Heliyon 6 (2020) e03903

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Economic growth in South Asia: the role of CO_2 emissions, population density and trade openness

Mohammad Mafizur Rahman [a,*], Kais Saidi [b], Mounir Ben Mbarek [b]

[a] School of Commerce, University of Southern Queensland, Australia
[b] Department of Economics, Faculty of Economics and Management, University of Sfax, Tunisia

ARTICLE INFO

Keywords:
CO_2 emissions
Population density
Trade openness
Economic growth
South Asia
Panel data
Environmental economics
Environmental hazard
Environmental pollution
International economics
Economic development
Econometrics
Economics

ABSTRACT

This study investigates the impact of CO_2 emissions, population density, and trade openness on the economic growth of five South Asian countries. Using data from 1990 to 2017 the panel co-integration approach of extended neoclassical growth model is used. The obtained results reveal that CO_2 emissions and population density positively and trade openness negatively affect the economic growth in South Asia. The extent of effect of population density is greater than that of CO_2 emissions. Granger causality results exhibit a bidirectional causality between economic growth and CO_2 emissions, and between trade openness and CO_2 emissions. There is a uni-directional causality running from trade openness to economic growth, from population density to CO_2 emissions and from labor to economic growth and population density. A detailed policy prescription is provided based on the findings.

1. Introduction

Desired economic growth is the major policy agenda of every country in the world. This is particularly important for developing countries of South Asia region which is the home for 40 percent of the world's poor (Daily Times, 2014). The per capita GDP of this region (US$ 1,779) is still much lower than that of the middle and low income countries and world which are US$10, 636 and US$ 4, 497 respectively (World Bank, 2019). However, it is inspiring that these countries are growing well in recent years. According to In 2017, Nepal experienced 7.9% annual GDP growth rate ranking the country 1st, followed by Bangladesh with 7.28% GDP growth rate ranking the country 2nd, India with 6.68% growth rate ranking the country 3rd and Pakistan with 5.70% growth rate ranking the country 4th in the region. Sri Lanka experienced the lowest GDP growth rate in the region which was 3.30% (World Bank, 2019). Considering the current poverty level, sustained and increased economic growth in these countries is very much crucial.

Economic growth is affected by many socio-economic factors such as population growth, energy use, trade openness, infrastructural development, financial sector development, corruption free society and good governance and policy, etc. Literature suggests that some of these factors, e.g. population growth, energy use which results in CO_2 emissions, and trade openness, play controversial roles towards economic growth. These inconclusive findings are revealed by researchers due to the fact that adopted approaches are ad-hoc, country specific characteristics are different, sample sizes of studies are different and there exists an omitted variable bias (Ozturk, 2010; Zeshan and Ahmed, 2013).

The lack of consensus in relation to the impact of these variables on economic growth is the main motivation for conducting this research to show further evidence. Our study aims at exploring the effects of CO_2 emissions, population density, and trade openness on the economic growth of five selected South Asian countries: Bangladesh, India, Nepal, Pakistan and Sri Lanka. The rationale for selecting these variables is as follows:

The guardian (2012) reports that India's ranking in the world is the 3rd in terms of total CO_2 emissions from energy consumption, followed by Pakistan (33rd), Bangladesh (57th), Sri Lanka (90th), and Nepal (137th). Per capita emission in India in 2010 was 1.4 tonnes. Therefore, inclusion of CO_2 emissions variable in our model is necessary as the

* Corresponding author.
E-mail address: mafiz.rahman@usq.edu.au (M.M. Rahman).

https://doi.org/10.1016/j.heliyon.2020.e03903
Received 5 November 2019; Received in revised form 16 March 2020; Accepted 29 March 2020
2405-8440/© 2020 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

literature supports that growth and emissions are interrelated (see Hamdi and Sbia, 2014 and Muftau et al., 2014, for example).

One of the most populous regions on earth is South Asia. UN (2015) reports that Bangladesh's ranking in the world is the 12^{th} by population density followed by India (28^{th}), Sri Lanka (40^{th}), Pakistan (53^{rd}) and Nepal (69^{th}). Human resources are essential for growth, because populations are used as inputs in the production process. Furthermore, big population size provides larger market for the goods and services, but excessive population means excessive human activities and excessive use of energy that result in CO_2 emissions. Therefore, inclusion of population density as a variable in our analysis is rational.

Undoubtedly, globalization affects economic growth although the direction of effects is mixed. Trade openness is used as a proxy of globalization in the literature (see Rahman, 2017 for example). In 2013, the world's rankings of India, Sri Lanka, Pakistan and Bangladesh are the 64^{th}, 65^{th}, 69^{th} and 73^{rd}, respectively, in terms of trade openness (Floating Path, 2013). Thus it is rational to include trade openness to explore the growth effect.

This paper contributes to the literature in a number of ways: (i) this is the first comprehensive research, to the best of our knowledge, on five South Asia countries that examines the impacts of three relevant explanatory variables on economic growth of the region, which will help the policy makers of these five countries; (ii) an extended Cobb-Douglas production function is used for better understanding of causal relationships; (iii) to cover the impact of globalization on economic growth, trade openness is used as a variable; (iv) population density, the most relevant variable for South Asia, is also included in the model. Hence this research is important especially for South Asia.

The rest of the paper is organized as follows. Section 2 provides literature review. Section 3 presents data description, methodology and model specification. Section 4 analyses the results, and section 5 draws conclusion and provides policy implications.

2. Literature review

Some empirical studies on the relationships between economic growth, CO_2 emissions, population density and trade openness are available in the literature. This paper reviews these related studies under three sub-sections: economic growth and CO_2 emissions nexus; (b) economic growth and trade openness nexus (c) economic growth and population density nexus. These are discussed below.

2.1. Economic growth and CO_2 emissions

For more than two decades, the relationship between economic growth and CO_2 emissions has been intensively analyzed empirically, and it is revealed that there is a nexus between CO_2 emissions and economic growth. Some existing works have argued that there exists an inverted U-shaped relationship between the level of CO_2 emissions and economic growth, known as the Environmental Kuznets Curve (EKC) hypothesis. For example, the studies of Grossman and Krueger (1991) and Selden and Song (1994) found the evidence of EKC hypothesis implying that economic growth degrades the environmental quality in its initial phase, and after a certain level of growth, environmental improvement occurred. This is opposite to the results of Shafik (1994) which showed that CO_2 emissions increased in parallel with economic growth.

Stern et al. (1996) exhibited that CO_2 emissions start to decline when the economy reached a certain income level. However, the findings of Akbostanci et al. (2009) did not follow the principles of the EKC hypothesis. Martinez-Zarzo and Bengochea-Morancho (2004) found that income and carbon emissions were negatively and positively related in low and high-income countries, respectively.

Joseph (2010) used panel co-integration method in a study in sub-Saharan Africaon climate change and sustainable development, and showed that there was a strong positive link and sensitivity of climate change to growth. On the other hand, Usenobomg and Chukwu (2011) found the contrasting results who examined economic growth and environmental problem in Nigeria. Their finding indicated an N-shaped link between economic growth and environmental degradation. They suggested that bold policy measures of environmental protection should be adopted irrespective of the country's income level.

Al Khathlan and Javid (2013) found a positive link between carbon emissions and GDP. They further opined that electricity generated less pollution than other energy sources. However, the study of Ozturk and Acaravci (2013) found the validity of the EKC hypothesis for the Turkish economy. Similarly, Hamdi and Sbia (2014) found the evidence of Environmental Kuznets Curve (EKC) hypothesis for a group of Gulf Cooperation Council (GCC) countries in the long-run while exploring the causality between carbon dioxide emissions, energy consumption and real output in these countries. In a separate study, Muftau et al. (2014) tested the link between CO_2 emissions and economic growth for West African countries using co-integration technique and found a long-run equilibrium link between CO_2 emissions and GDP. They found, in the long run, an N-shaped link between income and CO_2 emissions, and the EKC hypothesis does not hold in West Africa. Rahman and Kashem (2017) examined the causality between carbon emissions, energy consumption and industrial growth in Bangladesh, and found short and long run nexus between industrial production and CO_2 emissions. Rahman (2017) also found the unidirectional causality running from GDP toCO_2 emissions for 11 Asian populous countries. Mbarek et al. (2017) also found short and long run impacts of economic growth on CO_2 emissions in Tunisia. Saidi and Hammami (2015) examined the effect of energy use and the CO_2 emissions on economic growth for 58 countries, and their empirical results showed that CO_2 emissions negatively affected economic growth.

2.2. Economic growth and trade openness

The effect of trade openness on growth is a key element for trade policy. Some past studies used theoretical models to explain the economic growth effects of trade openness. Bouoiyour (2003) examined the link between trade openness and economic growth in Morocco. The results showed an absence of long-run causality. In the short run, increased imports and exports caused increased GDP. Calderon et al. (2004) found positive effects of trade openness on growth in rich countries, but found no evidence of growth effect due to openness in the poor countries. Using cross-country data of 126 countries, Freund and Bolaky (2008) found a positive impact of trade openness on per capita income. Their results also showed that an increase in trade increased the standard of living in the economies with greater flexibility, but not in rigid economies. In contrast, Sarkar (2008) found negative impact of trade openness on growth in India in a study of time series analysis. The study used trade-GDP ratio as the proxy for openness. Chang et al. (2009) also viewed that the positive link between growth and openness might be substantially improved if complementary policies were adopted.

Ulaşan (2012) analyzed the link between trade openness and long-run economic growth for the sample period of 1960–2000. The results exhibited that many trade openness variables were significantly and positively correlated with economic growth in the long-run. The study of Rahman et al. (2017) on major developed and developing countries also found bidirectional relationships between trade openness and economic growth. The same results also established in a separate study of Rahman and Mamun (2016) for Australia.

Eris and Ulasan (2013) did not find no evidence of direct and robust link between trade openness and economic growth in the long run. Fetahi-Vehapi et al. (2015) analyzed the impacts of trade openness on economic growth of South-East European countries. Their findings revealed positive effects of trade openness on economic growth which were conditioned by the initial income per capita as well as other variables; otherwise no robust evidence between these two variables was found.

Tahir et al. (2014) examined the link between trade openness and economic growth, where they found a positive effect of trade openness on economic growth. Furthermore, Musila and Yiheyis (2015) examined the effects of trade openness on the investment level and the rate of economic growth in Kenya. Their results indicated that a change in trade openness influenced the rate of economic growth in the long run via the interaction with physical capital growth.

2.3. Economic growth and population density

Many earlier studies, which examined the impact of population density on agricultural production, considered population density as an exogenous variable [Pender et al., 2006; Benin, 2006; Pender and Gebremedhin, 2006]. For instance, Carlino et al. (2007) showed that patent intensity and the density of employment were positively linked. Their findings suggested that if, ceteris paribus, a city with twice the employment density compared to another city, would exhibit 20 percent higher patent intensity. Ciccone and Hall (1996) affirmed that density could lead to increasing yields in production as a result of the availability of variety of intermediate products. They also argued that density could give rise to increasing returns in production. Simon (1977) and Frederiksen (1981) observed that population density had a positive impact on infrastructure construction. Rahman (2017) revealed a bidirectional panel causal link between GDP and population density for 11 Asian countries. The study of Rahman et al. (2017) also found a positive impact of population growth on economic growth. The same results were also revealed by the study of Owusu et al. (2012) where they found that population could actually be a major driver of knowledge and thus economic growth provided the government played an appropriate role.

The empirical results of above studies reveal that there is a lack of consensus on the growth–CO_2 emissions nexus, the growth–trade openness nexus and the growth-population density nexus in the literature. The main reasons for these disagreements arecountry or area heterogeneity with respect to levels of economic growth, energy consumption patterns, trade patterns and trade volume, and level of population density. Therefore, country or region-specific studies are vital to mitigate the ongoing debate in the literature. The present study in the context of South Asia is based on the countries' specific characteristics, and thus will contribute to the current literature significantly.

3. Materials and methods

3.1. Models specification

The theoretical notion behind our empirical model is neo-classical growth theory. Using panel data estimation technique we use Cobb-Douglas production function [Cobb, Douglas (1928)] of the following form:

$$Y = AK^{\beta 1}L^{\beta 2}e^{\mu} \tag{1}$$

Where, Y is output, K and L are, respectively, capital and labor. The term A is technology and e is the error term assumed N (iid). β_1, and β_2 are the output elasticity with respect to capital and labor is, respectively. We enhance this production function by assuming that technological progress can be affected by CO2 emissions, population density and trade openness. Therefore, technology can be expressed in the following form:

$$A(t) = \varnothing.CO2(t)^{\beta 3}PD(t)^{\beta 4}TR(t)^{\beta 5} \tag{2}$$

Where $\varnothing$ is time-invariant constant, CO_2 is CO_2 emissions, PD is population density and TR is trade openness. Replacing Eq. (2) into Eq. (1), we obtain Eq. (3):

$$Y(t) = \varnothing.CO2(t)^{\beta 3}PD(t)^{\beta 4}TR(t)^{\beta 5}K(t)^{\beta 1}L(t)^{\beta 2} \tag{3}$$

Therefore, transforming all variables in natural logarithms, we set our model as:

$$LnY_{it} = \beta_0 + \beta_1 LnK_{it} + \beta_2 LnL_{it} + \beta_3 LnCO2_{it} + \beta_4 LnPD_{it} + \beta_5 LnTR_{it} + \mu_t \tag{4}$$

The variables used in this study are presented in Table 1:

3.2. Econometric methodology

3.2.1. Unit root tests

Unit root tests will be performed to ensure the stationarity of variables. Some unit root tests are considered in the literature. The most popular tests in literature are the Augmented Dickey and Fuller (ADF) (1979, 1981), Phillips and Perron (1988) (PP), Breitung (2000), Maddala and Wu (1999), Levin et al. (2002) (LLC), Im et al. (2003) (IPS), and the Hadri (2000) tests. For all these tests, the presence of a unit root indicates non-stationarity as the null hypothesis, and the absence of the unit root implying the stationarity as the alternative hypothesis. The equation used to test for unit roots is:

$$y_{it} = \rho\, y_{i\,(t-1)} + \delta\, X_{it} + \varepsilon_{it} \tag{5}$$

Withi = 1,……, N for each country in the panel; t = 1,…., T design the time period; X_{it} is the symbol for the combination of all the exogenous variables in the model; ρ_i denote the autoregression coefficients and ε_{it} is the error term. If $\rho_i > 1$, y_{it} is reflected as having stationary trend while if $\rho_i = 1$, then y_{it} will contain a unit root. The study of Im et al. (2003) permits for different orders of serial correlation and uses the typical augmented Dickey Fuller (ADF) test which is on average:

$$\varepsilon_{it} = \sum_{j=1}^{Pi} \rho_{ij}\varepsilon_{it-j} + u_{it}, \tag{6}$$

If Eq. (6) is substituted into Eq. (5) we obtain Eq. (7):

$$y_{it} = \rho_i y_{it-1} + \sum_{j=1}^{Pi} \rho_{ij}\varepsilon_{it-j} + \delta_i X_{it} + u_{it} \tag{7}$$

Where ρ_i show the number of lags in the ADF regression. The statistic, t-bar specified by Im et al. (2003), is the average of individual statistics of ADF as shown below:

$$\overline{t_{NT(\rho i)}} = {}^{1}/_{N} \sum_{i=1}^{N} t_{iT}(\rho_i)$$

The alternative statistic "t-bar" permits testing the null hypothesis of the presence of unit root for all individuals. t_{iT} (ρ_i) denotes the estimated ADF; N is the number of individuals and T is the number of observations.

3.2.2. Panel co-integration tests

The panel unit roots test and panel cointegration test dramatically increase the power of the tests and often contain a two-step procedure. The first stage is to test the panel unit roots; the second stage is co-integration tests in the panel. The panel co-integration is regarded much well than the time series co-integration because it exhibits the long run link between the variables for N ($\geq$2) countries.

When the variables are stationary, the co-integration test is used. Pedroni (1997, 1999, and 2004) introduced a method of co-integration panel based on residuals which considers the heterogeneity of the specific effects, the slope coefficients and individual linear trends between countries. Pedroni (2004) uses the following regression:

$$y_{it} = \alpha_i + \delta_i t + \beta_i X_{it} + e_{it} \tag{8}$$

We consider time series y_{it} and X_{it} of country i (i = 1, 2, ... , N) in year t (t = 1, 2, ... , T) for each panel. These two series are expected to be

Table 1. Definition of variables.

Variables	Definition
LnY_{it}	Is the explained variable, representing the regional GDP. We choose per capita GDP as an agent variable.
$LnCO_{2it}$	Is the carbon dioxide emission, measured in metric tons per capita.
$LnPD_{it}$	Is the explanatory variable, representing the population density; population density is a measure of the number of inhabitants of a population in a given area. Population density is usually expressed as individuals per unit area (e.g., inhabitants/km2).
LnTR	Is the trade-GDP ratio.
LnK_{it}	Is the gross fixed capital formation. Here K is measured in per capita.
LnL_{it}	Is the total labor force.
μ_{it}	Is the random disturbance

integrated of order one, I (I). The parameters a_i and δ_i permit the opportunity to view the specific effects and specific linear trends, respectively. The $\beta_{i,}$ slope coefficients, are permitted to differ from one member to another. Usually, the co-integration vectors may be dissimilar among the panel members. Pedroni (2004) suggests seven possible statistics for testing the null hypothesis of no co-integration. These tests contain two types of co-integration tests; the first is based on the co-integration tests panel (within-dimension, namely panel v-statistic, panel ρ-statistic, panel PP-statistic, and panel ADF-statistic). The second is based on the co-integration tests group (Between dimension, namely group ρ, group PP, and group ADF statistics).

3.2.3. Panel Granger causality test

Before examining the co-integration series, we will proceed to test Granger causality to specify the variables that could intervene in the long-term relationship. In econometrics, the causality between two columns is generally studied for refining the prediction characterization of Granger.

Granger causality shows the dynamic relationship between variables. We can formulate the Granger causality as follows: suppose there are two series of data X and Y. If the two series are co-integrated of the same order, we can estimate the long-run parameters and analyse the causality in a dynamic panel data co-integration framework using a vector error correction model (VECM).

3.3. Data and descriptive statistics

This study considers annual time series data from 1990 to 2017. The period was chosen based on the availability of all the data series. The countries under study are Bangladesh (BGD), India (IND), Nepal (NPL), Pakistan (PAK) and Sri Lanka (LKA). The data on per capita GDP (constant 2010 US$) as the proxy for the economic growth, per capita gross fixed capital formation (constant 2010 US$) as a proxy of capital stock, total labor force, total trade as share of GDP as the proxy of trade openness, population density (people per sq. km of land area) and per capita CO_2 emissions (metric tons) are obtained from the World Development Indicators (World Bank, 2019). All variables are transformed into the natural logarithms form. Table2 presents some descriptive statistics of the selected variables for r the period of 1990–2017. The summary statistics show the means, median and standard deviation (Std. Dev.) of each series before transformation in logarithms form.

Table 2 shows the mean, maximum and minimum values of the variables used in the model. It is noted that standard deviation is the lowest for population density (0.3816), and the highest for per capita capital stock (1.6538).

Table 3 gives the results of the correlation matrix between the variables. The result shows that there is a positive correlation of CO_2 emissions, population density, capital and trade openness with economic growth. In addition, a positive correlation of population density, capital and total labor force with CO_2 emissions has existed. We note the strong correlation between capital and total labor force (0.83769).

4. Empirical results and analysis

4.1. Unit root test results

The results of the unit root tests, including Im et al. (2003) (IPS), augmented Dickey and Fuller (1979) (ADF) and the Phillips and Perron (1988) (PP) tests are presented in Appendix 1a. The results show that the per capita GDP (Y), CO_2 emissions (CO_2), population density (PD), trade openness (TR), labor (L), and gross fixed capital formation (K) are stationary at the first difference with 1% and 5% significance level. The results suggest that our three variables of interest contain a panel unit root.

4.2. Co-integration test results

Since this study finds that economic growth (Y), CO_2emissions (CO_2), trade openness (TR) and the population density (PD) are stationary at the first difference, we can continue to test for co-integration to explore the

Table 2. Summary statistics (after taking logarithm), 1990–2017.

	Per capita GDP (constant 2010 USD)	CO_2 emissions (metric tons per capita)	Population density (per sq. KM)	Trade openness (in %)	Per capita capital stock (constant 2010 USD)	Total labor force
Mean	6.454806	-0.814021	3.710353	5.828983	23.43476	17.48315
Median	6.391023	-0.526216	3.725690	5.716767	23.44723	17.66869
Maximum	8.255687	0.548122	4.484543	7.142856	27.46528	19.99187
Minimum	5.453052	-3.351620	2.723859	4.841441	21.12566	15.70763
Std. Dev.	0.621020	0.883270	0.381671	0.696857	1.653889	1.351091
Skewness	0.600401	-0.501852	-0.168596	0.714362	0.669376	0.472985
Kurtosis	3.165657	2.365502	2.701534	2.251644	2.663808	2.175300
Jarque-Bera	8.571298	8.225043	1.182887	15.17420	11.11415	9.187443
Probability	0.013765	0.016366	0.553528	0.000507	0.003860	0.010115
Sum	903.6728	-113.9630	519.4494	816.0577	3280.866	2447.642
Sum Sq. Dev.	53.60763	108.4431	20.24848	67.49969	380.2135	253.7371
Observations	140	140	140	140	140	140

Note: Std. dev. = indicates standard deviation.

Table 3. Correlation matrix.

	LNGDP	LN CO_2	LNPD	LNTR	LNK	LNL
LNGDP	1.000000					
LN CO_2	0.692476	1.000000				
LNPD	0.128485	0.141386	1.000000			
LNTR	0.372058	-0.139316	-0.167219	1.000000		
LNK	0.409017	0.825664	0.387696	-0.369135	1.000000	
LNL	-0.073393	0.565644	0.354711	-0.649902	0.837691	1.000000

long run link between the dependent variable Y, and the independent variables. Two types of panel co-integration tests are used in this study namely the Pedroni (1999, 2004) and Kao (1999) test. Appendix 1b presents the results of Pedroni test. The results exhibit that, out of seven statistics, one statistic is significant at 1% level, another statistic is significant at 5% level and four statistics are significant at 10% level.

Appendix 1c below reviews the Kao co-integration test results and exhibits clearly the rejection of the null hypothesis of no co-integration indicating that explanatory variables have the long run link with the dependent variable, economic growth (Y).

4.3. Granger causality test results

4.3.1. Short-run and long-run Granger causality test results

Appendix 2a illustrates the links between the variables. Carbon emissions Granger cause economic growth in the short-run. This finding is similar to the results of Mani et al. (2012) and Vidyarthi (2013) for India. Moreover, economic growth positively affects CO_2 emissions (significant at 5% level) implying that a 1% increase in economic growth increases the degradation of the environment by 1.39%. Similarly, there is a bidirectional causal link between CO_2 emissions and economic growth that supports the neutral hypothesis. The result is consistent with the findings of Saidi and Hammami (2015a). Unidirectional causality from capital to population density is also observed. In addition, there is a unidirectional causal link running from labor to economic growth and population density. A unidirectional causality ranging from trade openness to economic growth and no causal relationship between trade openness and labor is also revealed. Finally, there is a unidirectional causal link running from population density to CO_2 emissions.

Furthermore, there is a long-run unidirectional causal link running from capital to population density and from labor to economic growth at 5% level of significance. A unidirectional causal link running from labor to population density is also observed. In addition, there is a two-way causality between CO_2 emissions and economic growth. This result is different with some empirical studies such as Ang (2008), Dinda (2004), Menyah and Wolde-Rufael (2010), Hossain (2012) and Saboori et al. (2012). Finally, there is a unidirectional causal link running from population density to CO_2 emissions which is significant at 5% level.

4.3.2. The FMOLS and DOLS estimations

After finding the stationarity of variables and long-run co-integration among them, we now estimate the long-run impact of CO_2emissions (CO_2), population density (PD), trade openness (TR), capital and the labor on the economic growth of five South Asian countries by using the Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) estimation methods. The results of both methods are the same for the coefficient signs and almost similar in terms of significance and extent of effects of coefficients. These are reported in Appendix 2b.

The results of FMOLS estimation in Appendix 2b indicate that a 1% increase in per capita CO_2 emissions, population density and capital leads to increase of GDP per capita by 0.15%, 0.40% and 0.51%, respectively, in the panel of five South Asian countries. In addition, the results indicate that a 1% increase in trade opening leads to a decrease in per capita GDP of -0.29% for the five South Asian countries. For the DOLS estimate, the results show that population density, capital and labor positively affect economic growth at the 1% threshold, which means that a 1% increases in these three variables increase economic growth of 1.41%, 0.44% and 0.78%, respectively. The negative growth effect of trade openness, though not significant in DOLS estimation, deserves special attention. This may be due to the fact that the industrial base of all South Asian countries are not mature enough compared to other industrial/developed countries. Infant industry arguments are very much relevant for these countries to be too open in terms of trade liberalization. The manufacturing sector of these countries cannot compete with that of developed countries which adversely affect economic growth if these countries ae too open. Moreover, import figures of these countries are bigger than export figures; and imports contain more consumption goods rather than capital goods. For example, for South Asia as a whole, import-GDP ratio is 23.39 against the export-GDP ratio of 18.31. Also for Bangladesh, Pakistan and Nepal, the shares of consumer goods imports are 23.16%, 31.91% and 32.44%, respectively, against the shares of capital goods imports of 17.26%, 20.71% and 22.90% (World Bank, 2019). All these factors could be the reasons for trade openness having negative effect on economic growth of South Asia. Our results are consistent with the results of Jawaid (2014) but different from the results of Chang et al. (2009); Kim (2011) and Keho results (2017). Our findingsrecommend that since the imports of the countries are greater than exports, the governments should maintain current efforts for export diversification in the countries with an objective of export-led economic growth.

4.3.3. Estimation of the GMM system

In order to confirm and support our estimation results by FMOLS and DOLS models, we estimate a generalized method of moments (GMM) system. In fact, we are basing on the recent paper by Sarafidis and Wansbeek (2012) that emphasized that not all forms of CSD are detrimental to GMM system. Thereby, the GMM system tackles the endogeneity and autocorrelation problems and provides the unbiased, efficient and consistent estimates. The GMM system has been developed for panel dynamic models and introduced by Hansen (1982). The following regression equation presents their general form:

$$Y_{it} - Y_{it-1} = (\alpha - 1)Y_{it-1} + \beta_0 X_{it} + \mu_i + \varepsilon_{i,t}$$

where Yit present the GDP per capita in our case (LnY) and Xit is a a vector of explanatory variables (LnCO2, LnPD, LnTR, LnK and LnL), μi: is the country-specific effect (unobserved), εi is the error term, i and t denote, respectively, the country and the time.

The GMM estimate presented in Appendix 2c gives almost similar results to that by FMOLS model. In fact, the CO_2 emissions have a significant positive effect on GDP per capita at 1% level of significance. This result translates total dependence on non-renewable energy by the South Asian economy. The same applies to the effects of physical capital and labor on per capita GDP at 1% level. It has been confirmed by GMM System with the above estimates that there is feedback or the bidirectional links between GDP per capita and both capital and labor. The different results suggest that capital and labor considered as the driver of economic growth for these countries.

5. Conclusion and policy implications

The objective of this paper is to investigate the long and short-run effects of carbon dioxide emissions, population density, and trade openness on economic growth based on an extended neoclassical economic growth model. Our findings are based on a dataset for five South Asian countries for r the period of 1990–2017. We have used recently developed panel unit root and panel co-integration tests and also applied a more recently used method, FMOLS and DOLS approaches, in order to explore the long-run link between the variables. The GMM system has also been estimated to verify the link.

The results of co-integration tests show the existence of a long-run equilibrium link between the variables. The estimated results show that in the long run, CO_2 emissions, and population density positively and significantly affect the economic growth in South Asia while trade openness affects economic growth negatively. Capital and labour also have significant positive influence on the economic growth.

In the short run, there is a bidirectional causal link between CO_2 emissions and economic growth, and between CO_2 emissions and trade openness. A unidirectional causality running from trade openness and labour to economic growth, from population density to CO_2 emissions, and from CO_2 emissions to labour is also revealed. In addition, in the long-run, the results show a bidirectional causal link between CO_2 emissions and economic growth and unidirectional causal link running from population density to CO_2 emissions. Finally, there is a unidirectional causal link running from labor to economic growth and population density.

From the obtained results, the following policy implications can be drawn:

a) South Asia is a densely populated area. The most important resources of these 5 countries are their huge working forces (labours) which contribute to economic growth. Population density also has positive impact on economic growth. Therefore, skill based trainings and quality education must be ensured by the government and non-government organizations to produce more skilled labours which are essential for growth.
b) The positive effect of CO_2 emissions on economic growth implies that industrial production and manufacturing activities are contributing to economic growth. Hence expansion of manufacturing outputs should continue to grow. However, increased CO_2 emissions are not desirable for improved environmental quality. Therefore, smart national policies should be adopted to find out alternative source of energy (e.g., renewable energy) in order to minimize the CO_2 emissions of energy use. Clean, cost effective, secure, reliable, and sustainable energy should be targeted. Cordial efforts must be made for further supervisory and institutional reforms to confirm the efficient supply of growing energy needs.
c) Surprisingly trade openness has negative effect on economic growth. This may be due to the fact that the production capacities in these countries are not internationally competitive. The government of these countries should undertake proper steps in this regard. Import of intermediate and efficient capital goods, rather than consumption goods, should get priority. This will increase domestic production and export capacity. Proper development oriented trade policies, along with other macroeconomic policies, must be formulated and executed to achieve the desired goals both in the short and long runs.

Declarations

Author contribution statement

M.M. Rahman: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

K. Saidi: Performed the experiments; Wrote the paper.

M.B. Mbarek: Analyzed and interpreted the data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Appendix 1a. Unit root test results.

Variable	Im, Pesaran and Shin W-stat			
	Level		First Difference	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
Y	6.76924 (1.0000)	3.28930 (0.9995)	-4.40384 (0.0000)*	-4.75699 (0.0000)*
CO_2	-0.80145 (0.2114)	1.25458 (0.8952)	-4.57517 (0.0000)*	-3.66267 (0.0001)*
PD	0.78617 (0.7841)	-0.03616 (0.4856)	-1.58489 (0.0565)**	-1.23641 (0.0082)*
TR	-0.69914 (0.2422	1.10150 (0.8647)	-4.64775 (0.0000)*	-4.31509 (0.0000)*
K	5.17078 (1.0000)	1.76299 (0.9610)	-4.77770 (0.0000)*	-4.52237 (0.0000)*
L	0.89374 (0.8143)	1.63227 (0.9487)	-3.95016 (0.0000)*	-3.09607 (0.0010)*
ADF - Fisher Chi-square				
Y	0.03310 (1.0000)	0.62758 (1.0000)	37.5604 (0.0000)*	38.9309 (0.0000)*
CO_2	12.5212 (0.2517)	4.78522 (0.9051)	39.6077 (0.0000)*	30.4371 (0.0007)*
PD	10.0796 (0.4335)	8.90443 (0.5412)	20.4109 (0.0256)**	17.2016 (0.0700)***
TR	14.5213 (0.1505)	9.22565 (0.5108)	40.4378 (0.0000)*	36.3552 (0.0001)*

(*continued on next column*)

(*continued*)

Variable	Im, Pesaran and Shin W-stat			
	Level		First Difference	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
K	0.26416 (1.0000)	4.53481 (0.9200)	41.2036 (0.0000)*	37.4250 (0.0000)*
L	5.22892 (0.8754)	3.61202 (0.9632)	34.9158 (0.0001)*	28.2405 (0.0017)*
PP - Fisher Chi-square				
Y	0.01378 (1.0000)	0.73982 (1.0000)	73.0734 (0.0000)*	78.0215 (0.0000)*
CO_2	13.1839 (0.2136)	11.7320 (0.3034)	102.514 (0.0000)	96.3011 (0.0000)
PD	72.6656 (0.0000)	6.95683 (0.7295)	31.2311 (0.0005)*	26.0209 (0.0037)*
TR	12.6959 (0.2412)	6.76110 (0.7478)	70.2021 (0.0000)*	68.1307 (0.0000)*
K	0.14725 (1.0000)	6.25082 (0.7938)	74.5786 (0.0000)*	71.5042 (0.0000)*
L	5.66187 (0.8428)	2.69606 (0.9877)	66.2730 (0.0000)*	56.1903 (0.0000)*

Note: * and ** denotes significance at 1% and 5% levels.

Appendix 1b. Pedroni co-integration test results.

Alternative hypothesis: common AR coefs.				
	Within-dimension		Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	0.526909	0.2991	0.396211	0.3460
Panel rho-Statistic	0.483728	0.6857	0.431023	0.6668
Panel PP-Statistic	-1.549215	0.0607	-1.539915	0.0618
Panel ADF-Statistic	-1.326225	0.0924	-0.651287	0.0257

Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.
Panel rho-Statistic	2.559152	0.9948
Panel PP-Statistic	-4.792057	0.0000
Panel ADF-Statistic	-1.444139	0.0743

Appendix 1c. Kao co-integration test results.

	t-Statistic	Prob.
ADF	-3.253927	0.0006

Appendix 2a. Granger causality test results.

Dependent variable	LnY	Direction of causality					
		Short-run (Wald test χ^2 statistic)					Long-run
		$LnCO_2$	LnPD	LnTR	LnK	LnL	ECM_{t-1} [prob]
LnY		1.394 (0.014)**	0.317 (0.181)	-0.893 (0.151)	-0.268 (0.202)	-0.101 (0.349)	1.816 (0.035)**
$LnCO_2$	0.158 (0.091)***		-0.164 (0.108)	0.790 (0.088)***	-0.745 (0.121)	-0.136 (0.021)**	-0.507 (0.035)**
LnPD	0.436 (0.539)	-0.297 (0.053)***		1.212 (0.538)	1.044 (0.721)	-1.187 (1.244)	2.928 (0.042)**
LnTR	-0.709 (0.099)***	-0.506 (0.099)***	-0.459 (0.118)		-0.197 (0.132)	0.578 (0.229)	1.217 (0.035)**
LnK	0.540 (0.107)	-0.061 (0.105)	1.031 (0.012)**	0.582 (0.106)		0.948 (0.247)	2.918 (0.047)**
LnL	0.356 (0.027)**	-0.307 (0.274)	1.358 (0.031)**	1.447 (0.276)	1.026 (0.371)		-3.509 (0.022)**

Notes: ** and *** denote significance at 5% and 10 % levels, respectively; values within the parentheses are probabilities.

Appendix 2b. The results of FMOLS and DOLS (Dependent Variable LnY).

Panel FMOLS results				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Ln CO_2	0.153711	0.071076	2.162641	**0.0325****
LnPD	0.404244	0.090727	4.455615	**0.0000***
LnTR	-0.294416	0.051149	-5.756096	**0.0000***
LnK	0.513992	0.035217	14.59487	**0.0000***
LnL	0.079579	0.052412	1.518336	0.1315
Panel DOLS results				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LnCO2	0.033542	0.084824	0.395437	0.6932
LnPD	1.410053	0.342070	4.122119	**0.0001***
LnTR	-0.126916	0.098225	-1.292095	0.1988
LnK	0.448658	0.050209	8.935771	**0.0000***
Ln`L	0.787430	0.180735	4.356830	**0.0000***

Notes: * and ** denote significance at 1%, and 5% levels, respectively. The figures in parentheses are probabilities.

Appendix 2c. Panel GMM EGLS (Period random effects, Dependent Variable: LnY).

Cross-sections included: 5				
Cross-section weights instrument weighting matrix				
White cross-section standard errors & covariance (d.f. corrected)				
Instrument specification: C LnCO2 LnPD LnTR LnK LnL				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.720824	0.941967	9.258101	**0.0000***
Ln CO2	0.543909	0.048173	11.29081	**0.0000***
LnPD	0.146848	0.019405	7.567438	**0.0000***
LnTR	-0.101273	0.051314	1.973591	**0.0505*****
LnK	0.217148	0.033492	6.483543	**0.0000***
LnL	0.465808	0.018225	-25.55933	**0.0000***

References

Akbostancı, E., Türüt-Aşık, S., Tunç, G.İ., 2009. The relationship between income and environment in Turkey: is there an environmental Kuznets curve? Energy Pol. 37 (3), 861–867.

Alkhathlan, K., Javid, M., 2013. Energy consumption, carbon emissions and economic growth in Saudi Arabia: an aggregate and disaggregate analysis. Energy Pol. 62, 1525–1532.

Ang, J.B., 2008. Economic development, pollutant emissions and energy consumption in Malaysia. J. Pol. Model. 30, 271–278.

Benin, S., 2006. Policies and programs affecting land management practices, input use, and productivity in the highlands of Amhara region, Ethiopia. In: Pender, John, Place, Frank, Ehui, Simeon (Eds.), Strategies for Sustainable Land Management in the East African Highlands. International Food Policy Research Institute, Washington, D.C., pp. 217–256

Bouoiyour, J., 2003. Trade and GDP growth in Morocco: short-run or long-run causality? Braz. J. Bus. Econ. 3 (2), 14–21.

Breitung, J., 2000. The local power of some unit root tests for panel data. Adv. Econom. 15, 161–177.

Calderon, C., Loayaza, N., Schmidt Hebbel, K., 2004. External Conditions and Growth Performance, Working Papers Central Bank of Chile 292.

Carlino, G.A., Chatterjee, S., Hunt, R.M., 2007. Urban density and the rate of invention. J. Urban Econ. 61 (3), 389–419.

Chang, R., Kaltani, L., Loayza, N., 2009. Openness can be good for growth: the role of policy complementarities. J. Dev. Econ. 90 (1), 33–49.

Ciccone, A., Hall, R., 1996. Productivity and the density of economic activity. Am. Econ. Rev. 87, 54–70.

Cobb, C.W., Douglas, P.H., 1928. A theory of production. Am. Econ. Rev. 8 (Supplement), 139–165, 1928.

Daily Times, 2014. 40% Poor Live in South Asia, Staff Report. March 06.

Dickey, D., Fuller, W., 1981. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica e JEconom Soc 1057–1072.

Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. J. Am. Stat. Assoc. 74 (366), 427–431.

Dinda, S., 2004. Environmental Kuznets curve hypothesis: a survey, Elsevier. Ecol. Econ. 49, 431–455.

Eris, M.N., Ulasan, B., 2013. Trade openness and economic growth: Bayesian model averaging estimate of cross-country growth regressions. Econ. Modell. 33, 867–883.

Fetahi-Vehapi, M., Sadiku, L., Petkovski, M., 2015. Empirical analysis of the effects of trade openness on economic growth: an evidence for South East European countries. Procedia Econom. Fin. 19, 17–26.

Floating Path, 2013. Countries Ranked on Global Trade Openness. Retrieved from. http://www.floatingpath.com/2013/06/13/countries-ranked-on-global-trade-openness/. (Accessed 20 October 2015).

Frederiksen, p., 1981. Further evidence on the relationship between population density and infrastructure: the Philippines and electrification. Econ. Dev. Cult. Change 29 (4), 749–758. Jul., 1981.

Freund, C., Bolaky, B., 2008. Trade, regulations, and income. J. Dev. Econ. 87, 309–321.

Grossman, G., Krueger, A., 1991. Environmental Impacts of a North American Free Trade Agreement. National Bureau of Economics Research Working Paper. No. 3194.

Hadri, K., 2000. Testing for stationarity in heterogeneous panel data. Econom. J. 148–161.

Hamdi, H., Sbia, R., 2014. The dynamic relationship between CO_2 emissions, energy usage and Growth in Gulf Cooperation Council (GCC) countries: an aggregated analysis. Econ. Appl. 67, 161–182.

Hossain, S., 2012. An econometric analysis for CO_2 emissions, energy consumption, economic growth, foreign trade and urbanization of Japan. Low Carbon Econ. 3, 92–105.

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. J. Econom. 115 (1), 53–74.

Jawaid, S.T., 2014. Trade openness and economic growth: a lesson from Pakistan. Foreign Trade Rev. 49 (2), 193–212.

Joseph, A.O., 2010. Climate change and sustainable development in sub-saharan Africa: an application of panel cointegration in some selected countries, energy, environment and economic growth. Proceedings of the 2010 Nigerian Association for Energy Economics, pp. 187–197.

Kao, C., 1999. Spurious regression and residual–based tests for cointegration in panel data. J. Econom. 90 (1), 1–44.

Keho, Y., 2017. The impact of trade openness on economic growth: the case of Cote d'Ivoire. Cogen. Econom. Fin. 5 (1), 1332820.

Kim, D.-H., 2011. Trade, growth and income. J. Int. Trade Econ. Dev. 20, 677–709.

Hansen, Lars Peter, 1982. Large sample properties of generalized method of moments estimators. Econometrica 50 (4), 1029–1054.

Levin, A., Lin, C.F., Chu, C., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. J. Econom. 108, 1–24.
Maddala, G.S., Wu, S., 1999. A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin Econom. Statistic Spec. Issue 631–652.
Mani, M., Markandya, A., Sagar, A., Sahin, S., 2012. India's Economic Growth and Environmental Sustainability what Are the Tradeoffs? Policy Research Working Paper 6208, Disaster Risk Management and Climate Change. World Bank, Washington, DC.
Martinez zarzo, I., Bengochea-morancho, A., 2004. Cooled mean group estimation of an environmental Kuznets curve for CO_2. Econ. Lett. 82, 121–126.
Mbarek, M.B., Saidi, K., Rahman, M.M., 2017. Renewable and Non-renewable Energy Consumption, Environmental Degradation and Economic Growth in Tunisia. Qual. Quantity. April.
Menyah, K., Wolde-Rufael, Y., 2010. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Pol. 38, 2911–2915.
Muftau, O., Iyoboyi, M., Ademola, Abdulsalam S., 2014. An empirical analysis of the relationship between CO_2 emission and economic growth in West Africa. Am. J. Econ. 4 (1), 1–17.
Musila, J.W., Yiheyis, Z., 2015. The impact of trade openness on growth: the case of Kenya. J. Pol. Model. 37 (2), 342–354.
Owusu, A.S., Ernest, A., Nettey, O., Mbacke, C., 2012. Demographic patterns and trends in Central Ghana: baseline indicators from Kintampo Health and Demographic surveillance system. Glob. Health Action 5 (1), 19033.
Ozturk, A., 2010. A literature survey on energy-growth nexus. Energy Pol. 38 (1), 340–349.
Ozturk, I., Acaravci, A., 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ. 36, 262–267.
Pedroni, P., 1997. Panel co-integration, asymptotic and finite sample properties of pooled time series tests, with an application to the PPP hypothesis: new results. Economics Working Paper. Indiana University.
Pedroni, P., 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to PPP hypothesis: new results. Econom. Theor. 20 (3), 597–627.
Pedroni, P., 1999. Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxf. Bull. Econ. Stat. 61, 653–678.
Pender, J., Gebremedhin, B., 2006. Land management, crop production, and household income in the highlands of Tigray, Northern Ethiopia: an econometric analysis. In: Pender, John, Place, Frank, Ehui, Simeon (Eds.), Strategies for Sustainable Land Management in the East African Highlands. International Food Policy Research Institute, Washington, D.C., pp. 107–139
Pender, J., Place, F., Ehui, S., 2006. Strategies for sustainable land management in the East African highlands: conclusions and implications. In: Pender, J., Place, F., Ehui, S. (Eds.), Strategies for Sustainable Land Management in the East African Highlands. IFPRI, Washington, D.C.
Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika 75 (2), 335–346.
Rahman, M.M., 2017. Do population density, economic growth, energy use and exports adversely affect environmental quality in Asian populous countries? Renew. Sustain. Energy Rev. 77, 506–514.
Rahman, M.M., Kashem, M.A., 2017. Carbon emissions, energy consumption and industrial growth in Bangladesh: empirical evidence from ARDL cointegration and Granger causality analysis. Energy Pol. 110, 600–608. November.
Rahman, M.M., Mamun, S.A.K., 2016. Energy use, international trade and economic growth nexus in Australia: new evidence from an extended growth model. Renew. Sustain. Energy Rev. 64, 806–816. October (available online 14 July).
Rahman, M.M., Saidi, K., Mbarek, M.B., 2017. The effects of population growth, Environmental quality and trade openness on economic growth: a panel data application. J. Econ. Stud. 44 (3).
Saboori, B., Sulaiman, J., Mohd, S., 2012. Economic growth andCO_2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. Energy Pol. 51, 184–191.
Saidi, K., Hammami, S., 2015. Economic growth, energy consumption and carbon dioxide emissions: recent evidence from panel data analysis for 58 countries. Qual. Quantity 1–23.
Saidi, K., Hammami, S., 2015a. The impact of energy consumption and CO 2 emissions on economic growth: fresh evidence from dynamic simultaneous-equations models. Sustain. Cities Soc. 14, 178–186.
Sarafidis, V., Wansbeek, T., 2012. Cross-sectional dependence in panel data analysis. Econom. Rev. 31 (5), 483–531.
Sarkar, S., 2008. Trade openness and growth: is there any link? J. Econ. Issues 42 (3).
Selden, T.M., Song, D., 1994. Environmental quality and development: is there a Kuznets curve for air pollution? J. Environ. Econ. Manag. 27, 147–162.
Shafik, N., 1994. Economic development and environmental quality: an econometric analysis. In: Oxford Economic Papers, 46, pp. 757–773.
Simon, J., 1977. The Economics of Population Growth. Princeton University Press, Princeton, NJ.
Stern, D.I., Common, M.S., Barbier, E.B., 1996. Economic Growth and Environmental Degradation: the Environmental Kuznets Curve and Sustainable Development, 24. World Development, pp. 1151–1160, 1996.
Tahir, M., Haji, D.H.N.B.P., Ali, O., 2014. Trade openness and economic growth: a review of the literature. Asian Soc. Sci. 10 (9).
The Guardian, 2012. World Carbon Emissions: the League Table of Every Country, 21 June.
Ulasan, B., 2012. Openness to International Trade and Economic Growth: a Cross-Country Empirical Investigation. In: Economics Discussion Paper, (2012-25).
UN, 2015. List of Countries by Population Density. United Nations Department of Economics and Social Affairs, Statistics Times retrieved from. http://statisticstimes.com/population/countries-by-population-density.phpon20. (Accessed October 2015).
Usenobong, E.A., Chukwu, A.C., 2011. Economic growth and environmental degradation in Nigeria: beyond the environmental Kuznets curve. In: Proceedings of the NAEE Conference on Green Energy and Energy Security Option for Africa, pp. 212–234.
Vidyarthi, H., 2013. Energy consumption, carbon emissions and economic growth in India. World J. Sci. Technol. Sustain. Dev. 10 (4), 278–287.
World Bank, 2019. World development indicators. Accessed at: http://www.worldbank.org/data/onlinedatabases.
Zeshan, M., Ahmed, V., 2013. Energy, environment and growth nexus in South Asia. Environ. Dev. Sustain. 15 (6), 1465–1475.