-stat = 10.15$ $S.E = 0.02$ $DW-stat = 2.36$
India	Long-Run Estimates $y_t = 0.26\,enrg_t + 0.66k_t + 0.02trend$ $(5.53)^*$ $(2.62)^{**}$ (1.31) Short-Run Estimates $\Delta y_t = 0.40\,\Delta enrg_t + 0.21\Delta k_t + 0.008\Delta trend - 0.32\,Ecm_{t-1}$ $(4.33)^*$ $(3.83)^*$ (0.97) $(-3.04)^*$ $\overline{R}^2 = 0.73$ $F-stat = 28.53$ $S.E = 0.02$ $DW-stat = 2.14$
Pakistan	Long-Run Estimates $y_t = 2.97 + 0.40\,enrg_t + 0.21k_t - 1.05l_t + 0.09trend$ $(2.20)^*$ $(4.84)^{**}$ $(3.85)^*$ $(-2.81)^{**}$ $(7.77)^*$ Short-Run Estimates $\Delta y_t = 2.03\Delta Inpt + 0.27\,\Delta enrg_t + 0.30\Delta k_t + 4.05\Delta l_t + 0.06\Delta trend - 0.68\,Ecm_{t-1}$ $(2.28)^{**}$ $(2.81)^{**}$ $(6.58)^{**}$ $(3.41)^*$ $(3.88)^*$ $(-3.90)^*$ $\overline{R}^2 = 0.68$ $F-stat = 14.82$ $S.E = 0.02$ $DW-stat = 1.84$
Sri Lanka	Long-Run Estimates $y_t = 0.22\,enrg_t + 0.22\,k_t + 2.06l_t + 0.02trend$ $(3.07)^*$ $(6.52)^*$ $(10.03)^*$ $(2.39)^{**}$ Short-Run Estimates $\Delta y_t = 0.30\,\Delta enrg_t + 0.04\Delta k_t + 1.38l_t + 0.01\Delta trend - 0.70\,Ecm_{t-1}$ $(2.84)^*$ (0.91) $(3.98)^*$ $(2.15)^*$ $(-4.22)^*$ $\overline{R}^2 = 0.62$ $F-stat = 9.76$ $S.E = 0.03$ $DW-stat = 1.93$

* and ** indicate significant at the 1% and 5% level of significance.

II India

In the case of India both energy and capital are positively related to real output in the long run.[6] However, capital is the dominant factor in determining the output in the long-run as indicated by the size of the coefficients of the energy and capital. However, in the short-run energy positive and strong impact on growth and the relative impacts of energy consumption is more than the real capital stock. The key ingredients of economic growth in India are the energy and capital stock. Surprisingly labour plays no role in the economic growth process in India. This result is consistent with the findings of Cheng (1999). The error-correction term is negative and significant supporting the evidence of long-run causality between economic growth and the energy. The coefficient of energy is positive and significant in the short-run also support the presence of short-run causality between energy and growth. This result suggests that Indian economy is heavily energy dependent. In fact the gap between energy consumption and energy production consistently increasing (see figure 2b and table 2 a-d)

III Pakistan

The results suggest that both energy consumption and capital stock exerted positive impact on real output and the impact of energy is relatively higher. This result suggests that real GDP and energy consumption are significantly interrelated and the shortage of energy may retard economic growth process. Surprisingly labour effect real output negatively in the long-run. This could be due the large proportion of old and under age population not able to work. Although labour play a significant role in the Pakistan's economic development but the large share of children and old peoples offset the positive impact of labour.

In the short-run energy, capital and labour play positive role in boosting real output. The coefficient of energy (0.27) is relatively low as compared to the coefficient of labour

[6] During the estimation process we find that the variable labour is insignificant so we drop this variable from the analysis.

(0.87) and capital stock (0.30), implying that labour play dominant role in the process of development in the short-run. This result has very important implications for Pakistan that Pakistan reconsiders its employment policy and concentrates not only on the development of the energy sector but also take necessary measures to improve the quality of labour force. These results are consistent with the earlier findings of Siddiqui (2004) in terms of positive association between economic growth, growth in energy consumption, growth in labour and growth in capital stock. The error-correction coefficient is negative and significant supporting the evidence for the existence of long-run causality between real output, energy consumption and other factor entering in the model. The causality is running from energy to real output. The significance of the coefficient of energy consumption in the error-correction equation implies the existence of causality running from energy consumption to real output in the short-run. Thus, in order to enhance economic growth the authorities needs to further develop the energy sector and improve the quality of labour force.

IV Sri Lanka

We also find positive evidence with respect to the relationship between real output and energy consumption and capital and labour. The impact of labour is higher than the impact of energy and capital on real output in the long-run. In the short-un energy and labour growth play significant role in the promotion of domestic productivity. The significance of the error-correction term and the energy consumption coefficients in the error-correction equation supports the evidence of long-as well as short-run causality between growth and energy consumption. Thus development of the energy sector is very vital for the enhancement of economic growth in Sri Lanka.

From the empirical analysis we can draw the following general conclusions:

- Energy consumption in South Asian countries seems to play an important role in determining economic growth.
- There is evidence of long-as well as short-run causality between energy consumption and real GDP.

- The error-correction term for all countries remains significant, however, the size of this coefficient vary from 0.70-0.32 (in absolute term) depending on the economic structure and stages of domestic market development.

5. Conclusions

South Asian countries have facing the problem of energy shortage and the gap between energy consumption and energy production is persistently increases over time. This growing gap between demand for and the supply of energy is expected to retard the economic growth in these countries. Keeping in mind the vital and critical role of energy in the process of development this study developed the link between energy consumption and real output for four South Asian countries including Bangladesh, India, Pakistan and Sri Lanka. The study is based on annual data covering the period 1972-2004[7] and bound testing procedure is used to investigate the cointegration relationship. The bound test reveals the existence of cointegration among the real output, energy, capital and labour. To examine the long-and short-run impact of energy on real output autoregressive distributed lag (ARDL) technique is implemented. The results based on the long-run analysis suggest that energy consumption play an important role in enhancing productivity in all the countries. To determine the long-and short-run causality among the energy consumption and output, we have estimated short-run error-correction model for each country. The results support the evidence of causality running from energy consumption to GDP in all the countries in the long-as well as in the short-run. The overall results suggest that the economy of each country is energy dependent and shortage of energy may negatively affect the economic growth which eventually results in a fall in income and employment.

The important policy implications drawn from this study are that in order to achieve rapid economic growth, South Asian countries should adopt a policy of energy sector development. Besides the energy sector development, Pakistan should also take care of labour force up-gradation through the changes in labour composition and acceleration of

[7] The data available for Bangladesh cover the period 1974-2004.

capital formation. In India labour play no or little role at all in the development process. Hence, India should take necessary measures to utilize cheap and surplus labour in most efficient way in the process of development besides the development of the energy sector. Bangladesh and Sri Lanka should accelerate their rate of capital accumulation. Finally these countries may pursue energy conservation policies in such a way that these policies may not produce adverse affects on economic growth.

References

Akarca, A. T., and T.V. Long (1980), "On the Relationship between Energy and GNP: A Reexamination", Journal of Energy Development, Vol. 5, pp. 326-331.

Aqeel, A and M.S. Butt (2001), "The Relationship between Energy Consumption and Economic Growth in Pakistan", Asia-Pacific Development Journal, Vol. 8, No. 2, pp. 101-109

Asafu-Adjaye, J. (2000), "The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries", Energy Economics, Vol. 22, pp. 615-625.

Cheng, B.S. (1995), "An Investigation of Cointegration and Causality between Energy Consumption and Economic Growth", Journal of Energy and Development, Vol. 21, pp. 73-84.

_____ (1999), "Causality between Energy Consumption and Economic Growth in India: An Application of Cointegration and Error-Correction Modelling", Indian Economic Review, Vol. XXXIV, No. 1, pp. 39-49

Engle, R.F, and C.W.J. Granger (1987), "Cointegration and Error-Correction: Representation, Estimation, and Testing", Econometrica, Vol. 55, pp. 251-276.

Fatai, K., Oxley and F.G. Scrimgeour (2004), "Modelling the Causal Relationship between Energy Consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines and Thailand", Mathematics and Computer Simulation, Vol. 64, pp. 431-445.

Granger, C. W.J. (1988), "Some Recent Developments in a Concept of Causality", Journal of Econometrics, Vol. 39, pp. 199-211.

Johansen, S. (1988), "Statistical Analysis of Cointegrating Vectors", Journal of Economic Dynamics and Control, Vo. 12, pp. 231-254.

Jumbe, C.B.L. (2004), "Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi", Energy Economics, Vol. 26, pp. 61-68.

Kraft, J and A. Kraft (1978), "Note and Comments: On the Relationship between Energy and GNP", The Journal of Energy and Development, Vol. 3, pp. 402-403.

Masih, A.M.M., and R. Masih (1996), "Energy Consumption, real Income, and Temporal Causality: Results from and Multi-Country Study Based on Cointegration and Error-Correction Modelling Techniques", Energy Economics, Vol. 18, pp. 165-183.

_____ (1997), "On the Temporal Causality Relationship between Energy Consumption, Real Income, and Prices: Some New Evidence for the Asian Energy Dependent NIC's Based on Multivariate Cointegration/Vector Error-Correction Approach", Journal of Policy Modeling, Vol. 19, No. 4, pp. 417-440

Paul, S. and R.N. Bhattacharya (2004), "Causality between Energy Consumption and Economic Growth in India: A Note on Conflict Results", Energy Economics, vol. 26, pp. 977-983.

Pesaran, M.H., Yongcheol Shin and Richard J. Smith (1999), "Bounds Testing Approaches to the Analysis of Long Run Relationships", Working Paper, February 1999.

_____ (2001), "Bounds Testing Approaches to the Analysis of Level Relationships", Journal of Applied Econometrics, Vol. 16, pp.289-326.

Siddiqui, R. (200), "Energy and Economic Growth in Pakistan", The Pakistan Development Review, Vol. , No. , pp.

Wickramasinge, U. (2001), "Energy for Economic Development in South Asia: Present Status, Future Requirements, and Potential for Regional Cooperation", South Asia Economic Journal, Vol. 2, No. 2, pp. 221-251.

Yu, E.S.H. and B.K. Hwang (1984), "The Relationship between Energy and GNP: Further Results", Energy Economics, Vol. 6, pp. 186-190

_____ and J.Y. Choi (1985), "The Causal Relationship between Energy and GNP: An International Comparison", Journal of Energy Development, Vol. 10, pp. 249-272.

_____ and J.C. Jin (1992), "Cointegration Tests of Energy Consumption, Income and Employment", Resource Energy, Vol. 14, pp. 259-266.