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What drives carbon dioxide emissions in the long-run? Evidence from selected South Asian Countries

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ABSTRACT

This study empirically investigates the relationship between CO_2 emission and four of its potentially contributing factors (i.e., energy consumption, income, trade openness and population) using time series data from 1971 to 2013 on five selected economies of South Asia. After confirming that all the series are stationary using unit root test process, the study incorporates three different and advance panel cointegration tests i.e. Pedroni- Kao- and Johansen-Fisher-panel cointegration. All the panel cointegration tests confirm that all the variables cointegrated. The long-run association between the variables is checked using FMOLS-grouped and individual cross-section country in the panel. The FMOLS grouped results show that energy consumption, trade openness and population increases environmental degradation in the panel countries with exception of income which has negative impact and sounds the existence of Environmental Kuznet curve between income and emission. The innovative accounting approach using variance decomposition test and impulse response function is applied to examine the causality amongst the underlined vectors. The results show that there is bidirectional causality between energy consumption and trade openness and uni-directional causality running from energy consumption, trade openness and population to CO_2 emission. The results enumerate that the energy consumption and population density will increase in long-run and foresee further environmental degradation in the region.

1. Introduction

In recent years, the relationship between economic growth and environment has been the most debatable topic in both development and environmental economics literature [3]. While considering the environmental consequence of economic growth, the trade-off between economic growth and environmental quality depends upon the optimal use of energy [70]. Hence, the opportunity cost of opting either-increases, if the country is developing [55]. There is a wide range of literature available on growth-emission nexus, but the findings have been mostly inconclusive [4]. Consequently, this notion is becoming highly challenging for the policy makers unless empirical evidences are sufficiently robust and appropriate for policy use.

Since, the economic development has become the top most priority of developing countries, a major portion of their policies and efforts is also directed towards achieving such goal. Thence, over the few decades, the implications of such growth intensive exercise have resulted rapid economic transformation in many of the developing countries. Today, developing countries account more than 50% of world GDP and it is expected to rise to 60% by 2030 [52]. Notwithstanding the various socio-economic policy reforms, trade openness has been common and the most compelling factor behind such economic growth performance [41]. The benefits of trade liberalization are well established in economic theory dating back to Adam Smith's Comparative Advantage theory and the developing countries with open economic policies are the largest beneficiaries of trade liberalization [22]. Furthermore, the last few decades have observed the historic growth trend in global economy which is mainly associated with the trade openness in the form of agreements such as; WTO, NAFTA and ASEAN (See. [60]). Such agreements have made the flow of goods smooth- changing the composition of the total world industrial production. Over the last few decades, global economy has experienced a huge expansion in world aggregate demand and industrial output [54]. Such trends- no doubt produced great economic results for individual countries, however accompanied by some negative impacts especially on environment [67]. As the global economy has transformed into an inorganic economy, it has resulted in global warming due to climate change.

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Rapidly deteriorating environmental conditions is one of the biggest challenges that world is facing today. The ever rising world temperatures, the air-water-soil pollution, the changing pattern of rain are the signs of rapid environmental degradation and mainly associated with the industrialization [2]. The sea level is rising and the threat of global warming is always hanging in the atmosphere. However, the projections are even worse. A recent World Bank report declared that world means temperature is expected to rise 4 °C above the pre-industrial era. Heat extremes, sea-level rise, marine ecosystem, water availability, all have been projected to the dangerous level in the near future (World [15]). Scientific community unanimously declared greenhouse gases as the major cause of the global warming trend. Water vapor, nitrous oxide-N_2O, methane-$CH_{2,}$ and Carbon dioxide-CO_2 are the major contributors of the greenhouse effect. Of these, water vapor acts as feedback to the climate as it increases the chances of rains. N_2O, CH_2 and CO_2 ethane, nitrous act as “forcing” of climate change as they block the heat from escaping the surface of the earth making the atmosphere warmer. Of these, CO_2 is the most abundantly found in the atmosphere and poses greatest threat to the environment. These greenhouse-gases (GHG) are produced through natural activities as well as through human activities including deforestation, use of fertilizers, biomass burning, and fossil fuel burning.[1]

Environmentalists believe industrial revolution as the root cause of increased GHG emission, which further results in global warming followed by extreme climatic events [46]. Energy being the life blood of modern industry and non-industrial sectors is the major source of emission [63]. The recent data using the comparative analysis between atmospheric samples held in ice-cores and more recent direct measurements, reveals that atmospheric CO_2 has substantially increased since the industrial revolution [50]. Carbon dioxide information analysis center[2] reports that the per capita CO_2 emission has almost doubled since 1950 and similar trend is observed in global energy consumption. With such trends, research has been diverted in the last few decades to investigate the impacts of industrial revolution and economic growth on the climate change. Environmentalists are of the opinion that the production of enormous volume of industrial output requires the use of energy resources. The increase in energy consumption not only produces greenhouse gases, but also reduces the volume of non-renewable resources. Owing to highly energy intensive and fossil fuel driven, the establishment of new industrial units in developing countries largely compromise ecosystem. Therefore, the negative impacts of potential environmental degradation are more severe in developing and emerging countries than developed countries. Thus, investigating the effects of economic growth on environment in developing countries has become an important research topic for both growth and environmental economists.

The number of studies has been conducted on the relationship between economic growth and environment, with per capita income as proxy for economic growth and CO_2 emission as proxy for environmental degradation. Most of these studies test the Environmental Kuznet Curve (EKC) hypothesis. The EKC hypothesis suggests that the relationship between national income and environment is inverted-U shape. It means that the initial phase of economic development reduces the environmental quality, but after the certain threshold level, the environmental quality improves with increasing economic growth. The notable studies that evident such relationship are- [12,13,28,42,63–65,68,69,7]. The rationale behind EKC hypothesis is that economic growth brings technological changes which introduces more environmental friendly techniques of production [69] and that with high income, citizens demand for cleaner environment leading to strict environmental regulations [28].

Other studies have been conducted to test the causal relationship between economic growth and environmental degradation adding more variables like energy consumption, trade openness, urbanization and population [6,23]. Some studies have used data from individual countries while others used cross country data from different regions. Data from developed countries show that the environment has improved in the last few decades and emissions decreased [18], however the developing countries have showed mixed results. A possible reason for this can be that the developing countries have not achieved the level of economic development yet that induces a cleaner environment. However, developing countries have the opportunity to learn from history and to divert their attention to combating environmental degradation in the early stage of their development. Such awareness can help low income countries to develop policies for a cleaner yet environmental friendly production [28]. The increasing research on the topic has already changed the approach of the growth economists and governments to consider environmental concerns while making development policies [18]. Hence, it necessitates further investigations on developing countries that would be helpful in explaining the relationship of economic growth and the environment.

This study aims to investigate the growth-environment nexus in case of selected five South Asian countries (India, Pakistan, Bangladesh, Nepal and Sri Lanka). Because, South Asia is a home of 21% of global population, accounts 4% of global GDP, shares 6% of global energy consumption and contributes 3% to total world merchandise exports [75]. However, region's annual GDP is expected to grow at 8% and energy demand is projected to rise at 7.4% annually till 2020.[3] The competing growth rate between two indicators shows that the regional gross domestic production is highly energy intensive and this notion further caution about the emission potential of the industries. Fig. 1 illustrates the trend in the variables and graph of each cross-section country depicts strong positive correlation between GDP, CO_2 emission, energy consumption (EN), trade openness (TR) and population density (POP). However in recent years, the region has faced frequent natural disasters. For example: in 2004, South Asian tsunami affected 7 countries and killed more than two hundred thousand peoples; the 2008 earthquake in Pakistan followed by two floods in 2010 and 2011- making 10 million people homeless, and recent earthquake in Nepal killed around 9000 people.[4] Moreover the financial loss, health risks and future projections of climate change impacts are far intimidating. The consecutive natural and calamities and changing biodiversity has raises several questions for both environmental and development economists. The recent and projected emission trend forecasts more severe climatic changes and their negative repercussions on ecosystem. The future economic loss from such negative may exceed the threshold level.

This study uses time series data from five selected countries of South Asia (India, Pakistan, Bangladesh, Sri Lanka, and Nepal) to empirically investigate the relationship between CO_2 emissions and four of its potentially contributory factors i.e. energy consumption, income (GDP), trade openness and population. All the countries are developing economies and in transition to industrialization. In such phase of economic development, countries tend to increase their energy consumption to match up with the demands of new industries. However, the study of countries in their initial stage of development is important in order to understand their pattern of CO_2 emission. Developing countries have the opportunity to learn from the history of developed countries and to divert their attention to combat environmental degradation at the early stage of their development. Such awareness can help low income countries to develop policies for a

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[1] For details see OECD Environmental Outlook to 2050. http://www.oecd.org/env/indicators-modeling-outlooks/49846090.pdf (Accessed 08.02.2016).

[2] CDIAC, report available at: http://cdiac.ornl.gov.

[3] Projections are made by Asian Development Bank (ADB) and the percentage is compounded growth rate.

[4] For detailed analysis see. UNESCAP report available at: http://www.unescap.org/sites/default/files/Technical%20paper-Overview%20of%20natural%20hazards%20and%20their%20impacts_final.pdf.

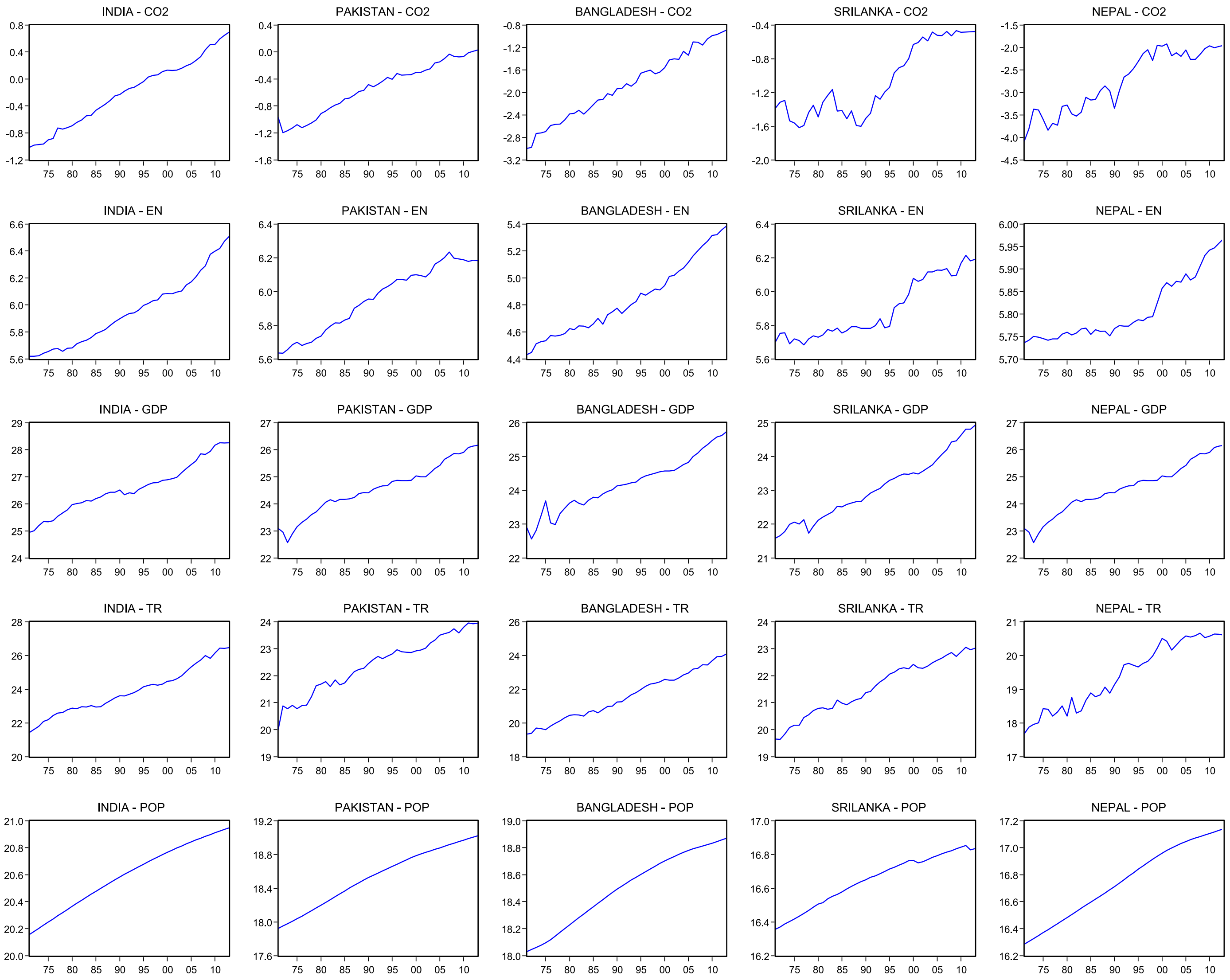

Fig. 1. Trend in the variables.

cleaner environment [28].

The rest of the paper is organized as: Section 2 presents a brief review of literature on the subject. Section 3 provides detail of the data and explanation of the model used. Section 4 produces the results and provides policy suggestions in both the group and individual context. Section 5 concludes the findings.

2. Literature review

The study of relationship between economic growth and environmental factors is not a new topic. Economists have studied the impact of environmental factors such as the use and availability of fossil fuels and other industrial inputs on economic growth since the early ages of industrial revolution [33,61]. Economists viewed the limited capacity of natural resources as a hurdle in the path of economic growth [18] and tried to find new sources of industrial inputs in order to boost production. However, industrial revolution has transformed the global economy from being organic to inorganic while increasing the per capita consumption of fossil fuels [66]. The increased fossil fuel consumption has led to the increased level of greenhouse gases in the atmosphere resulting in global warming and climate change [35]. The Growth-Environment literature sought meaningful attention after the Earth's summit 1992. Ever since, the research on the subject has grown and today a vast literature exists both in theoretical and empirical forms. The increase in research on the relationship of economic growth and environment and the existence of such vast literature have changed the attitudes where economists are worried more about global warming, cleaner environment and reduction in emissions rather than the ultimate exhaustion of fossil fuel reservoirs and other natural resources for the purpose of development [18].

The literature on the relationship of economic growth and environment can be divided into three categories; the growth-environment nexus, the growth-energy nexus and, combining the first two, the growth-energy-environment nexus [14]. The first group has focused mainly on testing the validity of Environmental Kuznet curve (EKC) hypothesis to study the relationship between economic growth and environment. EKC hypothesis asserts that the initial stage of economic growth will tend to increase the level of emission as the production rises. However, after attaining the certain threshold of income, the effect turns opposite and environmental conditions start improving [27]. The second group looked income and energy consumption as the main contributors of CO2 emission and analyzed the causal relationship among these variables. The third group combined the techniques of the first two to analyze the relationship among the variables [14,23,35,6,8,9].

Testing the EKC hypothesis has been the central idea of majority of studies conducted on the growth-environment nexus. The EKC has an inverted-U shape indicating that after reaching a threshold, the pollution will decrease eventually. This behavior of economic growth and environment is explained through scale, technique and composition effect [27]. Economic growth normally takes off with industrialization and production at a large scale. Such large scale production brings greater pollution as the economy is normally poor at this stage and cannot afford to obtain modern environmental friendly technology. However, as the economy grows and the income increases, innovations in production techniques take place and environment friendly technology is adopted. This results in lowering the emission level. Finally, as the economy grows further, the focus shifts from pollution-intensive manufacturing sector to pollution-free service sector thus causing the downward part of EKC [27]. However, the effects of economic growth on the shape of EKC are not obvious and automatic [25], and the different conditions of economy regarding the stage of economic development, the extent of participation in international trade and the strictness level of environmental control regulations will induce different effects of economic growth on environment in different countries [14]. Although the most probable explanation of the inverted U-shaped of EKC can be the technological advancement with higher income, however the biggest reason seems to be the fact that richer countries have more strict environmental laws due to the demand of their citizens for a cleaner environment [28]. Economic growth is very much dependent upon the use of energy. Thus higher economic growth calls for more energy consumption which increases the emission of greenhouse gases [36], unless renewable energy sources are used in production. Yildirim et al. [76] examine the relationship between energy consumption per capita and real GDP per capita for Indonesia, Malaysia, Philippines, Singapore and Thailand using both panel data causality which is taking into account cross-sectional dependence and heterogeneity among the countries and time series causality tests for the period 1971–2009. The conservation hypothesis is supported for Indonesia, Malaysia and Philippines. Although a bidirectional relation is found in the case of Thailand, since there is no positive effect of energy consumption on GDP, the conservation hypothesis is supported. In the pattern of Singapore, the neutrality hypothesis is supported. In addition, the increase in investment and labor force lead to more energy consumption in Indonesia, Malaysia and Thailand. [12,13] testeed the EKC hypothesis for 14 Asian countries spanning the period of 1990–2011. They focused on how both income and policies in these countries affect the income–emissions (environment) relationship. The Generalized Method of Moments (GMM) methodology using panel data is employed in a multivariate framework to test the EKC hypothesis. The multivariate framework includes: CO_2emissions, GDP per capita, population density, land, industry shares in GDP, and four indicators that measure the quality of institutions. In terms of the presence of an inverted U-shape association between emissions and income per capita, the estimates have the expected signs and are statistically significant, yielding empirical support to the presence of an EKC hypothesis. Uddin et al. [72] investigate the long run Granger causality relationship between energy consumption, carbon emissions, economic growth and trade openness in Sri Lanka. The analysis reveals that, there exists long–run causal relationship between carbon emission and economic growth for Sri Lanka over the period of 1971–2006. In addition, there is unidirectional causality running from economic growth to the carbon emission and energy consumption.

Another variable that has gained importance among environmental economists in recent years is trade liberalization. Theoretically, international trade can have both positive as well as negative impacts on environment. On the one hand, it increases income which eventually leads to demand for better environment, while on the other hand, it can tempt developing countries to increase their production without taking care of environment and thus increasing GHG emissions [24]. Trade liberalization is being argued, in the developing literature, to accelerate economic growth which, according to EKC hypothesis, will eventually reduce environmental pollution. Trade liberalization impacts environment in a positive way by increasing national income and allowing the countries to specialize in the activities that best suit their conditions. Trade liberalization not only brings opportunity to produce in huge quantities (scale effect), but also carries modern technology (technique effect) and managerial philosophy (composition effect) across the borders. Thus, it helps developing countries to reduce their emissions by making available modern technology and environmental friendly techniques of production to them [27]. Proponents of international trade argue that interactions with the international trade community encourage innovations and thus enabling countries to achieve sustainable growth. Furthermore, it allows consumers in developing countries to be exposed to a variety of products from all over the world, it can increase demand for environmental friendly products [25]. On the other side, firms that compete in international market i.e. exporters, tend to be cleaner than non-exporters mainly because of the international competitive pressures and because of high productivity which allows them to invest more in abatement technologies [24]. Having no competitive advantage, eventually the dirtier firms will be weeded out by cleaner firms in developing countries as a result of engaging in international trade [24].

While there are many proponents of international trade, many others think it will only worsen the environment, especially in developing countries. The most recent arguments against trade openness in literature are the *race to bottom hypothesis* and *the pollution haven hypothesis*. Environmentalists argue that with open trade less developed countries will slacken their environmental regulation standards, which are not strict at all, in order to retain competitiveness against their advanced rivals [25,37]. This is called the *race to bottom hypothesis*. The *Pollution Haven Hypothesis* argues that since developed countries have strict environmental regulations, the firms in developed countries are at disadvantage to produce pollution intensive products. They will, therefore, transfer their production of such goods to developing countries where the regulations are soft [28,45]. Opponents of trade openness accuses international trade for being the source for developed countries to externalize the environmental burden by shifting the pollution intensive industries to poor countries and importing the products back from there [74]. “Dirty” industries are, therefore, expected to flourish with trade liberalization especially in developing countries [69]. This strategy, although useful for decreasing pollution within the borders, however does no good for global emission level and does not help in combating global warming. Another issue is of “Carbon Leakage” where firms either relocate their production facilities from countries with stringent environmental regulations to countries having slack policies, or lose market share to those firms that relocate their facilities [37]. This fear of losing market share will enforce firms to transfer their facilities to less regulated countries and become an importer of pollution. The stage of economic development plays an important role in whether a country will be exporter or importer of pollution [69]. The results of [69] show that Japan has been an exporter, importer and again exporter of dirty goods to/from Singapore and Hong Kong in different stages of economic development in these countries. This status of exporter and importer changed with other East Asian countries as well. Thus, although developed countries are able to reduce their GDP to energy consumption ratio reaching the flat part of EKC, this reduction is mainly due to imports of pollution intensive goods from developing countries [68]. In such situation, the traditional production-based emission accounting approach, where the emission level is allocated to the countries where it is produced, is not the right approach to study the impacts of international trade on environment. A consumption-based approach must be adopted where the emission level is calculated by the emissions required for producing the goods consumed in a country [74].

There is a plethora of empirical studies conducted on the relationship of economic growth and environment. However, despite the vast literature, based on existing literature on individual countries data, no conclusive relationship can be established between economic growth and CO2 emission [59]. Although many studies have found the EKC hypothesis valid, many others did not find any sign of an inverted U-shaped for the EKC especially studies from developed and developing countries have produced different results. In their seminal study on the subject, [27] studied cross-section data for SO_2 and smoke from 42 countries and found that the pollutants decrease as the per capita GDP increases i.e. validity of EKC hypothesis. Kasman and Duman [35] tested the EKC hypothesis using panel data from new EU members and candidate countries taking income, energy consumption, trade openness and urbanization as the potential contributors of carbon emissions. Their results, obtained from panel unit root tests and panel cointegration tests confirmed the validity of EKC. They further found short term unidirectional causality among the variables towards carbon emissions and long run bidirectional causality suggesting that carbon emissions will increase with higher economic output in the near future. [32] tested the EKC hypothesis using panel data from 1971 to 2005 for China using CO_2 emission as proxy for environmental degradation. They found EKC valid in case of China. They also found a unidirectional causality running from economic growth to CO_2 emission and energy consumption and from trade openness to CO_2 emission. [59] studied long-run and causal relationship between economic growth and environment for Malaysia and found the significance of EKC. Their results found no short-run causality among the variables while in long-run, economic growth tends to increase CO_2 emission. Heidari et al. [30] analyzed data from five ASEAN countries and found a nonlinear relationship among economic growth measured by per capital GDP, environmental degradation measured by CO_2 emission and energy consumption. Their analysis confirmed the validity of EKC for the five countries and found that beyond the threshold parameter (i.e. 4648 USD per capita income) the CO2 emission starts to decline.

Whereas these studied found EKC to be valid, many others found different results. Suri and Chapman [68], in a study from both developed and developing countries, found the turning point of the EKC to be $55000 which is never achieved by any country yet. With the introduction of international trade in their model, the threshold point increased from $55000 to $224000 indicating that trade openness plays a positive role in increasing the emission level in all countries. Results of Managi et al. [45] indicate that emissions of so2 and CO2 increases as the production or income induced by trade openness increases in non-OECD (developing) countries while in OECD (developed) countries, the emissions decreases. However, emissions of BOD decreases in both OECD and non-OECD countries with increased income. One possible explanation for this can be that the social pressure against water pollution is stronger as compared to that against air pollution in developing countries. Also it is possible that because the cost of abatement technologies for BOD is less than those for SO_2 or CO_2, developing countries use these technologies more frequently [45]. [16] found a U-shaped curve (opposite of that suggested by EKC) between economic growth and environment for Malaysia. Their results further found that population growth has no impact of CO_2 emission. Hossain [31] using panel data from Newly Industrialized Countries found no long run relationship between CO_2 emission, economic growth, energy consumption, trade openness and urbanization. However, the study found that in short run, economic growth and trade openness have unidirectional relationship with CO_2 emission. The results indicate that for newly industrialized countries, the long run elasticity of CO_2 emission with respect to energy consumption is higher than short run indicating that pollution will continue to rise in long run for the NIC under study. Kozul-Wright and Fortunato [37] studied data of CO_2 emission and GDP from 181 countries to study EKC hypothesis. Their data showed no sign of any turning down point thus invalidating the EKC hypothesis, and that the CO_2 emission behaved to increase with higher income. Their results show that per capita income tends to increase emission of CO_2 as well as cumulative measure of GHG emission.

[10] analyzed data from 14 Middle East and North African (MENA) countries from 1996 to 2012 using Pedroni Cointegration test and FMOLS. Their results show that energy consumption, trade openness, urbanization, and industrial developments cause environmental degradation while political stability has favorable impacts on environment.

Impacts of trade openness on environment have been empirically tested by many researchers. Takeda and Matsuura [69] tested the impact of trade liberalization on CO_2 emissions by studying the trade pattern of dirty goods between ten East Asian countries and Japan and USA. Their results show that increase in exports of dirty goods to Japan increases domestic CO_2 emission in each country while imports of dirty goods from Japan has no impact on CO_2 emissions. For USA, they didn't find statistically significant impact of either exports or imports of dirty goods for any of the countries under study. The overall results of Takeda and Matsuura [69] support the *Pollution Haven Hypothesis* and indicate that trade liberalization increases co2 emission in East Asian countries. Wiebe et al. [74] using consumption-based approach to emission found that the net imports of OECD (developed) countries increased by 80% between 1995 and 2005 while the net exports of BRICSA and non-OECD countries increased for the same period of time therefore supporting the Pollution Haven hypothesis that the developed countries have externalized the environmental burden through international trade. Naranpanawa [49] investigated the relationship between trade openness and co2 emission in case of Sri Lanka and found that although the variables are related in the long run, there is no long run causality between trade openness and co2 emission. The results of Baek and Kim [14] supported the gain from trade hypothesis for developed countries while for developing countries they found that the Race to Bottom Hypothesis holds where the developing countries seem to lower the level of environmental regulations in order to attract multi nationals and foreign investments. The empirical results of Frankel and Rose [25] reject the race to bottom hypothesis and support the gains from trade hypothesis. Furthermore, the results did not find any support for the Pollution Haven hypothesis. Thus, according to Frankel and Rose [25] trade openness neither shifts pollution to developing countries through the environmental competitive advantage hypothesis nor does it increase pollution in countries which specializes in capital intensive production.

With such different and controversial results of the studies conducted on the topic, it is evident that economic growth and increase in income are not automatic cure for environmental degradation, rather there is a need for devising policy strategies that will make the EKC more flat for, especially, developing countries and help to reduce emissions worldwide [37]. However, such policies can only be materialized if proper institutions are in place to transform popular demand for cleaner environment into regulations [27,37]. There is a need for international cooperation to resolve the global environmental problems [25]. Various efforts have been initiated on the international level e.g. the United Nations Framework Convention on Climate Change, Kyoto Protocol, the Bali roadmap etc. However, as most countries are guided by their national self-interest to participate in global emission reduction agreements, the hope for cooperative efforts to reduce global emission is very little [19]. It is because the benefits of emission reduction are worldwide while the costs normally pertain to the country that makes efforts for emission reductions, no individual country would voluntary adopt emission abatement policies. Therefore, there is a need for multilateral efforts to address the issue [37].

3. Methodology and data

3.1. Methodology

3.1.1. Levine-Lin-Chu (L-L-C) panel unit root test

The test for unit root has become a standard practice in applied time series econometrics literature ([20,53]. However, [43] argue that the individual unit root tests have limited power to maintain the persistence of individual regression errors across the cross sections. Later, Levin et al. [40] develops a panel unit root test by pooling the cross section that allows trend and intercept coefficients to freely move across the cross sections and generated pooled t-statistics. hence, Levin-Lin-Chu (llc) unit root test provides better approximation results as compare to common panel unit root tests [5,51]. LLC test suggests the following hypothesis.

Null hypothesis (H_0): each time series contains a unit root.

Alternate hypothesis (H_1): each time series is stationary.

Here the lag order(p)allowed to vary across the cross-sections and the procedure functions in the following way;.

In the first step, we run augmented Dickey- Fuller (ADF) for each cross-section on the equation:

$$\Delta Y_{i,t}=\rho y_{i,t-1} + \sum_{L=1}^{pi} \theta iL\Delta Yi,\ t - L + \alpha midmt + \varepsilon it \tag{1}$$

The second step involves two auxiliary regressions:

1) $\Delta Y_{i,t}$ on $\Delta y_{i,t-L}$ & $d_{m,t}$ which obtain residual ˆ eit and,
2) $y_{i,t-1}$ on $\Delta y_{i,t-L}$ & $d_{m,t}$ which get residual ˆ νi,t−1.

In the third step, we standardize the residuals by performing;

$$\tilde{e}_{i,t} = \hat{e}_{i,t}/\dot{\tilde{O}}_{\varepsilon it} \tag{2}$$

$$_{i,t-1} = {}_{i,t}/\dot{\tilde{O}}_{\varepsilon it} \tag{3}$$

Where $\dot{\tilde{O}}_{\varepsilon it}$represents the standard-error in each ADF-test

Finally, the pooled OLS regression is performed by:

$$\tilde{e}_{i,t}=\rho\ _{i,t-1} + \varepsilon_{i,t} \tag{4}$$

The null hypothesis is$\rho = 1$. However, the Levin-Lin-Chu test requires to adjust the t-statistics under the condition $\sqrt{N_T}/\ T \rightarrow 0$. Levin et al. [40] suggest that the sufficient conditions are explained by $\sqrt{N_T}/\ T \rightarrow 0$ and $N_T/T \rightarrow k$, where the cross-sectional dimension (N) is a monotonic function of time dimension (T). The literature opines that the test is useful for macro panels if statistics fall between 10–250 and 5–250 in case of 'N' and 'T', respectively. The small value of T reflects that the panel is undersized and as a result bears low power. Whereas, the large T value insists to check the unit root for each cross-section individually. The test is considered restrictive in the sense that it's null-hypothesis accounts unit root for all cross-sections that ignores the notion that some cross-sections are subject to a unit root and some are not. Another disadvantage associated with this test statistic is that it assumes the panel is cross-sectional independent. Therefore, in order to avoid the disadvantages of Levin-Lin-Chu unit root test, we also apply Breitung panel unit root test developed in [17]. Breitung test qualifies for non-stationary panels as well (Moon et al., 2006).

3.1.2. Panel cointegration tests

The time series econometrics literature suggests that the development of cointegration to panel data is also recent. Therefore, following the panel unit root tests, we incorporate panel cointegration tests to investigate the long-run association among the variables. However, the techniques available so far are divided in to two main groups; one that uses null hypothesis as "no-cointgeration" (i.e. [56,34,39,26] and other takes "cointegration" as null hypothesis (i.e. [47,43,73]. For present analysis, we utilize three different panel cointegration techniques representing both approaches, proposed by [56,58,34,44]. Pedroni [56,58] proposes seven different statistics to test for cointegration relationship in heterogeneous panel. These tests are corrected for bias introduced by potentially endogenous regressors. The seven test statistics of Pedroni are classified into within dimension and between dimensions statistics. Within dimension statistics are referred to as panel cointegration statistics, while between dimension statistics are called group mean panel cointegration statistics. These cointegration test statistics are based on the extension of two step residual based strategy of Engle and Granger (1987). In the first step, procedure involves estimation of seven test statistics essential and stores the residuals. The model is run on the following test equation:

$$x_{i,t} = \alpha_{0i} + \rho_i t + \beta_{1i} Z_{1i,t} + \text{..........} + \beta_{mi} Z_{mi,t} + \mu_{it} \tag{5}$$

In the second step, the first difference of each cross-section in the panel from original data series is taken in order to calculate the residual of differenced regression:

$$\Delta x_{i,t} = \theta_{1i} \Delta Z_{1i,t} + \text{..........} + \theta_{mi} \Delta Z_{mi,t} + \eta_{it} \tag{6}$$

In the third step, estimate the long-run variance ($\hat{\kappa}^2{}_{11,i}$) from the residuals ($\hat{\eta}_{it}$) of the differenced regression. In the fourth step, using the residual ($\hat{\mu}_{it}$) of original co integrating equation, estimate the appropriate autoregressive model. Following these steps, the seven panel test statistics are computed with appropriate mean and variance adjustment terms as described by [56].

Panel v-Statistic:

$$Z_v \equiv T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}{}_{11,i} \hat{\mu}^2{}_{it-1} \right)^{-1} \tag{7}$$

Panel ρ -statistic:

$$Z_p \equiv T\sqrt{N} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}{}_{11,i} \hat{\mu}^2{}_{it-1} \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}{}_{11,i} (\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i) \tag{8}$$

Panel t-statistic (non-parametric):

$$Z_t \equiv \left(\tilde{\sigma}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}{}_{11,i} \hat{\mu}^2{}_{it-1} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}{}_{11,i} (\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i) \tag{9}$$

Panel t-statistic (parametric):

$$Z_t^* \equiv \left(\tilde{s}^{*^2}_{N,T} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}_{11,i}^{-2} \hat{\mu}_{it-1}^2 \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}_{11,i}^{-2} \hat{\mu}_{it-1}^* \Delta \hat{\mu}_{it}^* \tag{10}$$

Group ρ-statistic:

$$\widetilde{Z}_p \equiv TN^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{\mu}^2{}_{it-1} \right)^{-1} \sum_{t=1}^{T} (\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i) \tag{11}$$

Group t-statistic (non-parametric):

$$\widetilde{Z}_t \equiv N^{-1/2} \sum_{i=1}^{N} \left(\hat{\sigma}_i^2 \sum_{t=1}^{T} \hat{\mu}^2{}_{it-1} \right)^{-1/2} \sum_{t=1}^{T} (\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i) \tag{12}$$

Group t-statistic (parametric):

$$\widetilde{Z}^*{}_t \equiv N^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \tilde{s}^{*^2} \hat{\mu}^{2*}{}_{it-1} \right)^{-1/2} \sum_{t=1}^{N} \hat{\mu}^*{}_{it-1} \Delta \hat{\mu}_{it}{}^* \tag{13}$$

Where

$$Where\ \hat{\lambda}_i = \frac{1}{2}(\hat{\sigma}^2{}_i - \hat{s}_i^2)\ and\ \tilde{s}^{*^2}_{N,T} = \frac{1}{N} \sum_{i=1}^{N} \hat{s}^{*^2} \tag{14}$$

Having calculating the panel cointegration test statistics, necessary adjustment terms for mean and variance are assigned in order to ensure the asymptotic distribution of test statistics.

$$\frac{X_{N,T} - \mu\sqrt{N}}{\sqrt{V}} \Rightarrow N(0,\ 1) \tag{15}$$

Here, $X_{N,T}$ denotes the test statistics of N and T in a standardized form. u and v are the movement functions of Brownian motion. The null hypothesis of no cointegration for all test statistics is given by:

$$H_0\colon \rho_i = 1 \quad for\ \ all\ \ i = 1,\ 2,\ \text{........}\ ,\ N \tag{16}$$

Table 1
Panel Unit Root Tests.

Variables	*At level*				*At 1st Difference*			
	Constant	P-value	Constant & Trend	P-value[**]	Constant	P-value	Constant & Trend	P-value[**]
Levin, Lin & Chu (LLC) - Panel Unit Root Test								
$\ln CO_{2it}$	−0.18347	0.4272	*−2.83394*	*0.0023*	−15.1955	*0.0000*	*−13.0322*	*0.0000*
$\ln EN_{it}$	*4.84823*	*1.0000*	*1.87433*	*0.9696*	−11.8925	0.0000	*−12.7544*	*0.0000*
$\ln GDP_{it}$	1.19610	0.8842	0.57264	0.7166	−6.57301	0.0000	−11.7617	0.0000
$\ln TR_{it}$	−0.69070	0.2449	*−1.15319*	*0.1244*	−15.1754	*0.0000*	*−13.3729*	*0.0000*
$\ln POP_{it}$	−3.00871	0.0013	*−2.83394*	*0.0023*	−1.77421	*0.0380*	*3.63631*	*0.0999*[*]
Breitung - Panel Unit Root Test								
$\ln CO_{2it}$	–	–	−2.38214	*0.0086*	–	–	*−3.61742*	0.0001
$\ln EN_{it}$	–	–	−8.06662	*0.0000*	–	–	*−10.4771*	0.0000
$\ln GDP_{it}$	–	–	−1.57511	0.0576	–	–	−7.43008	0.0000
$\ln TR_{it}$	–	–	*−0.97879*	*0.1638*	–	–	*−6.48125*	*0.0000*
$\ln POP_{it}$	–	–	*6.88706*	*0.9000*	–	–	*2.99647*	*0.0986*[*]

Note:
[*] shows significant at 10% level.
[**] Probabilities are computed assuming asymptotic normality.

and, alternative hypothesis for between the dimension and within dimension for panel co integration is given by:

$$H_0\text{: } \rho_i < 1 \quad \textit{for all} \quad i = 1, 2, \ldots\ldots, N \tag{17}$$

Similarly, the alternative hypothesis for within dimension statistics is given by:

$$H_0\text{: } \rho_i = \rho < 1 \quad \textit{for all} \quad i = 1, 2, \ldots\ldots, N \tag{18}$$

Assume a common value for $\rho_i = \rho$. Under the alternative hypothesis, all the panel test statistics diverge to negative infinity. Thus, the left tail of the standard normal distribution is required to reject the null hypothesis.

3.1.3. Panel cointegration estimates

Subsequent of applying cointegration test and confirming that there exists a long run association among underlying variables, the next step is to estimate the associated long-run cointegration parameters. Fixed effect, random effect and GMM method could lead to inconsistent and misleading coefficients when applied to cointegrated panel data. For this reason, we estimate the long-run models using "group mean" fully modified OLS (FMOLS) methods. Following [57], FMOLS technique generates consistent estimates in small samples and does not suffer from large size distortions in the presence of endogeneity and heterogeneous dynamics. The panel FMOLS estimator for the coefficient β is defined as:

$$\hat{\beta} = N^{-1}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(y_{it}-\bar{y})^2\right)^{-1}\left(\sum_{t=1}^{T}(y_{it}-\bar{y})\right)z_{it}^{*} - T\hat{\eta}_i \tag{19}$$

Where $z_{it}^{*} = (z_{it}-\bar{z}) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}}\Delta y_{it}$, $\hat{\eta}_i \equiv \hat{\Gamma}_{21i} + \hat{\Omega}^{0}_{21i} - \frac{\hat{L}_{21i}}{\hat{L}_{22i}}(\hat{\Gamma}_{22i} + \hat{\Omega}^{0}_{22i})$ and $\hat{L}_i$ is a lower triangular decomposition of $\hat{\Omega}_i$. The associated t-statistics gives:

$$t_{\hat{\beta}^*} = N^{-1/2}\sum_{i=1}^{N} t_{\hat{\beta}^*,i} \quad \textit{Where} \quad t_{\hat{\beta}^*,i} = (\hat{\beta}_i^{*} - \beta_0)\left[\hat{\Omega}^{-1}_{11i}\sum_{t=1}^{T}(y_{it}-\bar{y})^2\right]^{1/2} \tag{20}$$

3.1.4. Decomposition analysis

In the recent applied economics literature, Granger causality analysis is commonly used method to test the causal links among the variables. However, Granger causality along with other causality test (i.e. Toda-Yamamoto) do not give relative strength of causal links [62]. Alternatively, impulse response function (IRF) and forecast error variance decomposition method (FEVDM) provide an Innovative Accounting Approach (IAA) for testing causal links among the variables. The IAA provides prominent method of explaining the estimated linear and non-linear multivariate time series models ([11,38]; Shahbaz, 2015). We preferred this approach over traditionally used Granger causality tests because IAA does not only provide the direction of causality but also the magnitude of causal links among the variables at different time periods ([48,29,62,71]. Furthermore, under FEVDM process, the variance in each vector is decomposed in exogenous (change occurs due to other variables in the model) and endogenous (change occurs due its own innovative shocks) during vector autoregression (VAR) and IRF characterize the reaction of endogenous variable; whereas, the Granger causality has limitation of calculating only exogenous change. However, the concept of exogeneity in IAA is different from Granger causality in a way that in IAA it refers to the contemporaneous value of an endogenous variable and the contemporaneous error term of another variable [21].

3.2. Data

This study uses the following log-linear model to investigate the relationship between CO_2 emission, energy consumption, economic growth, trade openness and population growth:

$$\ln CO_{2it} = \beta_1 + \beta_{EN}\ln EN_{it} + \beta_{GDP}\ln GDP_{it} + \beta_{TR}\ln TR_{it} + \beta_{Y}\ln POP_{it} + \mu_t \tag{21}$$

We use per capita CO_2 emission, energy consumption (oil use), GDP (current US$), trade (exports+imports) and population growth as the proxy of $\ln CO_{2it}$,$\ln EN_{it}$, $\ln GDP_{it}$, $\ln TR_{it}$ and $\ln POP_{it}$, respectively. The annual data over the period of 1971–2013 taken from World Bank's World Development Indicators (CD-ROM, 2014) for the panel of selected South Asian countries.

4. Results and discussion

As discussed in previous section, applied time series econometrics necessitates the stationary data before testing the long-run association between the variables based on cointegration. Therefore, the empirical analysis of this paper begins with the application of [40] and [17] approach to panel unit root test in order to check the stationarity of underlying time series. Unit root test also help us to avoid the problem of spurious or nonsense regression in the time series analysis. Table 1 displays the results of unit root analysis and indicate that we could reject the null hypothesis at level, but after considering the higher order (i.e. 1st difference) all the variables are stationary at 1% level of significance except $\ln POP_{it}$which is significant at 10% level. Hence, unit root tests characterize each underlying series integrated at order $I(1)$. This notion allows us to proceed further for cointegration to test the long-run equilibrium relationship among the variables.

As noticed in the literature review part, some studies report contrasting results due to difference in the technique used for cointegration analysis. Therefore, this study utilizes three different and commonly used cointegration methods to test the long-run association between CO_2 emissions, energy consumption, economic growth, trade openness and population density in case of five south Asian countries. [56,58] approach to panel cointegration is a residual based approach with seven different test statistics computed within dimensions (pooled) and between dimensions (collective mean) allowing individual heterogeneous fixed effect and trend terms. Hence, it provides comprehensive tool for analyzing the cointegration property of time series variables. However, Johansen-Fisher cointegration test solves the problem of heterogeneity by incorporating a Fisher's effect that aggregates *p*-value of Johansen test statistics (see [44]. [34] argues that asymptotic distribution of least-square dummy variable (LSDV) has deep implications for residual based panel cointegration test. Therefore, he develops residual based cointegration test using augmented Dickey Fuller test to test the null hypothesis. In summary, all the panel cointegration tests applied in this study have individual unique property of checking the long-run relationship among the underlying vectors. It also distinguishes this study in term of methodology used in the past.

The results of cointegration tests are reported in Table 2. Pedroni panel cointegration test confirms the existence of cointegration among the variables. It implies that there is a long-run equilibrium relationship between CO_2 emissions, energy consumption, economic growth, trade openness and population growth in case of five selected countries of South Asia. Pedroni cointegration test results are validated by Johansen-Fisher cointegration and Kao residual based test results also. Our findings are consistent with Hossain [31] who uses Johansen-Fisher cointegration test for the panel of newly industrializing countries. The overall cointegration test results serve the basic purpose of this study and permit us to further carry on to investigate the long-run elasticity between CO_2 emissions and four controlling variables i.e. energy consumption, economic growth, trade openness and population growth.

Table 2
Cointegration Tests.

(A) Pedroni panel cointegration test results

Alternative hypothesis: common AR coefs. (within-dimension)

Tests	Statistics	P-value	Weighted Statistics	P-value
Panel v-Statistic	1.656867	0.0488	0.822052	0.2055
Panel rho-Statistic	−1.480148	0.0694	−1.363888	0.0863
Panel PP-Statistic	−3.641114	0.0001	−4.138672	0.0000
Panel ADF-Statistic	−3.819671	0.0001	−4.189413	0.0000

Alternative hypothesis: individual AR coefs. (between-dimension)

Tests	Statistics	P-value
Group rho-Statistic	−0.688550	0.2456
Group PP-Statistic	−4.470020	0.0000
Group ADF-Statistic	−3.970477	0.0000

(B) Johansen Fisher Panel Cointegration Test
Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Tests	Fisher Stat. (from trace test)	P-value*	Fisher Stat.* (from max-eigen test)	P-value*
None	165.7	0.0000	92.92	0.0000
At most 1	95.53	0.0000	52.69	0.0000
At most 2	56.86	0.0000	27.76	0.0020
At most 3	36.71	0.0001	25.62	0.0043
At most 4	23.13	0.0103	23.13	0.0103

(C) Kao Residual Cointegration Test

None	t-Statistic	Prob.
Augmented Dickey-Fuller (ADF)	−5.008807	0.0000

[*] Probabilities are computed using asymptotic Chi-square distribution.

Table 3A
FMOLS Grouped Results.

ln C_{it}: Dependent variable

Country/Variables	Coefficient	Std. Error	t-Statistic	Prob.
ln EN_{it}	1.009067	0.089298	11.30003	0.0000
ln GDP_{it}	−0.065389	0.021558	−3.033123	0.0027*
ln TR_{it}	0.095101	0.031295	3.038897	0.0027*
ln POP_{it}	0.683343	0.173557	3.937278	0.0001*

Note:
[*] shows significant at 1% level.

The cointegration tests confirm the long-run association among the underlying vectors. However, it is essential to determine the long-run elasticities of dependent and independent variables. For this purpose, this study uses fully modified OLS (FMOLS) estimation technique developed by Pedroni [57] which gives consistent and unbiased long-run coefficients in the model. We analyze both grouped and as well country specific estimations to turn our study more robust in term of policy standpoint. The results of FMOLS group- and country specific test results are represented by Table 3A and Table 3B, respectively. The grouped long-run estimates indicate that the energy consumption, trade openness and population growth have positive and statistically significant effect on CO_2 emissions. However, economic growth has small but negative impact on carbon emissions. More specifically, 1% increase in energy consumption, trade openness and population growth increase CO_2 emissions level by 1.01%, 0.09% and 0.6%, respectively. In terms of economic growth, 1% increase in GDP decreases CO_2

Table 3B
FMOLS Country Specific Results.

ln C_{it}: Dependent variable

Country/Variables	Coefficient	Std. Error	t-Statistic	Prob.
India				
ln EN_{it}	0.931443	0.122592	7.597904	0.0000
ln GDP_{it}	−0.004398	0.039677	−0.110842	0.9123
ln TR_{it}	−0.058504	0.033774	−1.732237	0.0916***
ln POP_{it}	1.429013	0.084354	16.94077	0.0000
Constant	−33.64376	1.369472	−24.56697	0.0000
Pakistan				
ln EN_{it}	1.793608	0.182149	9.846944	0.0000
ln GDP_{it}	0.273024	0.026182	10.42806	0.0000
ln TR_{it}	−0.273405	0.033429	−8.178584	0.0000
ln POP_{it}	0.227079	0.134413	1.689405	0.0996***
Constant	−16.00431	1.225291	−13.06164	0.0000
Bangladesh				
ln EN_{it}	0.875865	0.079768	10.98010	0.0000
ln GDP_{it}	0.077823	0.019073	4.080186	0.0002*
ln TR_{it}	−0.035302	0.023676	−1.491079	0.0144**
ln POP_{it}	1.319072	0.069993	18.84580	0.0000
Constant	−31.64837	1.015230	−31.17360	0.0000
Sri Lanka				
ln EN_{it}	2.565174	0.303241	8.459204	0.0000
ln GDP_{it}	−0.217881	0.091923	−2.370246	0.0231**
ln TR_{it}	0.483722	0.147790	3.273037	0.0023**
ln POP_{it}	−2.305114	0.859879	−2.680743	0.0109**
Constant	16.76918	11.76277	1.425615	0.1624
Nepal				
ln EN_{it}	−1.120755	0.282430	−3.968251	0.0003*
ln GDP_{it}	−0.455513	0.045997	−9.903015	0.0000
ln TR_{it}	0.358995	0.055963	6.414843	0.0000
ln POP_{it}	2.746666	0.292136	9.401998	0.0000
Constant	−38.06728	3.269327	−11.64377	0.0000

Note: (*), (**), (***) shows significant at 1%, 5% and 10% level, respectively.

emissions by 0.06%. In South Asian region, energy consumption and population growth are major contributors to regional environmental degradation.

Furthermore, the country specific FMOLS results indicate that in India energy consumption and population growth have positive and statistically significant effects on CO_2 emissions, where 1% increase in energy consumption and population increases CO_2 emission by 0.93% and 1.42%, respectively. However, economic growth has negative but statistical insignificant effect and trade openness has very small positive impact on CO_2 emissions. It is concluded that population growth and energy use are the first and second highest indicators of environmental degradation in India. These results are consistent with group FMOLS test results. In case of Pakistan, energy consumption, economic growth and population growth have positive and statistically significant impact on CO_2 emissions, where 1% increase in energy consumption, economic growth and population increase CO_2 emission by 1.79%, 0.27%, and 0.22%, respectively. Whereas, trade openness reduces CO_2 emissions by 0.27%. Hence, energy consumption is the largest contributing factor towards the environmental degradation in Pakistan. These results are consistent with the estimation results of Ahmed and Long [1]. In Bangladesh, energy consumption, economic growth and population growth have positive and statistically significant impact on CO_2 emissions, where 1% increase in energy consumption, economic growth and population increase CO_2 emission by 0.87%, 0.07%, and 1.31%, respectively. Whereas, trade openness has small but negative impact on CO_2 emissions. Population growth is the highest contributing factor towards CO_2 emission in Bangladesh. For Srilanka, energy consumption and trade openness have positive and statistically significant impact on CO_2 emissions, where 1% increase in energy consumption and trade openness increase CO_2 emissions by 2.56% and 0.48%, respectively. Whereas, economic growth and population growth has negative effect on CO_2 emissions. Energy use in Srilanka is the highest contributing factor towards CO_2 emissions. In Nepal, trade openness and population growth have negative and statistically significant effect on CO_2 emissions. Whereas energy consumption and economic growth have negative effect on CO_2 emissions. Population growth serves highest CO_2 emissions in Nepal. The FMOLS country specific results are consistent with FMOLS-grouped long-run elasticities. Population and energy consumption are the major factors contribute to CO_2 emissions in South Asian region.

Table 4
Variance Decomposition Analysis.

Period	S.E	ln CO_{2it}	ln EN_{it}	ln GDP_{it}	ln TR_{it}	ln POP_{it}
Variance Decomposition of ln CO_{2it}:						
1	0.100623	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.133620	98.17476	0.117636	0.771020	0.650833	0.285752
3	0.156304	96.48307	0.120245	1.154198	1.498756	0.743730
4	0.173811	94.66206	0.132156	1.441679	2.547452	1.216655
5	0.188106	92.73612	0.149618	1.699665	3.771082	1.643515
6	0.200219	90.73254	0.172846	1.947157	5.142722	2.004739
7	0.210782	88.67396	0.201258	2.191128	6.634339	2.299318
8	0.220206	86.57844	0.234060	2.434258	8.219413	2.533830
9	0.228778	84.46221	0.270289	2.677357	9.872968	2.717178
10	0.236700	82.34047	0.308922	2.920396	11.57195	2.858266
Variance Decomposition of ln EN_{it}:						
Period	S.E.	ln CO_{2it}	ln EN_{it}	ln GDP_{it}	ln TR_{it}	ln POP_{it}
1	0.022241	7.629404	92.37060	0.000000	0.000000	0.000000
2	0.030043	7.686605	91.88043	0.060668	0.266028	0.106271
3	0.036099	6.997303	91.91376	0.066455	0.765871	0.256608
4	0.041204	6.313531	91.80621	0.058156	1.430881	0.391222
5	0.045732	5.681402	91.53386	0.048530	2.243475	0.492734
6	0.049865	5.115364	91.10297	0.040819	3.180145	0.560700
7	0.053712	4.614629	90.52747	0.035983	4.221488	0.600431
8	0.057344	4.174180	89.82285	0.034170	5.350380	0.618425
9	0.060810	3.787742	89.00465	0.035203	6.551822	0.620586
10	0.064144	3.448981	88.08796	0.038764	7.812589	0.611711
Variance Decomposition of ln GDP_{it}:						
Period	S.E.	ln CO_{2it}	ln EN_{it}	ln GDP_{it}	ln TR_{it}	ln POP_{it}
1	0.116153	2.687494	0.040978	97.27153	0.000000	0.000000
2	0.165619	1.881076	0.225186	97.51858	0.191352	0.183803
3	0.201981	1.909664	0.373262	97.15066	0.147643	0.418767
4	0.232060	2.167410	0.500267	96.56047	0.111953	0.659899
5	0.258170	2.530149	0.619997	95.86332	0.098795	0.887742
6	0.281455	2.949561	0.733869	95.11021	0.111195	1.095161
7	0.302594	3.400544	0.842726	94.32811	0.148088	1.280527
8	0.322021	3.867117	0.947016	93.53421	0.206914	1.444741
9	0.340037	4.338362	1.047093	92.74011	0.284770	1.589665
10	0.356856	4.806525	1.143249	91.95402	0.378800	1.717406
Variance Decomposition of ln TR_{it}:						
Period	S.E.	ln CO_{2it}	ln EN_{it}	ln GDP_{it}	ln TR_{it}	ln POP_{it}
1	0.134024	0.844303	0.302211	3.011936	95.84155	0.000000
2	0.173680	1.329319	0.342804	2.781971	95.53033	0.015577
3	0.208041	1.380341	0.366736	2.507035	95.71976	0.026127
4	0.237001	1.391752	0.376193	2.284128	95.91339	0.034538
5	0.262725	1.380122	0.380888	2.085560	96.11341	0.040018
6	0.286003	1.362285	0.381680	1.907432	96.30563	0.042977
7	0.307386	1.343616	0.379751	1.746687	96.48604	0.043904
8	0.327225	1.326853	0.375759	1.601540	96.65253	0.043317
9	0.345775	1.313259	0.370188	1.470712	96.80416	0.041680
10	0.363220	1.303434	0.363394	1.353239	96.94054	0.039392
Variance Decomposition of ln POP_{it}:						
Period	S.E.	ln CO_{2it}	ln EN_{it}	ln GDP_{it}	ln TR_{it}	ln POP_{it}
1	0.004107	0.128268	0.940347	0.134107	0.153531	98.64375
2	0.007994	0.306573	0.429004	0.037345	0.775121	98.45196
3	0.011881	0.473624	0.603683	0.061165	1.456020	97.40551
4	0.015654	0.687144	0.815403	0.131874	2.298001	96.06758
5	0.019284	0.936205	0.988517	0.233528	3.281867	94.55988
6	0.022782	1.210455	1.122308	0.358790	4.391314	92.91713
7	0.026170	1.499857	1.224221	0.502545	5.606012	91.16737
8	0.029469	1.795552	1.301342	0.660482	6.905326	89.33730
9	0.032703	2.090107	1.359185	0.828772	8.269552	87.45238
10	0.035890	2.377584	1.401894	1.004010	9.680793	85.53572

Chowlesky Ordering: ln CO_{2it}ln EN_{it}ln GDP_{it}ln TR_{it}ln POP_{it}.

Having confirmed the long-run association and generating the individual estimates, we now utilize the set of forecast error variance decomposition method (FEVDM) and impulse response function (IRF) in their generalized forms, called Innovative Accounting Approach (IAA) for causality analysis. IAA is a distinct approach to interpret the estimated linear and non-linear multivariate time series models. Moreover, it has a superiority over commonly practiced Granger causality approach does not capture the relative strength of causal links amidst variables beyond the selected time periods [62]. The model is simulated in a vector auto-regression (VAR) setting that examines the causal link between the CO_2 emission, energy consumption, economic growth, population and trade openness and, the results are reported in Table 4. The calculations are shown in 14 different time horizons over the period 1971–2013. Each section in the table itemizes the account change in an endogenous variable due its own innovative shock and rest of the exogenous variables. For example; the decomposition analysis of ln CO_{2it} between 1971 and 2013 reveals that 82.3% change in CO_2 emissions is endogenously contributed due its own innovative shocks and 11.5%, 2.9%, 2.8% and 0.3% is contributed by trade openness, economic growth and population growth and energy consumption, respectively. It implies that in the panel countries, carbon emission is mostly contributed by trade openness, economic growth and increasing population density. Similarly, in case of energy consumption, which is 88% is self-contributed and, 7.8, 3.4% and 0.6% is contributed by trade openness, CO_2 emissions, population density and economic growth, respectively. Whereas; economic growth, trade openness and population growth is mostly contributed by CO_2 emission (4.8%), economic growth (1.6%) and trade openness (9.6%) and self-contributed by 91.9%, 96.9%, 85.5, respectively.

The overall FEVDM test results suggest that there is a feedback effect between CO_2 emissions and energy consumption and trade openness and energy consumption. Trade openness leads to energy consumption and energy consumption results in increase to CO_2 emissions. Furthermore, FEVDM results of ln CO_{2it}ln EN_{it}, ln GDP_{it}, ln TR_{it} and ln POP_{it} are checked using impulse response function (IRF) and graphically illustrated by Fig. 2. The binary relationship

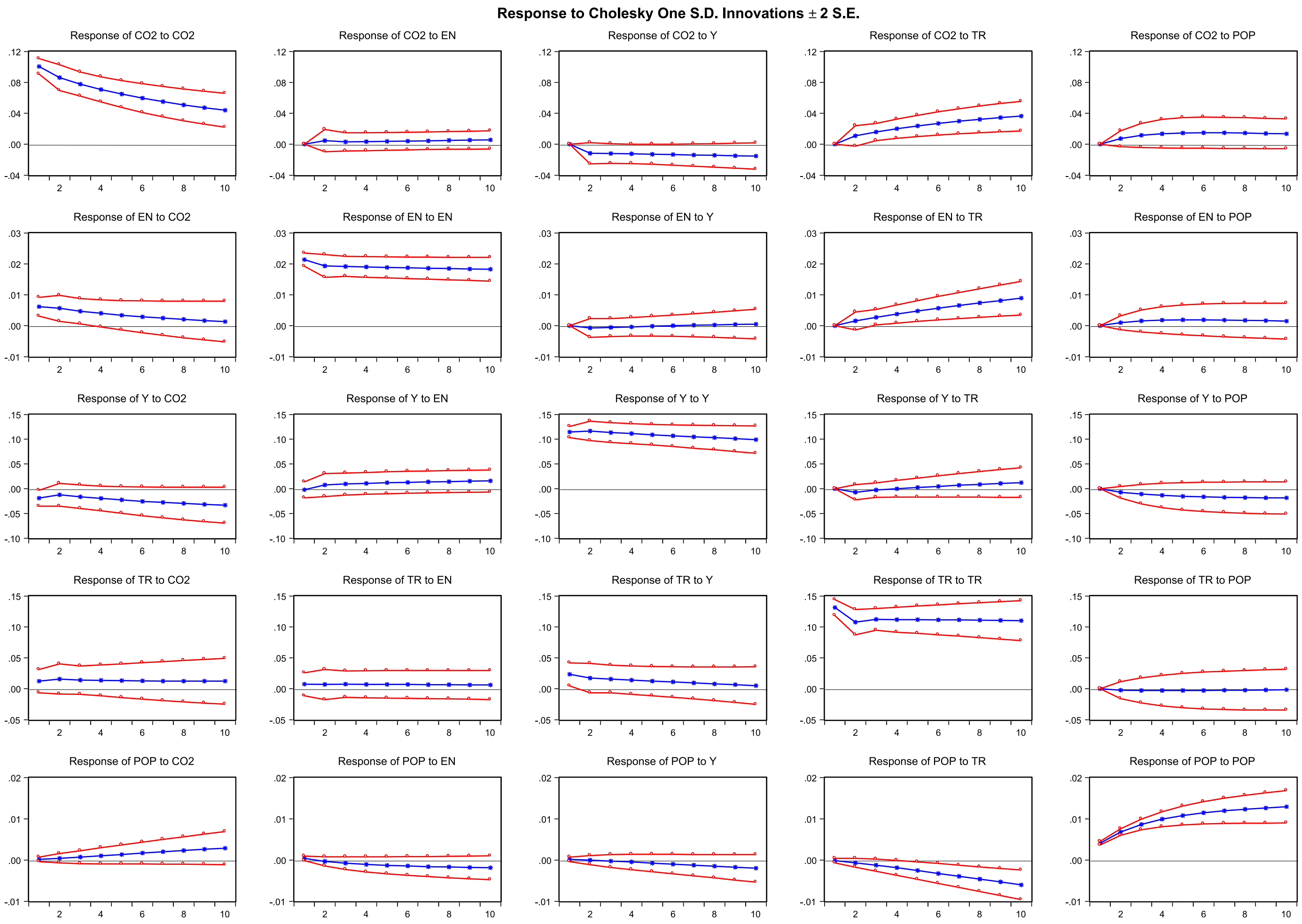

Fig. 2. Impulse Response Function.

between five underlying variables is characterized as exogenous response between the variables. The each figure is showing the response function of numerical FEVDM test results in the form of graph. The variance decomposition analysis results are consistent with long-run estimates, validates overall econometric modeling and ensures findings robust and appropriate for policy use.

5. Conclusion and policy implications

The aim of this paper is to examine the effect of energy consumption, income, trade openness and population on the CO_2 emission for selected five South Asia countries (India, Pakistan, Bangladesh, Sri Lanka, and Nepal) by using annual data from 1971 to 2013. After confirming that all the series are stationary using unit root test process, the study incorporates three different and advance panel cointegration tests. All the panel cointegration tests confirm that all the underlying variables are cointegrated. The long-run association between the variables is checked using FMOLS-grouped and individual cross-section country in the panel. The FMOLS grouped results show that the energy consumption, trade openness and population growth increase environmental degradation in the panel countries with exception of GDP which has negative impact on emissions. The innovative accounting approach (IAA) using variance decomposition test and impulse response function is applied to examine the causality amongst the vectors. The results show that there is bidirectional causality between energy consumption and trade openness and uni-directional causality running from energy consumption, trade openness and population to CO_2 emissions. The results enumerate that the energy consumption and population density increase CO_2 emissions in the long-run and foresee further environmental degradation in the region.

In regards to policy implications, there is a need for cooperation on the international level to resolve the global environmental problems. However, as also mentioned by Carbone et al. [19] that most of the countries are guided by their national self-interest to participate in global emission reduction agreements. Our empirical findings suggest that India, Pakistan, Bangladesh and Sri Lanka need to revisit the sustainable development policies. The energy consumption is highly emission intensive in these countries which potentially hinders their sustainable development goals. Furthermore, the current energy policy is unfriendly to sustainable development of the region. The population growth is the second largest factor contributing to CO_2 emissions in three largest economies- India, Pakistan and Bangladesh, which requires immediate policy response at national.

In comparison to other regional blocs, the South Asian Association of Regional Cooperation (SAARC) has been under utilized to address the common regional challenges. However, SAARC could be an appropriate platform in achieving sustainable development goal at regional level. The best example of such cooperation is available neighborly available in shape of ASEAN. The region can benefit from global efforts to solve environmental and energy security problems through global cooperation.

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