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Energy Consumption, Trade and GDP: A Case Study of South Asian Countries

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1. INTRODUCTION

Acute shortage of energy sources in developing countries in general and South Asian countries in particular has shown that energy has become a binding input for any production process. Nowadays operation of heavy machinery and electrical equipment, and transportation of raw material and final products from their place of origination to their destination require heavy consumption of energy in one form or the other. Therefore, energy consumption that was previously ignored in the production function of a firm and an economy is now considered a vital input in production process. It affects GDP directly as by increasing energy consumption; more output can be produced with given stock of capital and labor force in a country. Also uninterrupted availability of energy at reasonable cost improves competiveness of home products in international markets and thus increases exports of home country a great deal. Resulting increase in net exports further adds to the GDP through multiplier effect.

To acknowledge due importance of energy in production process, Energy Economics has been recognised as a new sub-discipline of Economics in the literature. Energy Economics mainly studies the relationship between energy consumption and output [e.g. Lee (2005); Khan and Qayyum (2006); Noor and Siddiqi (2010)]. Most of the studies have concluded a positive relationship between energy consumption and GDP. Some studies have shown unidirectional relationship running form energy consumption to GDP, some others from GDP to energy consumption and yet some others have proven bidirectional relationship between the two variables. Currently energy consumption is counted even more binding input than capital and labor in determination of GDP of developing counties in particular.

The relationship of trade and GDP has been widely discussed in classical theories from the era of Adam Smith to date. Trade enhances economic growth by increasing local market size, by allocating resources efficiently, by improving economies of scale and by increasing capacity utilisation. Blassa (1978) documented that besides traditional inputs of capital and labor of an aggregate production function, export orientation is another important factor in explaining inter-country differences in GDP growth rates.

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Moreover, exports of manufactured goods in a given year and their growth rate over time depend upon the level of energy consumption in the industrial sector of a country [Sadrosky (2011a)]. It means that energy consumption and trade have a long run relationship. It further implies that energy consumption also adds to GDP of a country indirectly through multiplier effect. However, there are few empirical investigations of this indirect effect.

The long run relationship among energy consumption, trade and GDP is relatively less studied area of economics particularly for South Asian countries. The understanding of the dynamics among these variables has important implications for energy and trade policies. For example, if unidirectional Granger causality running from GDP to exports is observed, then shortage of energy supply in a country may not have detrimental impact. However, if arrow of causality runs from exports to GDP, then uninterrupted supply of energy at reasonable cost becomes crucial for economic growth of the country. Consequently energy conservation policies to reduce energy wastage can offset the positive effects and benefits of trade promoting policies and thus may impede the economic growth of the country.

This study is different from previous ones in the following three respects: First, most of the previous studies have focused either on energy-GDP relationship or on export-GDP relationship, whereas this study explores the simultaneous relationship between energy consumption, exports and GDP. Second, in this study panel co-integration approach is used to identify the long run causality relationship among the variables. This approach is generally considered more advantageous than a single equation approach. Third, this study investigates impact of energy consumption along with exports on GDP for South Asian region,

The roadmap for the remainder of this study is as follows. Section 2 reviews the literature related to the topic. Section 3 describes theoretical framework of the study and presents descriptive analysis of its variables. Section 4 explains econometric methodology of the study and sheds light on data construction and data sources. Section 5 reports empirical results of this research and explains their economic relevance. The final section contains conclusion and policy implications.

2. LITERATURE REVIEW

This section is further divided into three parts: (1) review of energy consumption and GDP relationship, (2) review of trade/exports and GDP relationship, and (3) review of energy consumption, trade/exports and GDP relationship.

2.1. Energy Consumption and GDP

A number of studies have explored the nature of relationship between energy consumption and GDP. Production function in microeconomics and macroeconomics textbooks and neo-classical growth theories consider only labor and capital as important factors of production and ignore energy consumption. However, following the two oil crises in 1970s, energy consumption has gained considerable importance in explaining GDP growth rate of a country. Initially, Kraft and Kraft (1978) studied the casual relationship between energy consumption and GNP. Since then there is a plethora of studies on this topic. The results are, however, mixed about the relationship between these two variables. There are four basic hypotheses for the causality relationship between energy consumption and GDP: First is the neutrality hypothesis, which suggests that there is no significant causal relationship between energy consumption and GDP. Second is the conservation hypothesis, which suggests that there is one-way causality running from GDP to energy consumption. Third is the feedback hypothesis, which suggests that there is two-way causality between energy consumption and GDP. Fourth is the growth hypothesis, which suggests that there is one-way causality running from energy consumption to GDP.

Using ARDL approach and annual data for the period 1972-2004 for Pakistan, India, Sri-Lanka and Bangladesh, Khan and Qayyum (2006) found a positive relationship between energy consumption and GDP. Therefore, they concluded that energy consumption played a vital role in generating and accelerating economic activity in these countries. Noor and Siddiqi (2010) used panel co-integration and fully modified OLS technique to investigate relationship between energy consumption and GDP in five South Asian countries (Pakistan, Bangladesh, Nepal, Sri-Lanka and India). They found a negative long run relationship between energy consumption and GDP but they found short run unidirectional causality running from GDP to energy consumption.

Using a sample of 18 developing countries, Lee (2005) used panel co-integration technique and panel VECM to check the relationship between energy consumption and GDP for the period 1975-2001. The results supported growth hypothesis. He also found long run relationship between these two variables after allowing for individual county effects. Therefore, he suggested that any policy of energy conservation in these countries might be harmful for their economic growth. Lee and Chang(2008) confirmed long run relationship between energy consumption, GDP, capital stock and labor using panel co-integration technique for 16 Asian countries over the period 1971-2002. Their results were in support of growth hypothesis that indicated one-way causality running from energy consumption to GDP.

Using panel data of ten newly industrialised Asian countries for the period 1971-2001 and applying co-integration technique, Chen, *et al*. (2007) investigated the relationship between electricity consumption and GDP. They found long run feedback relationship between them. For the short run, there was one-way causality running from GDP to electricity consumption. Therefore, they recommended conservation policies to avoid wastage of energy in the short run and to ensure its sufficient supply in the long run to enhance economic growth.

Dahmardeh, *et al.* (2012) found a feedback relationship between energy consumption and GDP growth rate for 10 Asian developing countries. They used panel data of the variables concerned for the period 1980-2008. The panel VECM was used to investigate the causality relationship between the two variables. Their results indicated unidirectional causality running from energy consumption to GDP in the short run while a bidirectional causality between the two variables in the long run. Ghali and El-sakka (2004) used co-integration technique and VECM to study the long run relationship and causality direction between the two variables for Canada. The results of their estimation showed bidirectional causality between them. Therefore, they suggested energy consumption as the limiting factor for GDP growth rate in Canada.

Asufu-Adjaye (2000) found unidirectional causality running from energy consumption to GDP for India and Indonesia and bidirectional causality between the two variables for Philippines and Thailand. Their findings were based on co-integration and VECM approach by using ML method of estimation. Their results did not reject the neutrality hypothesis for India and Indonesia in the short run. Their results supported the notion that developing countries, which lacked natural sources of energy like oil and gas were more vulnerable to energy shocks than developed countries, which had access at least to renewable energy sources.

2.2. Trade and GDP

The relationship between trade and GDP growth has been discussed at length in various theories of international trade since the inception of Economics as a separate discipline of knowledge. Export promotion increases economic welfare and GDP growth rate of home country. Kemal, *et al.* (2002) investigated the export-led growth hypothesis for five South Asian countries (Pakistan, Bangladesh, India, Nepal and Sri Lanka) by using co-integration technique in a restricted VAR model. They found a one-way causality running from exports to GDP growth for Pakistan and India and two-way long run causality for the remaining three countries. Overall their findings were in support of export-led growth hypothesis. Therefore, they recommended export promotion policies for these countries to achieve sizable growth rates.

Din (2004) also investigated the export-led growth hypothesis for five South Asian economies by incorporating the role of imports as well. Results of the study suggested long run unidirectional causality running from GDP to exports and imports for the economies of Pakistan and Bangladesh and short run bidirectional causality for the economies of Bangladesh, Sri Lanka and India. However, no long run relationship was found between the two variables for Nepal, India and Sri Lanka.

Awokuse (2008) investigated the prevalence of export-led and import-led growth hypothesis in three Latin American countries (Peru, Colombia, Argentina) using a neoclassical production function and estimating it by multivariate co-integrating VAR. The findings were in support of import-led growth hypothesis as he found bidirectional and unidirectional causality running from imports to GDP growth for all three countries. However, impulse-response function provided support for export-led growth hypothesis for Argentina and Peru.

Bahmani-Oskee, *et al.* (1993) used panel data of 62 developing countries for the period 1960-1999. Their estimated results indicated co-integrating relationship between exports and GDP growth when GDP was taken as the dependent variable but the converse was not true. So their findings supported the export-led growth hypothesis. Giles and Williams (2000a, 2000b) tested export-led growth hypothesis with standard causality techniques. They discovered that Granger causality test was sensitive to the degree of deterministic component and to the method used to check non-stationarity.

Shirazi and Manap (2005) analysed imports, exports and GDP data of Pakistan for the period 1960-2003. They used Johansen co-integration technique and Toda and Yamamoto causality test for their analysis. They concluded that there existed long urn bidirectional relationship between imports and GDP, and unidirectional long run causality running from exports to GDP for the country.

2.3 Energy Consumption, Trade and GDP

There are few studies that simultaneously considered both energy consumption and trade as determinants of GDP and thus tried to highlight direct and indirect impacts of energy consumption on GDP. One such study was by Narayan and Smyth (2009) in which energy consumption was approximated by electricity used. Its results suggested a statistically significant long run feedback relationship or two-way causality between GDP, electricity used and exports for a panel of Middle Eastern countries. For the short run, they found unidirectional causality running from electricity used to GDP and from GDP to exports.

Another similar study by Lean and Smyth (2010a) identified capital, labor, electricity consumption and exports as the determinants of GDP and used annual data from 1970 to 2008 for Malaysia. The empirical results indicated unidirectional causality running from electricity consumption to exports. Therefore, the authors supported export-led growth hypothesis for the country. Yet another study by the same authors, Lean and Smyth (2010b), noted unidirectional causality running from GDP growth to electricity generation but found no causal relationship between exports and electricity generation. Thus, the latter study supported neither export-led growth hypothesis nor growth-led exports hypothesis for Malaysia.

Sadorsky (2011a) noted unidirectional short run Granger causality running from exports to energy consumption while a bidirectional Granger causality between energy consumption and imports and between energy consumption and GDP for a panel of eight Middle Eastern countries. In his subsequent research, Sadrosky (2011b) analysed corresponding data for seven South American countries and found a long run relationship between GDP, labor, capital and trade while short run results showed a feedback relationship for export and energy consumption and unidirectional causality running from energy to imports.

It is clear from all these studies that energy consumption has either unidirectional or bidirectional relationship with GDP and with trade/exports showing vital importance of energy consumption for formulation of trade and energy policies of any country. Therefore, the present study contributes to the literature by investigating both direct and indirect impacts of energy consumption on GDP of South Asian economies because there is little or no empirical research on this topic for this region.

3. ANALYTICAL FRAMEWORK AND DESCRIPTIVE ANALYSIS

This section is divided into two parts; analytical framework and descriptive analysis.

3.1. Analytical Framework

Sadorsky (2011b) modeled capital, labor, energy consumption and trade as the main determinants of GDP. He analysed the data of seven South American economies. The present study uses the same model and same variables for five South Asian economies. There is one exception that trade has been replaced with exports. The countries included in this study are Pakistan (PAK), Bangladesh (BAN), Sri Lanka (SRI), India (IND) and Nepal (NEP). Initially the objective was to include all the seven countries, which are currently members of SAARC in our study but due to data limitations for Bhutan and Maldives, these two countries were dropped. The data set is for the period of thirty years from 1980 to 2009.

$$Y = f(K, L, E, T) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.1)$$

Y denotes GDP at 2000 prices in US dollars; *K* denotes capital that has been represented by gross fixed capital formation at 2000 prices in US dollars; L represents labor force that includes both employed workers and unemployed ones looking for jobs, *E* represents energy that has been measured by energy consumption in kilo tons of oil equivalents and *T* is used for exports at 2000 prices in US dollars. Data on the first four variables have been taken from the World Bank CD-ROM 2012, which is also available in the World Development Indicators 2012, whereas data on exports was available in nominal terms only from the same source. Therefore, to convert data on exports at 2000 prices in US dollars, we used consumer price index of respective countries given in the Penn World Table version 7.1.

Assuming that the functional form is non-linear like the one of Cobb-Douglas type production functions, we have taken natural logarithms to convert the function into its linear form. For its estimation, we have added an error term with usual property of being independently and identically equal to zero on the average and a constant term (s_i) to represent the fixed country effect as given below:

$$y_{it} = \alpha_1 k_{it} + \alpha_2 l_{it} + \alpha_3 e_{it} + \alpha_4 t_{it} + s_i + \varepsilon_{it} \quad \ldots \quad \ldots \quad \ldots \quad (3.2)$$

3.2. Descriptive Analysis

To see the average trend of all variables in the model, we have calculated average annual growth rates of the variables over the period of 1980-2009 and presented them in Table 1.

Table 1

Average Annual Growth Rates of Variables in the Model Over 1980-2009

Country	Energy Consumption	Real GDP	Real Fixed Capital Formation	Labour	Real Exports
Bangladesh	4.47	4.74	7.78	2.73	13.21
India	4.21	6.09	8.55	2.63	14.36
Pakistan	4.38	4.99	4.33	3.25	8.87
Sri Lanka	2.57	4.77	4.40	1.18	7.67
Nepal	2.74	4.56	0.85	2.90	9.28

All the variables have positive growth rates over this period. Average annual growth rate of energy consumption ranges from the lowest value of 2.57 percent for Sri Lanka to the highest value of 4.47 percent for Bangladesh. It is more than 4 percent for Bangladesh, India and Pakistan and more than 2.5 percent for Sri Lanka and Nepal. For Pakistan and Bangladesh average annual growth rates of energy consumption are almost equal to their average annual growth rates of real GDP, while for the remaining countries, average annual growth rates of energy consumption are significantly less than their corresponding growth rates of real GDP. India stands out for having the highest average annual growth rate of real GDP while all remaining countries have almost same rate that is 4 percent. Bangladesh and India are the countries having double-digit average annual growth rates in their exports. To have an idea of the sign and magnitude of estimated coefficients of independent variables, we have prepared the correlations matrix for their first differences as given in Table 2.

Table 2

Correlation Matrix for Variables in the Model

Variable	ΔGDP	ΔK	ΔL	ΔE	ΔT
ΔGDP	1				
ΔK	0.399*	1			
ΔL	–0.019	0.027	1		
ΔE	0.264*	0.184*	0.106	1	
ΔT	0.261*	0.120	–0.002	0.203*	1

The asterisk (*) shows that correlation coefficient between two variables is significant at 5 percent.

The correlation coefficients between GDP and energy consumption, between GDP and exports, and between exports and energy consumption are all positive and significant. This suggests that energy is closely linked with GDP and exports. As exports are significantly correlated with GDP too; it points out to indirect impact of energy consumption on GDP. The correlation coefficient between GDP and capital is also significant that shows that capital is a crucial factor to explain GDP of a country. However, the correlation coefficient between capital and exports is though positive, yet it is insignificant. It means that capital has little indirect multiplier effect on GDP of a country through exports. The correlation coefficient between GDP and labor is positive but insignificant and between exports and labor is negative and insignificant statistically. This suggests that labor is no more a binding input for GDP and exports of a country. The reason could be relatively high rate of unemployment in these countries.

4. METHODOLOGY AND DATA CONSTRUCTION

This section is divided in four parts. The first part explains three alternative unit root tests to check the stationarity of data. The second part discusses co-integration test. The third part gives details of Granger causality test. The last part explains dynamic OLS estimation technique.

4.1. Alternative Unit Root Tests

The first step is to check co-integration among the variables of a model in order to ensure that the order of integration of the variables is same. So for this purpose, following two types of panel unit root tests have been used.

Im, Pesaran, and Shin (IPS) (2003), modified Levin, *et al.* (2002) (LL) test by allowing the coefficient of the lagged dependent variable to be heterogeneous. They proposed a test based on the average of single unit root test statistics. IPS test is different from LL test with respect to the alternative hypothesis as LL test assumes common unit root process while IPS assumes individual unit root process.

Maddala and Wu (1999) (MW) proposed a model, which can be estimated with an unbalanced panel and they also preferred heterogeneous alternative. MW type test performs well as compared to LL or IPS test when errors of different cross section units are cross correlated. Furthermore, MW has a small size distortion when T (time period) is large and N (cross section) is small.

In all of the tests, if the results do not reject the null hypothesis at standard significance levels in level form for any variable but reject the null hypothesis for the same variable in the difference form then this variable would be declared as non-stationary or integrated of order one i.e., I(1).

4.2. Panel Co-integration Test

According to the definition of Engle and Granger (1987), if any two variables x or y are integrated of same order (one or more) and if we estimate them by OLS and their residuals u_t are found to be stationary (or their order of integration is one less than those of the estimated variables) then they are said to be co-integrated and have a long run equilibrium relationship. Using the same approach of testing the non-stationarity properties of the residual from ordinary regression of the variables, Pedroni (1999, 2004) extended the above approach to panel data. For time series data, panel co-integration approach leads to more precise and reliable estimates. Panel framework is particularly preferable when sample size of each cross sectional unit is short because we can increase sample size and degrees of freedom by combining different cross sectional units.

Following panel co-integration approach adopted first by Pedroni, Equation (3.2) is estimated by OLS for each of the five countries. Then their residuals are worked out to estimate the following equation:

$$\mu_{it} = \rho_i \mu_{it-1} + \varepsilon_{it} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4.1)$$

In this equation, ρ_i refers to the autoregressive parameter and ε_{it} are the stationary error terms. The null hypothesis of co-integration test is:

H_0: ρ_i= 1, where I = 1,…..,6

The acceptance of the above hypothesis means that there is no co-integration among the cross sections of the panel. Pedroni has provided seven statistics to test null hypothesis of no co-integration.

The test is divided into two categories with respect to the alternative hypothesis. The first category is called within-dimension (panel test) in which the AR coefficient across the cross sectional units of the panel are pooled to apply unit root test on the residuals obtained by the procedure described above. There are four tests with respect to within-dimension category and these tests involve calculating the average test statistics for each country in the panel. These four tests called panel-v, panel-PP-ρ panel-PP-t and panel-ADF-t give us four statistics and the alternative hypothesis for all these statistics is as follows:

H_1: $(\rho_i = \rho) < 1$, where i=1,…..,N

The second category is called between-dimension (group-means approach) in which autoregressive coefficients are averaged for each country of the panel to apply unit root test on the residuals obtained by estimating Equation (3.2) by OLS method. For the between-dimension approach, averaging is done in pieces and it includes group-PP-ρ statistic, the group-PP-t statistic and group-ADF-t statistic. The alternative hypothesis for these 3 tests is as follows:

H_1: $\rho_i =< 1$, where i=1,…..,N

So the null hypothesis is same for both categories but the alternative hypothesis is different for within-dimension and between-dimension categories. The group-means or between-dimension test is considered less restrictive as it does not put a condition on the value of ρ to be common for all cross sections in the alternative hypothesis so this allows more heterogeneity of the parameters across the countries of the panel.

4.3. Panel Granger Causality Test

If there is found evidence in support of the co-integration relationship among the variables, then there exists an error correction mechanism by which a variable is adjusted towards its long run equilibrium. Following the approach of Engle and Granger (1987), we can estimate the error correction model (ECM) for the panel. With this approach, a change in the dependent variable is estimated with the level of the disequilibrium in the co-integration relationship and other independent variables. The estimation is done with independent variables in difference form with appropriate lag lengths. Further, there exists Granger causality in at least one direction, if a co-integration relationship is found between a set of variables. The panel VECM for Equation (3.2) is written as follows:

$$\Delta y_{it} = \propto_{1i} + \sum_{j=1}^{p} \beta_{11ij}\, \Delta y_{it-j} + \sum_{j=1}^{p} \beta_{12ij}\, \Delta k_{it-j} + \sum_{j=1}^{p} \beta_{13}\, \Delta l_{it-j} + \sum_{j=1}^{p} \beta_{14}\, \Delta e_{it-j} + \sum_{j=1}^{p} \beta_{15}\, \Delta t_{it-j} + \beta_{16i}\mu_{it-1} + \omega_{1it} \quad \ldots \quad \ldots (4.2a)$$

$$\Delta k_{it} = \propto_{2i} + \sum_{j=1}^{p} \beta_{21ij}\, \Delta y_{it-j} + \sum_{j=1}^{p} \beta_{22ij}\, \Delta k_{it-j} + \sum_{j=1}^{p} \beta_{23}\, \Delta l_{it-j} + \sum_{j=1}^{p} \beta_{24}\, \Delta e_{it-j} + \sum_{j=1}^{p} \beta_{25}\, \Delta t_{it-j} + \beta_{26i}\mu_{it-1} + \omega_{2it} \quad \ldots \quad \ldots (4.2b)$$

$$\Delta l_{it} = \propto_{3i} + \sum_{j=1}^{p} \beta_{31ij}\, \Delta y_{it-j} + \sum_{j=1}^{p} \beta_{32ij}\, \Delta k_{it-j} + \sum_{j=1}^{p} \beta_{33}\, \Delta l_{it-j} + \sum_{j=1}^{p} \beta_{34}\, \Delta e_{it-j} + \sum_{j=1}^{p} \beta_{35}\, \Delta t_{it-j} + \beta_{36i}\mu_{it-1} + \omega_{3it} \quad \ldots \quad \ldots (4.2c)$$

$$\Delta e_{it} = \propto_{4i} + \sum_{j=1}^{p} \beta_{41ij}\, \Delta y_{it-j} + \sum_{j=1}^{p} \beta_{42ij}\, \Delta k_{it-j} + \sum_{j=1}^{p} \beta_{43}\, \Delta l_{it-j} + \sum_{j=1}^{p} \beta_{44}\, \Delta e_{it-j} + \sum_{j=1}^{p} \beta_{45}\, \Delta t_{it-j} + \beta_{46i}\mu_{it-1} + \omega_{4it} \quad \ldots \quad \ldots (4.2d)$$

$$\Delta t_{it} = \propto_{5i} + \sum_{j=1}^{p} \beta_{51ij}\, \Delta y_{it-j} + \sum_{j=1}^{p} \beta_{52ij}\, \Delta k_{it-j} + \sum_{j=1}^{p} \beta_{53}\, \Delta l_{it-j} + \sum_{j=1}^{p} \beta_{54}\, \Delta e_{it-j} + \sum_{j=1}^{p} \beta_{55}\, \Delta t_{it-j} + \beta_{56i}\mu_{it-1} + \omega_{5it} \quad \ldots \quad \ldots (4.2e)$$

In all of the above Equations from (4.2a) to (4.2e), the Δ is used to show the first difference operator, p is the appropriate lag length, y is the real output, k is the real fixed capital formation, l is the labor force, e is the real energy consumption, t is the trade variable (measured by real exports) and all of the above variables are in natural logarithm form, μ is the lagged error correction term and it is obtained by the residual estimated from Equation (3.2) for each country and ω shows the random disturbance terms. The panel VECM is obtained by using OLS with panel corrected standard errors. The coefficients of the lagged difference explanatory variables show the short run dynamics and they are used to interpret the short run Granger causality relationship among the variables while for the long run Granger causality interpretation, adjustment coefficients of the lagged error correction terms are used.

4.4. Dynamic OLS (DOLS)

In case of the above panel co-integration test, if there is an indication for a significant co-integrating relationship, then estimation of Equation (3.2) is also recommended and its estimates show long run elasticities. However, estimation of panel data by OLS method gives asymptomatically biased estimators and their distribution depends on the nuisance parameters. Pedroni (2000, 2001) documented that nuisance parameters are the regressors that could generate unwanted endogeneity and serial correlation although they are not part of the true data generating process. So to address the problem of endogeneity and serial correlation, Pedroni (2000) proposed dynamic OLS (DOLS) method. Pedroni (2001) further modified DOLS method to handle panel data in the presence of nuisance parameters and called it fully modified dynamic OLS (FMOLS) method.

FMOLS employs a non-parametric correction to deal with endogeneity and serial correlation problem, whereas DOLS employs a parametric correction by adding leads and lags dynamics of the right hand side variables. FMOLS is preferred over DOLS in small samples as DOLS consumes more degrees of freedom than FMOLS but in large samples both methods are equally good. Since sample size of this research is sufficiently large, therefore only DOLS method has been used. The DOLS equation is written as:

$$y_{it=} \alpha_{ki}k_{it} + \alpha_{li}l_{it} + \alpha_{ei}e_{it} + \alpha_{ti}t_{it} + \sum_{j=1}^{p}\beta_{k1ij}\,\Delta k_{it-j} + \sum_{j=1}^{p}\beta_{l1ij}\,\Delta l_{it-j} + \sum_{j=1}^{p}\beta_{e1ij}\,\Delta e_{it-j} + \sum_{j=1}^{p}\beta_{t1ij}\,\Delta t_{it-j} + s_i + \varepsilon_{it} \quad \ldots \quad \ldots \quad \ldots \quad (4.3)$$

Here p shows the lag length, s_i is the country specific fixed effect and ε_{it} is the random error term.

5. EMPIRICAL RESULTS AND DISCUSSION

This section is divided in four parts. The first part presents and interprets the results of panel unit root tests; the second part discusses the results of co-integration test, the third part gives details of Granger causality test and the last section reports results of DOLS or elasticities of variables.

5.1. Results of Panel Unit Root (Stationarity) Tests

The results of all the panel unit root tests on the variables in level form and in first difference form are reported side by side in Table 3.

Table 3

Results of Panel Unit Root Tests

Method	Y	Δy	k	Δk	L	Δl	e	Δe	x	Δe
Im, Pesaran and Shin	6.33	–4.73	3.08	–4.48	3.52	–3.55	3.12	–5.60	1.95	–4.16
W-stat	(1.00)	(0.00)	(0.99)	(0.00)	(0.99)	(0.00)	(0.99)	(0.00)	(0.97)	(0.00)
ADF - Fisher Chi-square	1.378	42.99	3.15	38.5	5.17	32.92	4.38	50.69	4.77	37.00
	(0.99)	(0.00)	(0.97)	(0.00)	(0.87)	(0.00)	(0.92)	(0.00)	(0.90)	(0.00)
PP - Fisher Chi-square	7.62	67.77	3.117	76.16	24.11	73.37	13.45	92.47	7.21	101.4
	(0.66)	(0.00)	(0.97)	(0.00)	(0.00)	(0.00)	(0.19)	(0.00)	(0.70)	(0.00)

Probability value for each test is given in parentheses below its test-statistic. Im, Pesaran and Shin test assumes an asymptotic normal distribution while the other two tests assume an asymptotic Chi-square distribution.

The results of all three tests run for level form accept the null hypothesis of unit root as p-values of their test-statistics are greater than 0.05 except for labour as indicated by PP-Fisher Chi-square test, while results based on difference form reject the null hypothesis of unit roots as p-values of their test-statistics are less than 0.05. It means that at level, all the variables are integrated of order one and at their first difference, they are integrated of order zero. It implies that these variables have a long run equilibrium relationship or they are co-integrated.

5.2. Results of Panel Co-integration Test

The results of panel co-integration test both for within-dimension and between-dimension categories are shown in Table 4.

Table 4

Panel Co-integration Test Result

Test	Test-statistic	Probability	Test	Test-statistic	Probability
Panel v-statistic	–0.688822	0.7545	Group rho-statistic	0.700439	0.7582
Panel rho-statistic	–0.912894	0.1806	Group PP-statistic	–1.694875	0.0450
Panel PP-statistic	–3.382694	0.0004	Group ADF-statistic	–0.528387	0.2986
Panel ADF-statistic	–1.483608	0.0690			

Note: The null hypothesis for all these seven tests-statistics is that there is no co-integration among the variables.

To test co-integration among the variables, first Equation 3.2 was estimated and then seven test-statistics; four for within-dimension or panel test-statistics and three for between-dimension or group test-statistics as suggested by Pedroni were calculated. The probabilities for panel PP, panel ADF and group PP test-statistics are less than 0.1; therefore these tests reject the null hypothesis of no co-integration at 10 percent level of significance, whereas panel-v and panel rho, and group rho and group ADF accept the null hypothesis. Since four tests accept the hypothesis and three reject if, therefore, it may be concluded that there is a co-integration relationship between real GDP, real fixed capital formation, labor, energy consumption and exports or the residuals from Equation (3.2) are stationary.

5.3. Results of Granger Causality Test

To determine the direction of Granger causality between GDP, energy consumption, labor, capital and exports, first we estimated Equation (3.2) for each country separately. Then we worked out their residuals and saved them. Finally using the saved residuals, we estimated Equations (4.2a) to (4.2e) outlined in Section 4.3. The results are reported in Table 5.

Table 5

Results of Granger Causality

To	From Δy	Δk	Δl	Δe	Δx
Δy		4.49 (0.00)	–0.94 (0.34)	3.06 (0.00)	2.37 (0.01)
Δk	4.82 (0.00)		0.61 (0.54)	0.85 (0.39)	–0.10 (0.92)
Δl	–0.95 (0.34)	0.60 (0.54)		1.30 (0.19)	–0.20 (0.84)
Δe	3.18 (0.00)	0.85 (0.39)	1.31 (0.19)		1.65 (0.10)
Δx	2.47 (0.01)	–0.20 (0.92)	–0.10 (0.84)	1.64 (0.10)	
μ_{t-1}	–4.43 (0.00)	1.50 (0.13)	–0.91 (0.36)	2.26 (0.02)	0.15 (0.87)
Speed of Adjustment	–.445133	.803		–.075	.326

Probability value for each test is given in parentheses below its test-statistic.

All rows in this table except the last one show t-statistics of respective variables, whereas the last row contains coefficients of lagged error correction terms, which show speed of adjustment towards long run equilibrium after any shock.

The results of short run Granger causality test show that there exist feedback relationships between energy consumption and GDP, between trade and GDP, between capital and GDP, and between energy consumption and exports. The first three relationships are significant at 1 percent and the last one is significant at 10 percent level of significance. For other variables, the results are not significant statistically implying no Granger causality relationships.

For the long run Granger causality relationship to exist, coefficients of lagged error correction term need to be significant. For Equation (4.2a) with GDP as dependent variable, the coefficient of the lagged error term has a value of –0.44 that is significant at 1 percent level of significance. It means that 44 percent of a given variation due to any shock is driven back to long run equilibrium in the first year and 44 percent of the remaining error is corrected in the next year and so on. So there is evidence of long run Granger causality running from capital, labor, energy consumption and exports to GDP.

Similarly Equation (4.2d) with energy consumption as dependent variable shows that the coefficient of the lagged error term has a value of 0.32 that is significant at 1 percent level of significance. So there is evidence of long run Granger causality running from capital, labour, exports and GDP to energy consumption. Equations (4.2b), (4.2c) and (4.2e) indicate that the coefficients of lagged error correction terms are not significant implying no long run causality between respective variables on the left-hand side and the ones on the right-hand side.

The results confirm feedback relationship between exports and GDP in the short run and unidirectional relationship running from exports to GDP in the long run. This supports export-led growth hypothesis both in short and long runs and growth-led exports hypothesis only in the short run for the South Asian region. This finding is similar to that of Kemal, *et al.* (2002). The feedback relationship between capital and GDP suggests that capital formation is also an important determinant of GDP in the short run and vice versa. Moreover, evidence of feedback relationship between energy consumption and GDP suggests that energy is a limiting factor to GDP growth and GDP is an important factor in explaining changes in energy consumption both in short and long runs. This finding is similar to the one derived from Noor and Siddiqi (2010). It suggests that energy shortfall adversely affects GDP growth in the South Asian region.

5.4. Results of DOLS or Long Run Elasticities

Table 6 contains the results of DOLS estimation of Equation (4.3). Since the equation is in log linear form, therefore its estimated coefficients show elasticities of dependent variable with respect to corresponding independent variables.

Table 6

DOLS Results

Dependent Variable = y Coefficient		t	P - value
k	0.113	2.31	0.021
l	0.514	2.04	0.041
e	0.328	1.30	0.202
x	0.270	5.57	0.000

The sign of all coefficients is positive as expected. However, coefficients of capital, labour and exports are 0.11, 0.51 and 0.27 that are statistically significant at 5 percent level while coefficient of energy is 0.32 that is insignificant even at the 10 percent level of significance. This means that one percent increase in capital increases GDP by 0.11 percent; one percent increase in labor increases GDP by 0.51 percent and one percent increase in exports increases GDP by 0.27 percent.

The results of DOLS suggest that energy is insignificant in explaining GDP in the long run. It is in contradiction with positive correlation coefficient between energy consumption and GDP that is statistically significant as reported in descriptive analysis in section 3.2. It is however less peculiar than the findings of Noor and Siddiqi (2010) who reported a negative relationship between energy and GDP for the South Asian countries. A possible reason could be that energy consumption has gained importance in explaining GDP only recently. That is, in earlier years of panel data, energy might not have been so crucial input.

6. CONCLUSION AND POLICY IMPLICATIONS

The purpose of present study was to investigate the dual role of energy consumption for economic activity of a country; its direct impact on GDP as a crucial input for every production process and its indirect impact as an important input in the industry of exportable goods which, if increased, affect the GDP through multiplier effect in subsequent periods. For this purpose, we used panel data of five South Asian economies (Bangladesh, India, Pakistan, Sri Lanka and Nepal) for the period 1980–2009. In addition to energy consumption and exports, we used capital stock and labor force as other explanatory variables of GDP. We used panel co-integration approach with Granger causality test.

The results of our estimation support the feedback relationship or two-way causality between energy consumption and GDP, between trade and GDP, and between energy consumption and exports for the short run. However, in the long run, the feedback relationship between energy consumption and GDP is confirmed but for other variables, it is unidirectional such that arrow of causality runs from exports to energy consumption and exports to GDP. It means that any shortage of energy supplies or any energy conservation policy that decreases energy consumption in the current period adversely affects GDP and exports. Any reduction in exports, in turn, hampers competitiveness of the country in international markets that may take years to get back at the par. It means that benefits of export promotion and trade liberalisation policies may be offset if there is shortage of energy supply in a country.

One of the policy implications of the causal linkages among crucial variables of this research is that policies to ensure uninterrupted supply of energy should be given priority over export promotion and trade liberalisation policies. Otherwise if trade liberalisation policies are implemented before formulating suitable energy policies, then competitiveness of the country in the international market will deteriorate and benefits of trade policies may be reversed. Another implication is that protectionist policies for trade are not advisable if sufficient supply of energy is ensured. To sum up, trade liberalisation policies are beneficial for South Asian countries provided that they develop new resources of energy production such as construction of dams, solar panels, and wind power plants to fulfill energy demand.

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