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An econometric study of energy consumption, carbon emissions and economic growth in South Asia: 1972-2009

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Abstract

Purpose – The purpose of this paper is to empirically examine the relationship between energy consumption, carbon emissions and economic growth for a panel of five South Asian economies namely India, Pakistan, Bangladesh, Sri Lanka and Nepal over the period 1972-2009 within multivariate framework.

Design/methodology/approach – The study uses Pedroni cointegration and Granger causality test based on panel vector error correction model to examine long-run equilibrium relationship and direction of causation in short run and long run between energy consumption, carbon emissions and economic growth in South Asia.

Findings – Cointegration result indicates the long-run equilibrium relationship between economic growth, energy consumption and carbon emissions for panel. Causality results suggest that bidirectional causality exist between energy consumption-GDP, and unidirectional causality from carbon emissions to GDP and energy consumption in long run. However, energy consumption causes carbon emissions in short run.

Practical implications – Implementing energy efficiency measures and reducing dependence on fossils fuels by scaling up carbon free energy resources like nuclear, renewables including hydropower in energy mix is necessary for sustainable and inclusive growth in the region.

Originality/value – South Asia economies need to sacrifice economic growth for reducing the carbon emissions in long run if the region dependence on fossils fuels including coal, oil and natural gas in energy mix continues at same pace.

Keywords Carbon emissions, Economic growth, Causality, Energy consumption, South Asia, Panel VECM

Paper type Research paper

1. Introduction

Environmental pollution, global warming and extreme climate change primarily due to ever-increasing carbon dioxide and other greenhouse gas emissions[1] has become major concern worldwide. Carbon dioxide alone accounts for nearly 60 per cent greenhouse gas emitted to the atmosphere. Acting on this concern, international communities through Kyoto Protocol in 1997 called for reduction of greenhouse gas emissions in 37 developed (Annex 1) economies to 5.20 per cent lower than 1990 level during 2008-2012. This came in to effect from 2005. However, Kyoto protocol does require monitoring and reporting GHG emissions without reducing GHG emissions for developing (Non-Annex 1) economies and further notified by Doha conference – 2012. Although all South Asian countries including India, Pakistan, Bangladesh, Sri Lanka and Nepal have ratified the Kyoto protocol (currently ratified by more than 190 countries) to reduce emissions levels as it allow to access the technology transfer and related foreign investments for adaptation projects.

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Rapid population and economic growth in the South Asia have primarily responsible for increased energy consumption in the last decades. The region heavenly depends upon fossils[2] fuels for its energy needs in spite of very high potential of hydro[3] and renewable energy (World Bank, 2013). This has lead into higher carbon emissions and energy imports up to the quarter of gross energy needs in South Asia (See Table I). Still 600 million people don't have the access of the electricity at all. Power outage of an average of 10-12 hours per day and energy supply shortage in Bangladesh, Pakistan and Nepal are hurting their growth momentum. Apart from expected robust growth in the region, ambitious development plans like "Power for All by 2013", "Rajeev Gandhi Grameen Vidyutikaran Yojna" in India or Millennium Development Programme initiatives in other countries will further increase energy consumption in near future.

Reduction of carbon emissions is feasible either through reducing energy consumption directly or switching to carbon free energy[4] in phased manner in a technically and resource constraint economies. Reducing energy consumption may affects the economic prospects of these economies adversely as energy is considered to be direct input to production or complements the labour or capital in production process. Therefore, examining the relationship between energy consumption, carbon emissions and economic growth is vital for shaping environmental and energy policy formulation for sustainable development.

Generally, the relationship between economic growth, carbon emissions and energy consumption has been examined empirically by various researchers in the three research strands. First strand focuses on the carbon emissions and economic growth linkage, i.e. validating the environmental Kuznets curve (EKC) hypothesis. EKC postulates that there is an inverse *U*-shaped relationship between income and environmental pollutants. It explains that environmental degradation increases with the increase in income until a threshold point and then it declines with a corresponding increase in income. However, empirical results[5] on EKC hypothesis remain debatable and inconclusive till date.

Second approach investigates the relationship between energy consumption and economic growth nexus under four testable hypothesis namely growth, conservation,

Indicators	South Asia	World	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Energy use per capita (kt of oil equivalent)	518.87	1,787.91	196.80	567.32	375.26	494.27	444.44
CO_2 emissions (metric tons per capita)	1.40	4.71	0.34	1.66	0.13	0.95	0.62
Fossil fuel energy consumption (% of total)	70.52	80.76	70.21	72.76	11.04	62.55	43.80
Access to electricity (% of population)	62.36	74.12	41.00	66.30	43.60	62.40	76.60
Energy imports, net (% of energy use)	24.78	−3.53	16.38	25.15	11.44	24.30	43.80
Electricity production from coal, oil and natural gas sources (% of total)	82.07	66.65	95.90	84.26	0.42	67.52	60.29
Population, total (in millions)	1,585.46	6,805.25	149.50	1,190.14	26.54	170.09	20.45

Source: World Bank (2013)

Table I. Summary of energy sector indicators in South Asia, 2009 feedback and neutrality. Since the seminal study of Kraft and Kraft (1978), various studies[6] have analysed the relationship between energy consumption and economic growth using cointegration and Granger causality. However, conflicting results of these studies may be attributed to different time period, country-specific policies, econometric methodologies employed, omitted variable bias, model specification and level of economic development.

Lastly third strand, a combination of the first two strands validates the dynamics between energy consumption, carbon emissions and economic growth simultaneously. Related empirical literatures[7] are listed in Table II. Studies specifically related to South Asian context have been briefly discussed below. Chary and Bohara (2010) examined the causal relationship between carbon emissions, energy consumption and income for four SAARC countries over the period 1971-2006. They found that energy consumption and income together Granger cause carbon emissions in India, Pakistan, Bangladesh and Nepal. Further, they supported growth hypothesis in case of Nepal, and conservation hypothesis for Pakistan and Bangladesh.

Ghosh (2010) analyzed the dynamic relationship between carbon emissions, energy consumption and income after incorporating real investment and employment for India over the period 1971-2006 using autoregressive distribution lag cointegration and causality. Study confirmed the absence of long-run causality between carbon emissions-national income. However, bidirectional causality between carbon emissions-national income, unidirectional causality from national income to energy supply and energy supply to carbon emissions exists in short run. Using Toda-Yamamoto (TY) procedure, Alam *et al.* (2011) investigated the causal relationship between carbon emissions, energy consumption and economic growth after incorporating capital formation and labour for India during 1971-2006. The study revealed bidirectional causality between energy consumption and carbon emissions, while no causality between energy consumption-economic growth and income-carbon emissions in either direction.

Nasir and Ur Rehman (2011) examined the relationship between per capita carbon emissions, per capita energy consumption and per capita GDP after incorporating trade openness for Pakistan during 1972-2008 using Johansen cointegration and vector error correction model (VECM). They confirmed that EKC holds for Pakistan and unidirectional causality runs from per capita GDP to per capita energy consumption and per capita carbon emissions in long run. Using same methodologies, Alam *et al.* (2012) confirmed the bidirectional causality between energy consumption-carbon emissions and electricity consumption-economic growth; and unidirectional causality from energy consumption and carbon emissions to economic growth in long run for Bangladesh during 1972-2006.

The goal of this paper is to examine the dynamic relationship between energy consumption, carbon emissions and economic growth for a panel of five South Asian countries namely India, Pakistan, Bangladesh, Sri Lanka and Nepal over the period 1972-2009. The novelty of our work is fourfold. To best of my knowledge, this is the first study to consider five major South Asian countries namely India, Pakistan, Bangladesh, Sri Lanka and Nepal to investigate the causal relationship between energy consumption, carbon emissions and economic growth within panel framework with longer data sets. Second, given the relatively limited time series data, usually 30-40 observations on energy consumption and carbon emissions that reduces the power and size properties of conventional unit root and cointegration techniques. This study uses panel unit root and cointegration techniques, which yields additional power by combining the cross-section and time series data while allowing for heterogeneity across countries.

Authors	Country	Variables	Methodology	Conclusion
Soytas *et al.* (2007)	USA (1960-2004)	GDP, energy consumption, carbon emission, labor forces and gross fixed capital formation	Toda-Yamamoto (TY) procedure	GDP $\neq$ CO_2 EC $\neq$ GDP EC $\rightarrow$ CO_2
Ang (2008)	Malaysia (1971-1999)	GDP per capita, energy consumption, CO_2 emission	VEC Granger causality, JJ cointegration	GDPP $\rightarrow$ EC CO_2 $\rightarrow$ GDPP
Soytas and Sari (2009)	Turkey (1960-2000)	Energy consumption, output, carbon emission, labor forces and gross fixed capital formation	Toda-Yamamoto (TY) procedure	GDP $\neq$ CO_2 CO_2 $\rightarrow$ EC
Zhang and Cheng (2009)	China (1960-2007)	GDP, gross fixed capital formation, energy consumption, CO_2 emission, urban population	Toda-Yamamoto (TY) procedure, generalized impulse response	GDP $\rightarrow$ EC EC $\rightarrow$ CO_2
Halicioglu (2009)	Turkey (1960-2005)	CO_2 emission, energy consumption, per capita income, foreign trade	Granger causality, ARDL cointegration	CO_2 $\leftrightarrow$ GDP EC $\neq$ GDP FT $\neq$ CO_2
Lean and Smyth (2010)	ASEAN (1980-2006)	CO_2 emission, electricity consumption, GDP per capita	Johansen Fisher cointegration, Panel VECM, Panel Granger causality	ELC $\rightarrow$ GDP CO_2 $\rightarrow$ GDP
Ozturk and Acaravci (2010)	Turkey (1968-2005)	GDP, CO_2 emission, energy consumption, employment	Granger causality, ARDL cointegration	EC $\neq$ GDP CO_2 $\neq$ GDP Employment $\rightarrow$ GDP
Pao and Tsai (2010)	BRIC (1971-2005)	GDP, CO_2 emission, energy consumption	Pedroni cointegration, Panel VECM, Panel Granger causality	EC $\leftrightarrow$ CO_2 EC $\leftrightarrow$ GDP CO_2 $\rightarrow$ GDP
Chang (2010)	China (1982-2004)	GDP, energy consumption, CO_2 emission	JJ cointegration, VECM, Granger causality	GDP $\leftrightarrow$ CO_2 EC $\leftrightarrow$ GDP EC $\rightarrow$ CO_2
Menyah and Wolde-Rufael (2010)	South Africa (1965-2006)	GDP, CO_2 emission, energy consumption, gross fixed capital formation, employment	Granger causality, ARDL cointegration	CO_2 $\rightarrow$ GDP EC $\rightarrow$ GDP EC $\rightarrow$ CO_2
Pao and Tsai (2011a, b)	Brazil (1980-2007)	CO_2 emission, energy consumption, GDP	JJ cointegration, Granger causality, Grey prediction model	GDP $\leftrightarrow$ CO_2 GDP $\leftrightarrow$ EC EC $\leftrightarrow$ CO_2
Pao *et al.* (2011)	Russia (1990-2007)	GDP, energy consumption, CO_2 emission	Granger causality, JJ cointegration, VECM	GDP $\leftrightarrow$ CO_2 GDP $\leftrightarrow$ EC EC $\leftrightarrow$ CO_2

Notes: $\leftrightarrow$, $\rightarrow$, $\neq$, is the bi-directional, uni directional and no causal relationship, respectively. VECM, JJ and ARDL denotes vector error correction model, Johansen- Juselius, and autoregressive distributed lag, respectively. GDP, EC and CO_2, indicates gross domestic product, energy consumption and carbon dioxide emission, respectively

Table II. Summary of literature review

Third, South Asian countries account for nearly one quarter of world population with about one-third of population below the poverty line (World Bank, 2013) where per capita energy consumption and carbon emissions in the region is even less than the one-third of world's average (See Table I). However, rapid population increase, urbanization and industrialization across the region in the recent past has increased energy consumption and carbon emissions significantly (by more than 5 and 7.6 per cent, respectively, on year on year basis), thus pushing carbon intensive development plan. For example, India is fifth largest consumer of energy after USA, China, Russia and Japan and fourth largest carbon dioxide emitter after USA, China and Russia. Fourth, current energy import for the region is almost quarter of gross needs (See Table I), putting serious implication for its energy security to achieve faster, inclusive and sustainable growth.

The remainder of the paper is organized as follows. Section 2 describes model and econometric methodology employed. Section 3 discusses the data and empirical results. Section 4 concludes the study.

2. Model and econometric methodology

This study analyses the relationship between energy consumption, carbon emissions and economic growth for a panel of five South Asian economies namely India, Pakistan, Bangladesh, Nepal and Sri Lanka over the period 1972-2009 within panel multivariate framework. For this purpose, study specifies the econometric model in log linear form as:

$$\log \mathrm{Y} = f(\log \mathrm{EC},\ \log \mathrm{CO_2}) \tag{1}$$

Log Y, EC, and CO_2, represents natural logarithm, real GDP, energy consumption and carbon emissions, respectively.

The methodology adopted for the analysis purpose consists of three-step procedure. In the first stage, panel unit root tests are employed to examine the order of integration of variables under consideration. In the second stage, panel cointegration test is applied to reveal the possible long-run equilibrium relationship among variables. Finally, panel error correction model is used to determine the direction of causality among variables in short run and long run.

2.1 Panel unit-root test

Before proceeding to cointegration analysis, study uses Levin *et al.* (2002) and Lm *et al.* (2003) unit root test (hereafter referred to as LLC and IPS test, respectively) to examine the order of integration of all variables namely energy consumption, carbon emissions and real GDP in a panel framework. Levin *et al.* (2002) is the most commonly used procedure based on the ADF test in homogenous panel settings. The basic equation for the LLC unit root test is as follows:

$$\Delta \mathrm{y_{it}} = \alpha_\mathrm{i} + \rho_\mathrm{i} \mathrm{y_{i,t-1}} + \sum_{\mathrm{j}=1}^{p} \varphi_\mathrm{ij} \Delta \mathrm{y_{i,t-1}} + \varepsilon_\mathrm{i,t} \tag{2}$$

Δ is first difference operator; $y_{i,t}$ is the series of observation for country i for the time period $t = 1, 2, \ldots, T$; α_i is the individual fixed effect; and ρ is selected to make the residuals uncorrelated over time. The null hypothesis for LLC test is $\rho_i = 0$ against the alternative of $\rho_\mathrm{i} < 0$ all i.

IPS test is an extension of LLC test by relaxing the homogeneous assumption and allows heterogeneity in the autoregressive coefficients for all panel cross sections.

2.2 Panel cointegration

The second step of our empirical analysis involves Pedroni's cointegration test to investigate the possible long-run relationship between energy consumption, carbon emissions and real GDP for the panel of five South Asian economies. The heterogeneous panel cointegration test advanced by Pedroni (1999, 2004) allows for cross-section interdependence with different individual effects. The empirical equation for the Pedroni cointegration is given as follows:

$$\left(\log \mathrm{Y}_{it} = \eta_i + \delta_i \mathrm{t} + \beta_{1i} \log \mathrm{EC}_{it} + \beta_{2i} \log \mathrm{CO}_{2_{it}} + \varepsilon_{it}\right) \quad (3)$$

$i = 1, 2, \ldots, N$ for each country in the panel and $t = 1, 2, \ldots, T$ refers to the time period. η_i and δ_i is country and time fixed effects, respectively. ε_it denotes the estimated residuals, which represent deviations from the long-run relationship.

Pedroni (1999) has proposed seven different statistics to test cointegration. Out of these seven statistics, first four (panel v-statistic, panel ρ-statistic, panel PP-statistic and panel ADF-statistic) are based on pooling, what is referred to as the "within" dimension. The last three (group ρ-statistic, group PP-statistic and group ADF-statistic) are based on the "between" dimension. The panel v-statistic is one-sided test where large positive value rejects the null of no cointegration. For the remaining statistics, large negative values reject the null of no cointegration.

2.3 Panel granger causality tests

Presence of cointegration among energy consumption, carbon emissions and real GDP implies the long-run relationship without indicating the direction of causation. We employ panel VECM to test short run as well as long run Granger causality. The dynamic error correction model is specified as follows:

$$\Delta \log \mathrm{Y}_{it} = \theta_{1i} + \sum_{i=1}^{p} \theta_{11ip}\, \Delta \log \mathrm{Y}_{it-p} + \sum_{i=1}^{p} \theta_{12ip}\, \Delta \log \mathrm{EC}_{it-p} + \sum_{i=1}^{p} \theta_{13ip}\, \Delta \log \mathrm{CO}_{2_{it-p}} + \phi_{1i}\, \mathrm{ECT}_{t-1} \quad (5)$$

$$\Delta \log \mathrm{EC}_{it} = \theta_{1i} + \sum_{i=1}^{p} \theta_{21ip}\, \Delta \log \mathrm{EC}_{it-p} + \sum_{i=1}^{p} \theta_{22ip}\, \Delta \log \mathrm{Y}_{it-p} + \sum_{i=1}^{p} \theta_{23ip}\, \Delta \log \mathrm{CO}_{2_{it-p}} + \phi_{2i}\, \mathrm{ECT}_{t-1} \quad (6)$$

$$\Delta \log \mathrm{CO}_{2it} = \theta_{1i} + \sum_{i=1}^{p} \theta_{31ip}\, \Delta \log \mathrm{CO}_{2_{it-p}} + \sum_{i=1}^{p} \theta_{32ip}\, \Delta \log \mathrm{Y}_{it-p} + \sum_{i=1}^{p} \theta_{33ip}\, \Delta \log \mathrm{EC}_{it-p} + \phi_{3i}\, \mathrm{ECT}_{t-1} \quad (7)$$

Here all variables are previously defined, Δ denotes first difference operator, p denotes the lag length and ECT is lagged error correction term (ECT) derived from long-run cointegrating relationship. The statistical significance of the first differenced variables provides the evidence on the direction of causality in short run. Long-run causality is explained by the significance of the *t*-statistic coefficients of ECTs (ϕ_{1i}, ϕ_{2i} and ϕ_{3i}).

3. Data and empirical results

This study uses annual data of total primary energy consumption (kt of oil equivalent), real GDP (at constant US$2,000 in millions), and total carbon dioxide emissions (kt of CO_2 equivalent) for the period of 1972-2009 obtained from World Development Indicators (World Bank 2013) as a proxy for energy consumption, economic growth and carbon emissions, respectively, for the South Asian countries based up on the common practices in the literature[8]. Following Soytas *et al.* (2007), study employed total data rather than per capita data as dividing the variables by population will only scale down the variables. Further, as the Kyoto protocol calls for a reduction in the percentage of emissions, Friedl and Getzner (2003) suggested the use of total emissions instead of per capita emissions. All data series are converted into the natural logarithms to reduce heterogeneity of data before empirical analysis. Figure 1 shows the data trend of each series (log Y, log EC and log CO_2) for South Asian countries during 1972-2009.

3.1 Panel unit root results

Empirical analysis begins with testing the stationarity of the variables within panel framework as a prerequisite for cointegration and Granger causality. Table III presents the results of LLC and IPS unit root tests for the level and first differenced series of the all three variables (log Y, log EC and log CO_2) used in the study. Results indicate that null hypothesis of a unit root cannot be rejected for LLC and IPS tests at level. However, after taking the first difference variables, both tests reject the null hypothesis at 1 per cent significance level. Thus, we conclude that all the series are non-stationary and integrated of order one, i.e. *I(1)*.

3.2 Panel cointegration results

Table IV presents the within and between dimension results of Pedroni panel cointegration tests. The results indicate that null hypothesis of no cointegration can not be rejected at 1 per cent significant level for all tests. Therefore, we conclude that there is long-run equilibrium relationship between variables, indicating that energy consumption, carbon emissions and GDP move together in long run for the panel.

3.3 Panel Granger causality results

Table V presents the results of the short run and long run Granger causality tests. The optimal lag length selection is based on the Schwarz information criterion. For the panel of five South Asian countries, there is no short run causality between energy consumption-real GDP, real GDP-carbon emissions in either direction. However, we find weak unidirectional causality from energy consumption to carbon emission (at 10 per cent significant level) in short run which means the South Asian countries have relatively higher proportion of carbon fuels in energy mix. Thus reducing fossils fuels consumption or implementing may help to reduce carbon emissions.

The long-run causality based on the statistical significance of the ECT in real GDP, and energy consumption equations shows bidirectional causality exist between energy consumption-real GDP, and unidirectional causality from carbon emissions to real GDP and energy consumption, respectively. Bidirectional Granger causality between energy consumption and economic growth indicates that energy consumption and economic

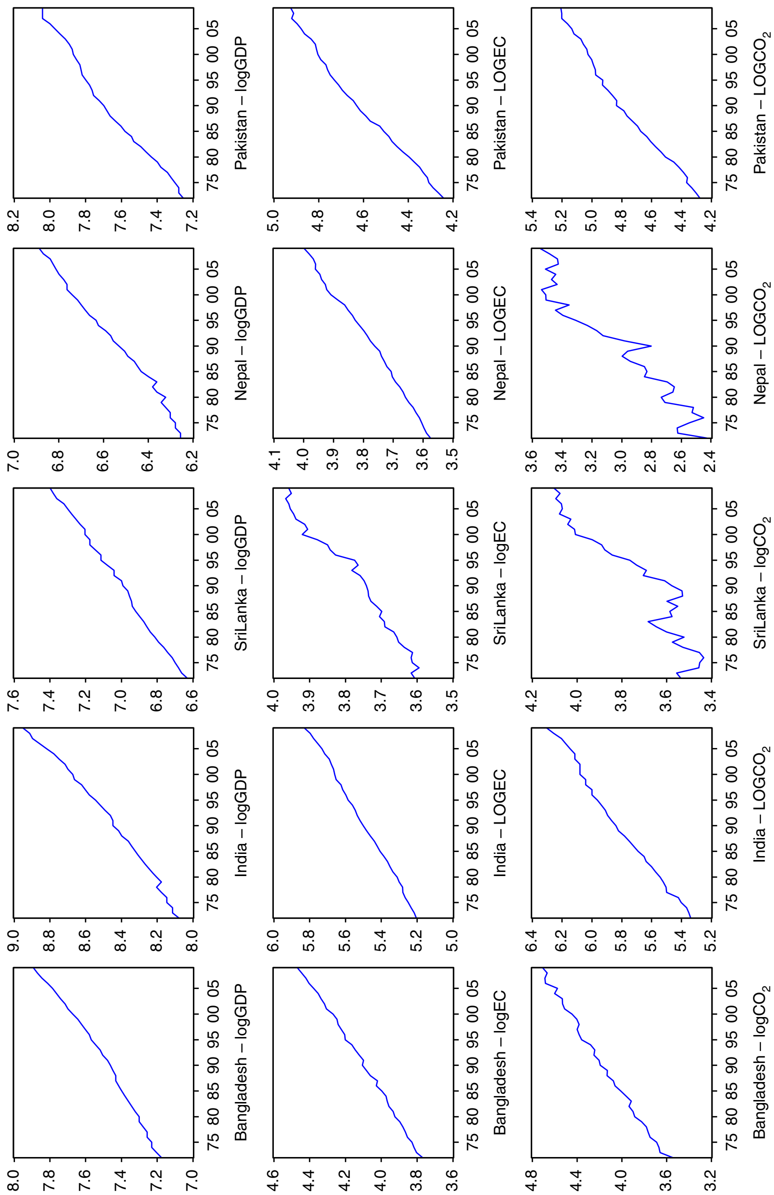

Figure 1.
Data trends for selected variables for individual South Asian countries, 1972-2009

growth are jointly determined and effected simultaneously. These South Asian countries as a panel are less energy dependent countries for its growth. Initially energy acts as a significant driver for economic growth, which in turn induces higher energy consumption due to higher economic activity and more dispensable income available to the people. Unidirectional causality from carbon emissions to economic growth indicates that higher carbon emissions promote economic growth. This shows the inability of South Asian countries towards reducing carbon emissions without sacrificing its economic growth in long run. Further, unidirectional causality from carbon emissions to energy consumption suggests that reducing fossils fuel consumption may help in regulating carbon emissions as regional dependence on coal, oil and natural gas for total primary energy supply and electricity production is much higher.

Table III.
Panel unit root test results

Tests	Levin, Lin and Chu (LLC) test		Im-Pesaran-Shin (IPS) test		Inference
Variables	At level	At 1st difference	At level	At 1st difference	
Log Y	3.9596	−3.0182*	7.0282	−7.0992*	I(1)
Log EC	1.1232	−6.3727*	4.4354	−7.2053*	I(1)
Log CO_2	−2.0924	−4.9491*	1.3709	−5.3320*	I(1)

Note: *Significant at 1 per cent level
Source: Author's estimation

Table IV.
Panel cointegration test results

Tests	Test statistic
Pedroni test	
Within dimension	
Panel v-stat	5.9270*
Panel ρ-stat	−3.1431*
Panel PP-stat	−4.7309*
Panel ADF-stat	−4.7466*
Between dimension	
Group ρ-stat	−1.9840**
Group PP-stat	−4.2605*
Group ADF-stat	−4.2735*

Notes: *,**Significant at 1 and 5 per cent level, respectively
Source: Author's estimation

Table V.
Selected results of Granger causality tests based on Panel VECM

		Short run		Long run
Dependent variable	Δlog Y	Δlog EC	Δlog CO_2	ECT
Δlog Y	–	0.4461	0.2040	−0.003*
Δlog EC	0.7811	–	0.1938	−0.0042*
Δlog CO_2	0.0319	2.9379***	–	−0.0117

Notes: *,***Significant at 1 and 10 per cent level, respectively
Source: Author's estimation

4. Conclusion

This paper examined the linkage between energy consumption, carbon emissions and economic growth for five South Asian countries (India, Pakistan, Bangladesh, Nepal and Sri Lanka) over the period 1972-2009 within panel framework. Empirical results indicates that all the three variables are non-stationary and integrated of order one. Cointegration result shows that these variables share equilibrium relationship in long run. Study finds bidirectional causality between energy consumption-real GDP, and unidirectional causality running from carbon emissions to real GDP and energy consumption, respectively, in long run. Weak unidirectional causality from energy consumption to carbon emission (at 10 per cent significant level) exists in short run. Therefore, there is urgent need to implement policy focusing towards reducing carbon emissions through implementing energy efficiency measures, use of super critical technologies in power generation (especially based on coal, oil and natural gas), and massive development of renewable energy resources including hydropower across the region for sustainable future.

Notes

1. Byproduct of combustion of conventional fossils fuels including coal, crude oil and natural gas.
2. South Asian countries are heavily dependent upon fossils fuels (coal in India, natural gas in Bangladesh and Pakistan, oil in Nepal and Sri Lanka) to meet the energy needs for its growth. Proportion of coal, oil and natural gas in total primary energy supply for South Asia during year 2009 is 35.66, 23.51 and 11.33 per cent, respectively (Source: IEA Energy Balance Report, 2009). Further in case of electricity generation, proportion of coal, oil and natural gas fired power stations in India, Bangladesh, Nepal, Pakistan, Sri Lanka and South Asia is about 84.26, 95.90, 0.41, 67.51, 60.29 and 82.06 (coal – 58.99, oil – 6.29, and natural gas – 16.77) per cent respectively during 2009 (Source: WDI, 2013).
3. Installed capacity in India, Nepal and Pakistan is 39,623, 600 and 6,595 MW against feasible hydropower potential of 84,000, 43,000 and 41,722 MW, respectively.
4. Average generation cost per megawatt in case of thermal, hydro, nuclear, solar and wind power is 6, 8, 10, 13 and 6 crores at 2011-2012 price level (Planning Commission, Government of India).
5. Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), Selden and Song (1994), Shafik (1994), Unruh and Moomaw (1998), Heil and Selden (1999), Friedl and Getzner (2003), Dinda and Coondoo (2006), Managi and Jena (2008), Coondoo and Dinda (2008) and Romero-Avila (2008).
6. Masih and Masih (1998), Asafu-Adjaye (2000), Stern (2000), Ghosh (2002), Soytas and Sari (2003, 2006), Ghali and El-Sakka (2004), Paul and Bhattacharya (2004), Lee (2005, 2006), Narayan and Smyth (2005), Mehrara (2007), Sari *et al.* (2008), Akinlo (2008), Apergis and Payne (2009), Wolde-Rufael (2005, 2009), Ozturk (2010), Payne (2010), Apergis and Payne (2012), Tang and Tan (2013), Apergis and Tang (2013) and Baranzini *et al.* (2013). Ozturk (2010), and Payne (2010) provide detailed review of empirical studies on energy-growth nexus.
7. Soytas *et al.* (2007), Soytas and Sari (2009), Ang (2008), Halicioglu (2009), Zhang and Cheng (2009), Chang (2010), Lean and Smyth (2010), Pao and Tsai (2011a, b), Pao and Tsai (2010), Ghosh (2010), Chary and Bohara (2010), Alam *et al.* (2011), Nasir and Ur Rehman (2011), Pao *et al.* (2011), Menyah and Wolde-Rufael (2010), De Freitas and Kaneko (2011) and Jafari *et al.* (2012).
8. See Table II.

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