Environmental Science and Pollution Research (2019) 26:29978–29990
https://doi.org/10.1007/s11356-019-06154-2

RESEARCH ARTICLE

Per capita income, trade openness, urbanization, energy consumption, and CO_2 emissions: an empirical study on the SAARC Region

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Received: 14 February 2019 / Accepted: 31 July 2019 / Published online: 14 August 2019

Abstract

The developing world in general is facing so many crucial problems including global warming in recent years. Global warming has multiple consequences on each segment of the society and therefore, its root causes are important to identify. The present study examines the impact of per capita income, trade openness, urbanization, and energy consumption on CO_2 emissions. Countries located in South Asian Association for Regional Cooperation (SAARC) are considered in the study. The selection of the SAARC region is motivated by the diverse nature of its members and further lack of available empirical literature on the same relationship. Annual data from 1980 to 2016 are analyzed using appropriate panel data techniques. The results revealed the presence of environmental Kuznets curve (EKC) in the SAARC region. Further, the introduction of cubic function into the model indicated that the shape of the EKC is N shaped. Besides, trade openness has negative while urbanization and energy consumption have impacted CO_2 emissions positively. Moreover, the causality exercise explored a bidirectional causality between urbanization, energy consumption, per capita income, and CO_2 emissions. Similarly, energy consumption, per capita GDP, and urbanization are also bidirectionally related. Further, a unidirectional causality running from CO_2 emissions, urbanization, and energy consumption to trade openness is detected. Lastly, a unidirectional causality is witnessed from per capita income to energy consumption.

Keywords Kuznets curve · Cubic functionCO_2 emissions, SAARC, Panel data

Introduction

The current trends of global warming have posed serious threats to the lives of human beings across the countries. However, humans are the major contributors to global warming. Human activities are responsible for climate change. The consumption of fossil fuels has increased dreadfully. The literature has vastly discussed CO_2 as the main responsible factor for global warming. The recent report of the National Aeronautics and Space Administration (NASA 2018) shows that CO_2 emissions never crossed the line of 30 ppm (parts per million) for centuries but since 1950, CO_2 emissions have crossed its sustained level and currently, its level is 400 ppm which is of significance because most of it is to be the outcome of human activities. Intergovernmental Panel on Climate Change (IPCC) also demonstrated in its 5th assessment report that there is more than 95% probability that human actions have increased the temperature of our planet. The alarming level of increased CO_2 urged the researchers (Gokmenoglu and Taspinar 2018; Gökmenoğlu and Taspinar 2016; Iwata et al. 2012; Katircioğlu and Taşpinar 2017; Ozatac et al. 2017; Sharma 2011) to dig out the causes of CO_2 emissions.

Responsible editor: Eyup Dogan

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Due to income-increasing policies, the developing countries are opening their economies and its population is in the process of urbanization causing potential threats to the environment. Growing urbanization in developing countries may lead to increase in energy consumption and CO_2 emissions (He et al. 2017; Hossain 2011; Ozatac et al. 2017). According to Ellis and Roberts (2018), the urban population of SAARC countries grew by 130 million between 2001 and 2011—more than the entire population of Japan—and is expected to rise by almost 250 million by 2030. With the increased demand for energy in South Asia countries and a huge dependence upon the fossils fuels has created an alarming situation for the environmental quality, pollution, and greenhouse gas emissions (Wijayatunga and Fernando 2013).

Besides urbanization, trade openness is also central in causing CO_2 emissions and it is evident from the literature (Adams and Klobodu 2017; Al-Mulali et al. 2015; Ertugrul et al. 2016). Over the years, trade volume and emissions grow simultaneously as the emissions increased by 85% during 1980–2016 (EIA 2017) and trade volume swelled more than four times (WDI 2018) in the same period. Similarly, in the SAARC region, trade has also risen from 20% of GDP in 2016 to 41% of GDP in 2018. Further, the SAARC countries share geographical borders, and more than 20% of the world's population lives in this region and the potential of increase in intra-region trade cannot be ruled out. Trade openness in relation to CO_2 emissions has been discussed in detail by Ertugrul et al. (2016) explaining the pollution haven hypothesis suggesting that increase in income demand clean environment resulting in relocation of high CO_2 emitting industries to the countries where polluting environment is less concern (Kukla-Gryz 2009) and where income is chosen in the tradeoff between income and pollution. This hypothesis has been validated by Gökmenoğlu and Taspinar (2016) in the case of Turkey. Hence, trade openness could be vital in determining CO_2 emissions, but the evidence from the literature (Dogan 2015; Dogan and Seker 2016; Dogan and Turkekul 2016; Halicioglu 2009; Jalil and Mahmud 2009; Jayanthakumaran et al. 2012; Nasir and Rehman 2011; Shahbaz et al. 2013) is inconclusive. Further, the literature on the presence of an environmental Kuznets curve (EKC, hereafter) hypothesis, i.e., the effect of income on the environment is controversial and debatable as they ignore important explanatory variable like trade openness. Hence, including trade openness in the model can avoid the possible problem of omitted variable bias. Moreover, trade openness is also relevant while studying the EKC hypothesis as Grossman and Krueger (1991) argued that trade positively impacts the environment by the income channel.

Increased energy consumption is also responsible for environmental degradation. Sasana and Putri (2018) pointed out that increased energy consumption has multiplied CO_2 emissions worldwide. Multiple factors are responsible for increased energy consumption such as burning of factories, power plants, and burning of fossil fuels (Mallick and Tandi 2015). Energy consumption in the SAARC region has also increased significantly in recent years. Chary and Bohara (2010) pointed out that increased energy consumption in the SAARC region have increased CO_2 emissions significantly.

Considering the adverse consequences of CO_2 emissions, SAARC has taken numerous measures to control pollution and environmental degradation such as regional centers has been established which direct different aspects of the environment, climatic change, and natural disasters. The SAARC Environment Center is unified with SAARC Energy Center (SEC) in 1987, for the protection of environmental resources by adopting best practices through research, education, and coordination among member states. Despite all these mentioned measures, the environmental quality of SAARC member countries has deteriorated significantly in recent years mainly due to CO_2 emissions. Hasnat et al. (2018) termed the environmental deterioration in SAARC as global warming owing to varying rainfall pattern, declining glaciers, rising sea level, and increasing cyclones and floods. Further, according to IPCC (2014), the number of cold days and nights reduced significantly and vice versa. This environmental degradation may be related to the high-paced urbanization and liberalized economies with rising income and enhance energy consumption.

The ideal situation for SAARC countries is to collaborate in terms of economic ties keeping aside political and historical frictions. This has resulted in increased bidirectional trade among SAARC countries between 2009 and 2015. The eight countries in South Asia signed the SAARC charter in 1985 in Dhaka and stressed the economic, social, and technological aspects to enhance the welfare in South Asia. SAARC countries are emphasized to establish and broaden their trade ties, and two trade agreements[1] were signed. This agreement lifted trade restrictions to increase economic cooperation and created a free trade area influencing 1.8 billion people. Moreover, the industry and SAARC chamber of commerce encouraged intra-regional trade by creating business linkages among member states. Like many other countries, SAARC member nations have a relatively higher level of urbanization, increasing per capita income, demand for energy, and free trade all of which tend to increase CO_2 emissions. The main contributors to CO_2 emissions among SAARC countries are India and Pakistan.

The study is important because the SAARC region is most populous region consisting one-fifth of the world population (out of which 34 % population lives in urban areas) and is fastest-growing region in the world (WDI 2018). The growth

[1] The first, SAARC Preferential Trading Arrangement (SAPTA) and the second, South Asian Free Trade Area (SAFTA) were signed.

has led to an increase in the demand for energy[2] and the dependence on traditional energy source has implications of deteriorating environmental quality in the region. Further, the region is also experiencing changes in biodiversity and has been hit by natural disasters[3] in the last decade. The potential of calamities in the future and the projections of climate change have raised concerns for the policymakers of the region. Hence, this paper explores the linkages between per capita income, trade, urbanization, energy, and CO_2emissions for SAARC countries. Previous literature has largely ignored Maldives, Nepal, and Bhutan to extend the time dimensions of their longitudinal data. However, ignoring these economies has serious repercussions particularly when it comes to the generalization of findings for the whole region. Therefore, unlike the previous literature, we have focused on all economies except Afghanistan to provide comprehensive policy-relevant suggestions applicable to all countries. This is going to be the first empirical paper that will explore linkages between per capita income, trade openness, energy consumption, urbanization, and CO_2emissions, for all SAARC countries. Further, we will also examine the possible shape of the EKC by incorporating the cubic term of per capita income which contrasts with the conventional literature. We expect that our findings will assist the environmental authorities to recognize the impacts income, trade, energy consumption, and urbanization on CO_2 emissions, and they may able to manage the environmental problems using appropriate policies.

The rest of the paper is continued like the following. "Literature review" sheds light on literature while descriptive statistics are discussed in the "Descriptive statistics." Modeling and estimating methodology are described in the "Modeling and methodology." Regression results are analyzed in "Results and discussion" while the causality results are discussed in the penultimate section while the last section consists of conclusion and recommendations.

Literature review

Grossman and Krueger (1991) examined the impact of trade on the environment for the first time. This impact was then classified into three types by Antweiler et al. (2001), which are composition, scale, and technology effect. Hence, the debate on the link between trade and environment has started then and was examined from various perspectives (Cherniwchan et al. 2017; Kreickemeier and Richter 2014; Managi et al. 2009). However, the results are mixed, and the relationship is still controversial. One strand of literature (Ahmed et al. 2016; Ahmed et al. 2016; Ozatac et al. 2017) argues the pro-environmental role of trade openness as it allows trading countries to trade in pollution-free green production technologies to reduce the level of pollution. The other strand of literature (Shahbaz et al. 2013; Shahzad et al. 2017) claims the adverse effect of trade on the environment resulting from the composite effect of production. This argument is valid in the case of poor countries where an absence or weak regulatory institutions allow the production of goods and polluting environment but the developed countries where the presence of strong environmental regulatory institutions prevent dirty production. Nevertheless, there is evidence in the literature where income plays a role in trade-environment nexuses, e.g., Antweiler et al. (2001) argue that environment deteriorates in rich countries when they are more open to trade, while in the case of poor countries, trade openness improves the environment, whereas Le et al. (2016) conclude that trade is favorable for environment in developed countries but unfriendly for environment in poor countries. The inconsistency in results may be due to various reasons, e.g., using different econometric model specification and techniques, datasets, and different regressors. A comprehensive review of the trade-environment nexuses has been done by Cherniwchan et al. (2017).

Similarly, urbanization has been considered a key determinant of CO_2 emissions (Sheng and Guo 2016). The theoretical explanation of the linkages of urbanization and environment may come from ecological, environmental, and compact city theories (Poumanyvong and Kaneko 2010). But, the empirical results are mixed on the impact of urbanization on the environment. The studies by Pariakh and Shukla (1995); Cole and Neumayer (2004); Wang et al. (2016); and Ozatac et al. (2017) show an affirmative connection between urbanization and environmental quality. Nevertheless, there are studies (Fan et al. 2006; Saidi and Mbarek 2017; Sharma 2011) which present the evidence that environmental quality gets better because of increase in urban population. Moreover, the literature also exists which indicate that urbanization and environmental quality are non-linearly related.

With the increased urbanization and trade openness coupled with the intent to enhance the quality of the environment by controlling CO_2 emissions, research is imperative and needs scholarly attention. Some researchers have tried to figure out the relationship of openness to trade and urbanization with environmental quality. Hossain (2011), in a panel study, provides evidence of negative of one-way relationship from trade and urbanization to CO_2 emissions. Another study by Lv and Xu (2019) found that trade openness improves the environment in the short run, but it has a deteriorating impact in

[2] According to Asian Development Bank, energy demand is expected to grow at 7.4% per annum until 2020.

[3] For instance, in 2004, the tsunami affected 7 South Asian countries and killed more than 200,000 people; the 2005 and 2008 earthquakes in Pakistan followed by two floods in 2010 and 2011—making millions of people homeless, and recent earthquakes in Nepal killed around 9000 people. 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.

the long run. They also provide evidence that urbanization is good for the environment.

The N-shaped EKC proposes that the EKC will disappear beyond a particular level of income; higher income would again convert to a positive association between income and environment (de Bruyn et al. 1998). Various studies (Culas 2012; Dinda 2004; Kaika and Zervas 2013; Stern 2004) focused on EKC and some of them (Al-Mulali et al. 2016; Culas 2012; Leitão 2010; Shafiei and Salim 2014; You et al. 2015) validated the inverted U-shaped EKC. However, these studies largely ignored the existence of N-shaped EKC. The pioneering work which successfully explored an "N"-shaped EKC was done by Moomaw and Unruh (1997). Further, Panayotou (1997) also found an N-shaped association between economic growth and environment using sulfur dioxide as a proxy. A recent study by Allard et al. (2018) confirmed an N-shaped EKC for 74 countries. Moreover, Shahbaz and Sinha (2018) reviewed in detail the literature on inverted U- and "N"-shaped EKC hypotheses.

The nexus between income trade openness, urbanization, energy consumption, and the environment in the SAARC region is important as the welfare of billions of people is on stake. Despite political differences among major countries of the SAARC region, efforts are always made to establish economic ties and increase trade relations among the neighboring countries. Further, the accelerating urbanization along with worsening environmental quality is a point of concern in the SAARC region. Increased industrial activities, number of vehicles on the roads, and brick kilns have elevated regional pollution (Khwaja et al. 2012). India followed by Pakistan is the main air polluting countries in the SAARC region (Khwaja and Khan 2005). The main reason of CO_2 emissions in Bangladesh is an industrial activity, large number of vehicles, and brick kilns while in Bhutan and Nepal, the major reason of CO_2 emissions is a high level of dangerous pollutants (Khwaja et al. 2012). Similarly, Senarath (2003) found a number of vehicles and burning of industrial wastages as the main source of CO_2 emissions. Besides, the growing population, accelerating economic activities in SAARC countries also demand more energy and the huge dependence on fossil fuels is alarming and pose threat to environmental quality; hence, a scholarly exercise is much needed.

Descriptive statistics

We have provided descriptive statistics such as mean, maximum, and minimum values for selected variables in Table 1. Data is averaged for all variables for the period 1980 to 2016.

From Table 1, it is inferred that on average, Maldives is having the highest CO_2 emissions per capita (1.466) with a maximum and minimum values of 3.269 and 0.277 respectively during the period 1980–2016. Higher CO_2 emissions in Maldives compared with the giant economies of India and Pakistan could be explained by the higher trade openness. Based on the traditional trade-volume measure of trade openness, Maldives is a more open economy in the SAARC region according to the data reported. Similarly, India and Pakistan have the second and third positions in terms of CO_2 emissions in the SAARC region. Both economies are having larger

Table 1 Descriptive statistics

Country	Variables	Mean	Maximum	Minimum
Bangladesh	CO_2	0.234	0.459	0.093
	UPOP	31151574	57090079	12099237
	OPEN	29.005	48.110	16.687
	ENG	148.422	236.097	102.414
	Y	540.116	1022.69	344.594
Bhutan	CO_2	0.534	1.289	0.053
	UPOP	151764.2	314136	41457
	OPEN	82.181	113.597	51.347
	ENG	458.613	726.956	104.182
	Y	1272.526	2801.258	377.288
India	CO_2	0.972	1.730	0.450
	UPOP	285775471.9	438777420	160943057
	OPEN	29.250	55.793	12.352
	ENG	428.911	698.537	287.054
	Y	840.158	1854.769	377.123
Maldives	CO_2	1.466	3.269	0.277
	UPOP	91268.08	199078	35241
	OPEN	175.158	375.378	115.769
	ENG	854.567	979.333	228.017
	Y	6635.341	11031.60	3348.349
Nepal	CO_2	0.110	0.283	0.028
	UPOP	2926477	5505277	907691
	OPEN	43.896	64.035	30.101
	ENG	338.883	435.430	304.125
	Y	457.199	702..069	285.351
Pakistan	CO_2	0.730	0.991	0.410
	UPOP	44956437.27	75782131	21910605
	OPEN	33.747	38.909	25.139
	ENG	436.996	523.763	317.154
	Y	839.533	1162.29	552.311
Sri Lanka	CO_2	0.466	0.885	0.203
	UPOP	3396643.054	3902836	2823583
	OPEN	68.162	88.636	46.363
	ENG	399.603	572.297	301.578
	Y	1883.829	3832.343	900.930

Authors' calculation from WDI data

economic sizes as compared with other countries. Afghanistan and Nepal are having the lowest CO_2 emissions in the SAARC region respectively. The possible explanation for their lowest CO_2 emission is that both Nepal and Afghanistan did not experience industrialization nor higher trade openness.

With respect to trade openness, the economies of Maldives and Bhutan have the highest trade to GDP ratios of 175% and 82% respectively. It is indeed surprising to conclude these economies as the most open in the SAARC region in the presence of some huge size economies such as India, Pakistan, and Bangladesh. The possible reason which could explain this is that the trade-volume measure of openness is indeed endogenous and hence could be affected greatly by other factors such as the size of the economy. Similarly, the Sri Lankan economy has witnessed a steady improvement in trade openness over the study period. The simple trade to GDP ratio of the island economy of Sri Lanka is 68%. The trade of GDP ratio for the war-affected economy of Afghanistan and Nepal is above 40% which is reasonably a good indication of their outward-oriented policies. Lastly, Pakistan, India, and Bangladesh have had the lowest trade to GDP ratios respectively in the SAARC region despite their relatively higher economic sizes. The statistics show that Pakistan is relatively more open as compared with Bangladesh and India. The trade to GDP ratio for Pakistan is 33%, for India is 29%, and for Bangladesh is 29%. Compared with countries of the world such as the East Asian, the SAARC region is struggled to liberalize their trade. And, this low trade to GDP ratios could be one of the possible reasons which could explain poor economic growth of the SAARC region.

Moreover, in terms of income per person, the residents of Maldives have enjoyed the highest income level on average during the period 1980–2016. Average per capita income of the economy was recorded to be 6635.314 US $ with the lowest and highest values of 11031.60 US $ and 3348.349 US $ respectively. Similarly, the Sri Lankan and Bhutan economies have also experienced considerable improvements in per capita income during the last few decades. Per capita income on average was 1883.829 US $ for the Sri Lankan economy and 1272.526 US $ for the Bhutan economy. The large economies such as India and Pakistan have almost similar income per capita during the study period. The income per capita for both the countries remained approximately 840 US $. One of the possible reasons for low income per capita for both countries could be their higher population among others. Finally, Afghanistan, Bangladesh, and Nepal have the lowest per capita income in the SAARC region respectively. All these economies have not had any significant improvement industrialization and therefore per capita did not accelerate during the study period. Also, the economy of Afghanistan is constantly in the state of war for the last few decades and hence, low per capita income compared with other SAARC member countries is expected.

Lastly, in terms of the urban population, India has the largest share of the urban population owing to its higher population. According to the reported statistics, over 228 million people are living in an urban area in India. Pakistan and Bangladesh have the second and third highest urban population in the SAARC region. Both these countries are suffering from the higher population. Higher population exerts high pressure on the urban area as the urban area has more facilities and opportunities compared with the rural area. Afghanistan, Sri Lanka, Bhutan, and Maldives are having the lowest urban population living in urban areas respectively. The general observation from Table 1 is that small-sized economies in terms of the population have the lowest urban population.

To conclude the descriptive statistics reported in Table 1, the economy of Maldives is ranked first in CO_2 emissions, trade, and per capita income. Nepal is observed to have not only the lowest CO_2 emissions but also the lowest per capita income in the SAARC region. The economy of Bangladesh is observed to be having the lowest trade openness in the SAARC region. India is having the highest number of urban population while in Maldives, people mostly live in a rural area.

Modeling and methodology

The objective of this paper is to model the relationship between per capita income, energy consumption, trade openness, urbanization, and CO_2 emissions for the countries belonging to the SAARC region. For the empirical analysis, the following model panel data model is specified.

$$\mathrm{lnco}_{2\mathrm{it}} = \beta_0 + \beta_1 \mathrm{lny}_{\mathrm{it}} + \beta_2 \mathrm{lny}^2{}_{\mathrm{it}} + \beta_3 \mathrm{lnopen}_{\mathrm{it}} + \beta_4 \mathrm{lnupop}_{\mathrm{it}} + \beta_5 \mathrm{lneng}_{\mathrm{it}} + U_{\mathrm{it}} \quad (1)$$

where $\mathrm{lnco}_{2\mathrm{it}}$ is the log of CO_2 emissions, $\mathrm{lny}_{\mathrm{it}}$ is the log of per capita income, $\mathrm{lny}^2{}_{\mathrm{it}}$ is the log of the square of per capita income, $\mathrm{lnopen}_{\mathrm{it}}$is the log of trade openness, $\mathrm{lnupop}_{\mathrm{it}}$ is the log of urbanization, and $\mathrm{lneng}_{\mathrm{it}}$ is the log of energy consumption.

In model 1, the dependent variable is the natural logarithm of CO_2 emissions. The independent variables include trade openness, urbanization, and per capita income. The square term is included to explore whether the EKC do exist for the SAARC member countries. CO_2 emissions are captured in “metric tons per capita” while trade openness is approximated as trade as a percentage of GDP. Urbanization and energy consumption are captured through total urban population and energy use (kg of oil equivalent per capita) respectively. Similarly, per capita income in constant US $ is used as a proxy for income per capita. The parameters β_1 and β_2 are expected to be positive if EKC do exist and vice versa. In the next phase, we have deviated from the conventional literature by including the cubic term of the per capita income to identify the shape of the EKC. Model 1 can be rewritten as follows:

$$\mathrm{lnco}_{2\mathrm{it}} = \beta_0 + \beta_1 \mathrm{lny}_{\mathrm{it}} + \beta_2 \mathrm{lny}^2{}_{\mathrm{it}} + \beta_3 \mathrm{lny}^3{}_{\mathrm{it}} + \beta_4 \mathrm{lnopen}_{\mathrm{it}} + \beta_5 \mathrm{lnupop}_{\mathrm{it}} + \beta_6 \mathrm{lneng}_{\mathrm{it}} + \mathrm{U}_{\mathrm{it}} \quad (2)$$

In model 2, the cubic term is included to observe the shape of the EKC. All other variables are defined earlier.

Estimating methodology

For the estimation of models 1 and 2, we have collected longitudinal data for the period 1980 to 2016 for all 8-member countries of the SAARC region from UNCTAD and WDI. The fixed and random effects estimation techniques are extensively used in literature to estimate panel data models (Tahir and Azid 2015; Tahir and Khan 2014). The typical form of the fixed effects model is given below.

$$y_{\mathrm{it}} = \beta_1 x_{\mathrm{it}} + \ldots ..\beta_{\mathrm{k}} x_{\mathrm{kit}} + U_{\mathrm{it}} - U_{\mathrm{i}}^{-} \quad (3)$$

The fixed effects estimation provides efficient standard errors and estimates but unable to yield the intercepts and it relies on the variation occurring within the individual observations as discussed by Murray (2006). Similarly, the random effects modeling is based on complete variations in the independent variables including both within the observations and across the different means of the independent variables of different cross-sections. The selection between the random and fixed effects could be done using the well-known procedure of Hausman test (Hausman 1978). The Hausman test is given as follows:

$$W = s_{\mu}^2 \left(\beta_1^{\wedge\mathrm{FE}} - \beta_1^{\sim\mathrm{RE}}\right) / \sum\sum \left(X_{\mathrm{it}} - X_{\mathrm{i}}^{-}\right)^2 \quad (4)$$

The Hausman test is based on the chi-square statistic and its associated probabilities. Results for the Hausman test shown in Table 2 show that fixed effects modeling is more appropriate to estimate models 1 and 2.

Before moving to the regression-based results, we have carried out the unit root testing by employing the testing procedure of Levin and Lin (1993) (LLC, hereafter) and Im et al. (2003) (IPS, hereafter) to identify the order to the integration of variables. The results of the unit root testing provided in Table 5 presented in the Appendix section. Results of the IPS test highlighted that variables selected for the current analysis are non-stationary at the level. Similarly, the LLC test also showed that except for energy consumption, all other variables are stationary at first difference and non-stationary at the level. However, at first difference, all variables are stationary. Having identified the order of integration of variables, in the next step, we have employed different approaches such as Pedroni (1999), Kao (1999), and Johansen Fisher Panel Cointegration test (1932) to check the presence of a cointegrating relationship. Results of the cointegration testing are shown in Table 6 presented in the Appendix section. The results of Pedroni (1999) indicated the presence of long-run cointegrating relationship among the variables as the majority of the tests carried out rejected the null hypothesis of no long-run relationship. Similarly, the Kao and Johansen Fisher panel cointegration tests and Fisher tests reported in the bottom of Table 6 presented in the Appendix section also showed that variables are cointegrated in the long run. Further, we have also employed the cross-sectional dependency test of Pesaran (2004) and its results presented at the bottom of Table 2 rejected the null hypothesis of cross-sectional dependency.

Results and discussions

In Table 2, results for estimated models are shown. Column 2 of Table 2 consists of results for the estimated model 1 while column 3 includes results for model 2. The results displayed in the last two columns of Table 2 are obtained using the generalized least squares method (GLS hereafter). The GLS estimator in the literature is used to check the robustness of the fixed effects estimation as discussed by Chen and Gupta (2009). The GLS employs a more sophisticated variance structure to handle the problems of cross-sectional heteroscedasticity and contemporaneous correlation. Hence, it provides a robustness check to the results obtained with fixed effects estimator based on OLS. Therefore, we have used the GLS estimator to estimate models 1 and 2 in order to obtain robust results.

According to results demonstrated in Table 2, the coefficient of per capita income is carrying a positive coefficient and further this relationship is different from zero at 1% level of significance. Similarly, the square term of per capita income is observed to be inversely and significantly related with CO_2 emissions. The positive and negative impacts of per capita

Table 2 Regression results

Variables	Fixed effects (OLS) Coefficients	Fixed effects (OLS) Coefficients	Fixed effects (GLS) Coefficients	Fixed effects (GLS) Coefficients
$lnopen_{it}$	− 0.340*** (0.085)	− 0.121 (0.081)	− 0.036 (0.043)	− 0.097* (0.057)
$lnupop_{it}$	0.226*** (0.016)	0.426*** (0.111)	0.573*** (0.044)	0.337*** (0.071)
$lneng_{it}$	0.333*** (0.065)	0.155 (0.136)	0.417*** (0.099)	0.454*** (0.108)
lny_{it}	2.099*** (0.407)	14.359*** (5.004))	1.158*** (0.302)	16.247*** (3.174)
lny^2_{it}	− 0.055** (0.024)	− 1.830*** (0.640)	− 0.055*** (0.021)	− 2.075*** (0.409)
lny^3_{it}		0.081*** (0.027)		0.089*** (0.017)
Constant	− 16.945 (1.094)	− 46.751 (11.635)	− 17.741 (0.866)	− 51.345 (7.195)
R^2	0.889	0.979	0.989	0.989
Adj. R^2	0.862	0.978	0.989	0.988
F-stat	33.328	793.638	1750.943	1501.797
Prob. F-stat	0.0000	0.0000	0.0000	0.0000
Hausman test	39.004	719.394	39.004	719.394
Prob. (Hausman test)	0.000	0.000	0.000	0.000
CD test	− 0.265	0.981	0.041	− 0.021
Prob. (CD test)	0.790	0.326	0.966	0.983

The natural logarithm of CO_2 emissions is the dependent variable. Values in parenthesis are standard errors. ***, ** and * means significance at 1% , 5% and 10% level respectively. The Hausman test statistics and associated probability indicated and favored the presence of fixed effects estimation. The white robust estimator is used to tackle the heteroscedasticity problem. The CD test confirmed no cross-sectional dependency

income and its square term respectively on CO_2 emissions are the indication of the presence of the EKC in the SAARC region. The results imply that per capita income could raise CO_2 emissions initially but, however, in the long run, per capita income is expected to lower CO_2 emissions eventually. Besides income per capita, other environmentally friendly policies are also needed to be put in place to limit CO_2 emissions. Similarly, Chary and Bohara (2010) concluded that CO_2 emissions can be caused by income and energy consumption and further suggested the SAARC member countries to control energy consumption without reducing income.

Table 3 Pairwise Dumitrescu Hurlin panel causality tests

Null hypothesis	W-stat.	Zbar-stat.	Prob.
LNOPEN to $LNCO_2$	3.52791	1.59202	0.1114
$LNCO_2$ to LNOPEN	3.83348	1.94325	0.0520
LNUPOP to $LNCO_2$	6.42871	4.92628	8.E-07
$LNCO_2$ to LNUPOP	7.09508	5.69222	1.E-08
LNENG to $LNCO_2$	4.28056	1.71863	0.0857
$LNCO_2$ to LNENG	5.38599	2.69292	0.0071
LNY to $LNCO_2$	4.02621	2.16478	0.0304
$LNCO_2$ to LNY	3.58575	1.65850	0.0972
LNUPOP to LNOPEN	4.65843	2.89147	0.0038
LNOPEN to LNUPOP	1.92040	− 0.25570	0.7982
LNENG to LNOPEN	5.79647	3.05471	0.0023
LNOPEN to LNENG	1.34646	− 0.86741	0.3857
LNY to LNOPEN	3.50141	1.56156	0.1184
LNOPEN to LNY	2.33916	0.22563	0.8215
LNENG to LNUPOP	4.77697	2.15615	0.0311
LNUPOP to LNENG	22403.7	19743.9	0.0000
LNY to LNUPOP	6.62277	5.14934	3.E-07
LNUPOP to LNY	6.33524	4.81885	1.E-06
LNY to LNENG	10.6767	7.35600	2.E-13
LNENG to LNY	1.91830	− 0.36340	0.7163

The results depicted in the third column of Table 2 inferred the possible shape of the EKC. The results demonstrated that at level, income per capita is positive and significant; at square level, income per capita is negative and significant and at cubic level, income per capita is again positive and significant. Therefore, the possible shape of the EKC is "N" shape as given below in Fig. 1. Results are in line with Allard et al. (Akbostancı et al. 2009; Allard et al. 2018; Dong et al. 2016; Moomaw and Unruh 1997; Panayotou 1997; Sinha et al. 2017) who proved the presence of EKC having "N" shape by focusing on the Chinese economy. This result shows that the increase in income primarily will reduce carbon emissions to a certain point after which the relationship becomes positive and increase in income improves environmental quality before it once again becomes negative. This result is surprising and intuitively hard to explain. The possible explanation could be the efficient energy consumption offsetting carbon emissions produced due to scale effect. Perhaps, the reason might be the impact of trade openness on attracting and improving clean production technologies from developed countries. Further, a possibility could be the competition as a result of trade openness which urge firms to adopt clean production technologies. The effects of the adoption of clean production technologies

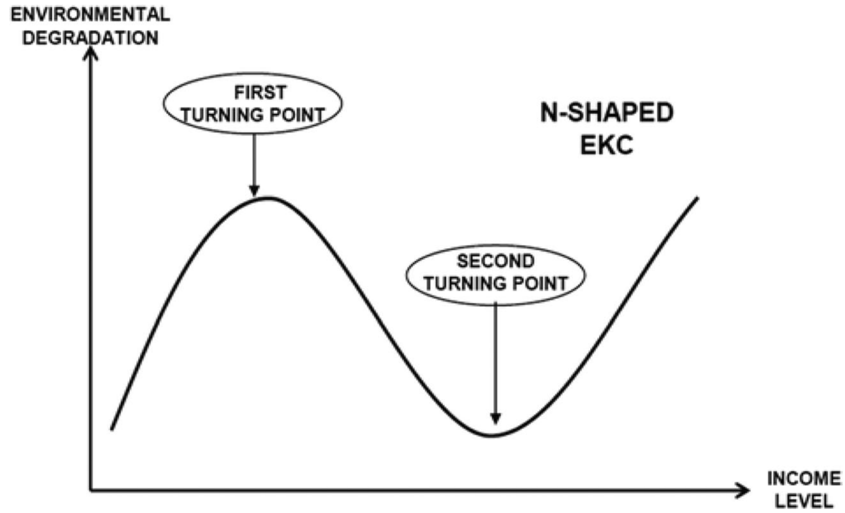

Fig. 1 N-shape curve

may dominate the scale effect. This implies that the implication of the adoption of clean production technologies by the countries can dominate the scale effect, resulting in reducing carbon emissions.

Similarly, the results inferred that trade openness has a significant negative impact on CO_2 emissions in the SAARC region implying improvement in environmental quality. Our results are in line with Sinha and Shahbaz (2018) and Rafindadi (2016), and our results are in contradiction to the results of the studies by Shahzad et al. (2017), Ben Jebli and Ben Youssef (2017), and Chen and Lei (2018). The results are indeed surprising as the conventional wisdom believes that higher trade openness shall increase CO_2 emissions. However, there are sound reasons to believe that trade openness may reduce emissions. First, the current trade openness except for the tiny economies of Maldives and Bhutan is indeed too low in the SAARC region to affect CO_2 emissions positively. The joint economies of India and Pakistan and even the moderate size economy of Bangladesh are still struggling to open their economies to foreign trade. The current trade to GDP ratio for the Indian and the Bangladesh economies are still less than 30% while for Pakistan, it is slightly above 30% indicating the protected trade policies practiced in the SAARC region during the last few decades. Secondly, it is also possible that with more trade countries, their production shifts from outdated and polluting technologies to more advanced and environmentally friendly technologies due to which the CO_2 emissions might fall eventually instead of increasing.

Furthermore, the findings also reveal that urbanization impacted CO_2 emissions positively. The results are consistent with Ali et al. (2019), Ohlan (2015), Al-mulali et al. (2015), and Dogan and Turkekul (2016). It is a normal practice especially in countries belonging to the developing world that people prefer to migrate to urban areas because of higher facilities and opportunities. Thus, it exerts higher pressure on the existing infrastructure and hence, the process of deforestation gets upward momentum. Higher deforestation exponentially increases CO_2 emissions especially in the forest-poor developing countries.

Lastly, the results provide evidence on the positive relationship between energy consumption and CO_2 emissions emphasizing the role of energy demand in economic growth at the cost of environmental quality. The results are like Mirza and Kanwal (2017), Zaidi et al. (2018), and Gokmenoglu and Taspinar (2018) who found that energy consumption in Pakistan increase CO_2 emissions while Akhmat et al. (2014) presented the evidence on the same relationship in case of SAARC countries.

In the last two columns of Table 2, the reported results are obtained by employing the GLS estimator. The GLS estimator is employed to check the robustness of the findings based on the fixed effects estimation. It is observed from the results that changing the method of estimation did not change the results significantly reported earlier. The results indicated that income per capita and its square term are positively and negatively linked with CO_2 emissions respectively for the SAARC region countries. However, the square term of income per capita has lost its significance in the GLS-based estimation. Similarly, the introduction of cubic term into the model revealed that the shape of the EKC is “N” shape. Finally, urban population and trade openness have maintained their positive and negative influence on CO_2 emissions observed earlier. We have taken the lag values of trade openness as instruments to address the endogeneity problem and the results are presented in Table 4 in Appendix section. The results are consistant with the findings presented in Table 2.

Causality analysis

In this section, our focus is to investigate the causality among the variables. It is possible that there may be the causal relationship among the variable because, in most of cases, macroeconomic variables affect each other in one way or the other. For this purpose, we employed the pairwise Dumitrescu and Hurlin (2012) causality tests to explore the causal relationship among variables. The causality model along with null and alternative hypothesis is given by the following expressions 5–7:

$$y_{i,t} = a_i + \sum_{k=1}^{K} \beta_{ik} y_{i,t-k} + \sum_{k=1}^{K} \gamma_{ik} x_{i,t-k} + \varepsilon_{i,t} \quad (5)$$

$$\text{Null hypothesis } H_0: \gamma_{i\,1} = \ldots \gamma_{i\,k} = 0 \quad \forall_i = 1, \ldots, N \quad (6)$$

$$\text{Alternative hypothesis } H_1: \gamma_{i\,1} \neq \ldots \gamma_{i\,k} \neq 0 \quad \forall_i = 1, \ldots, N \quad (7)$$

The causality results of DH approach are shown in Table 3. The results demonstrated unidirectional causality between CO_2 emissions and trade openness. CO_2 emissions affect trade openness in various ways. The possible reason is that due to rapid industrialization, economic activities are generated on the cost of environmental deterioration. Thus, in this scenario, causality results show the unidirectional causality where the industrial production is represented with CO_2 emissions and economic activities are generated through trade liberalization policies. It is fact that increased industrialization increases CO_2 emissions and hence consequently trade openness increases. As trade is the engine of growth declared by previous literature (Dollar 1992; Frankel and Romer 1999; Tahir and Khan 2014; Tahir and Azid 2015); therefore, supplementary efforts focusing on the reduction of CO_2 emissions through environmentally friendly production technologies shall be adopted.

Similarly, we found strong support in favor of a two-way causal relationship between urbanization, energy consumption, per capita GDP, and CO_2 emissions. It implies that the larger economies such as India, Pakistan, and Bangladesh shall keep a check on the growing urban population and energy consumption as they lead to deforestation and increases CO_2 emissions. Similarly, energy consumption, per capita GDP, and urbanization are also observed to be related bidirectionally. Further, the results revealed unidirectional causality running from urbanization and energy consumption to trade openness, and from per capita GDP to energy consumption.

Concluding remarks

There are various attempts in the theoretical as well as empirical literature to study the linkages between trade openness, per capita income, energy consumption, urbanization, and environmental quality, but results are mixed. This study tries to provide evidence on SAARC countries where countries are opening their economies and the pace of urbanization is fast which ultimately have an environmental implication. According to the results, trade openness has favorable and urbanization has a negative relationship with the quality of the environment. Similarly, energy consumption has also impacted CO_2 emissions positively. The findings of the study reveal that the link between income and CO_2 emissions exists and it is beyond EKC, i.e., it is of "N" shaped. Moreover, the causality exercise explored a two-way causality between urbanization, energy consumption, per capita GDP, and CO_2 emissions. Similarly, energy consumption, per capita GDP, and urbanization are also bidirectionally related. Further, a one-way causality from CO_2 emissions, urbanization, and energy consumption to trade openness is observed. Lastly, a unidirectional causality is witnessed from per capita income to energy consumption.

The finding of this study offers some policy implications. Firstly, urbanization is determinantal for environmental quality as urbanization brings along increased domestic demand for goods and services resulting in increased energy consumption which results in enhanced CO_2 emissions implying that SAARC countries should slow down the pace of urbanization and focus on income-enhancing policies in rural areas. Although urbanization process may benefit in terms of low-cost labor and skills, the findings of this suggest that damages due to urbanization may dominate the benefits. Secondly, trade openness reduces carbon emissions leading to enhance the quality of the environment; therefore, the SAARC countries should open their economies to increase competition and further attract clean production technologies. Thirdly, energy consumption is also responsible for the increased CO_2 emissions. Therefore, renewable and environmentally friendly energy sources shall be encouraged. Finally, the finding of this study reveals more than EKC while explaining the relationship between income and CO_2 emissions as we found an "N"-shape relationship between income and CO_2 emissions. This implies that income-enhancing policies may not necessarily help in reducing CO_2 emission as advocated by EKC hypothesis rather it depends on the structure/design of the "N"-shape curve. If the "N" shape curve is steep and the distance between two turning point is less, then income-enhancing policies may be harmful to the environment as the quality of environment will be compromised at the cost of increasing income. If the "N"-shape curve is flat and the distance between two turning points is large, then the income-enhancing policy may help in reducing CO_2 emissions and improve environmental quality. Though the results add new dimensions on the connection between trade, income, energy consumption, urbanization, and CO_2 emissions, there are limitation/caveats while interpreting these results. Firstly, the study considers only macro-data for the SAARC region while exploring a firm-level data will be more revealing. Moreover, a new measure of trade openness like the KOF index of globalization or trade potential index by Waugh and Ravikumar (2016) will give more insights as compared with using the traditional trade openness index.

Appendix section

Table 4 Regression results (adjusted for the endogeneity of trade openness)

Variables	Fixed effects (OLS) Coefficients	Fixed effects (OLS) Coefficients	Fixed effects (GLS) Coefficients	Fixed effects (GLS) Coefficients
$lnopen_{it}$ (− 1)	− 0.363*** (0.094)	− 0.129 (0.086)	− 0.071* (0.042)	− 0.133** (0.057)
$lnupop_{it}$	0.218*** (0.017)	0.423*** (0.115)	0.571*** (0.049)	0.302*** (0.076)
$lneng_{it}$	0.338*** (0.067)	0.164 (0.148)	0.442*** (0.103)	0.479*** (0.113)
lny_{it}	2.186*** (0.427)	14.732*** (4.835)	1.376*** (0.289)	17.789*** (3.120)
lny^2_{it}	− 0.061** (0.025)	− 1.874*** (0.614)	− 0.071*** (0.200)	− 2.266*** (0.400)
lny^3_{it}		0.082*** (0.025)		0.097*** (0.017)
Constant	− 17.074 (1.136)	− 47.747 (11.255)	− 18.468 (0.812)	− 54.877 (7.034)
R^2	0.886	0.978	0.989	0.989
Adj R^2	0.859	0.977	0.989	0.988
F-stat	32.746	752.144	1733.944	1493.976
Prob. F-stat	0.000	0.000	0.0000	0.0000
Hausman test	50.377	676.965	50.377	676.965
Prob. (Hausman test)	0.000	0.000	0.000	0.000
CD test	− 0.177	0.873	0.207	0.001
Prob. (CD test)	0.858	0.382	0.835	0.998

The natural logarithm of CO_2 emissions is the dependent variable. Values in parenthesis are standard errors. ***, ** and * means significance at 1%, 5% and 10% level respectively. The Hausman test statistics and associated probability indicated and favored the presence of fixed effects estimation

Table 5 Unit root testing

Variables	LLC		IPS	
	Level	First difference	Level	First difference
$lnCO_{2it}$	1.230	− 9.846***	1.076	− 11.125***
$lnopen_{it}$	1.100	− 8.319***	0.370	− 10.290***
$lnupop_{it}$	− 3.496***	− 2.696***	− 1.239	− 2.852***
$lneng_{it}$	1.995	− 6.898***	2.984	− 8.793***
lny_{it}	0.083	− 6.234***	1.586	− 8.241***

Note: *** means 1% significance level

Table 6 Panel cointegration analysis

H_0: no cointegration				
Regression	Statistics	Prob.	Weighted statistics	Prob.
Panel v-statistics	− 1.573	0.942	− 2.274	0.988
Panel rho-statistics	− 0.170	0.432	− 0.452	0.325
Panel PP-statistics	− 2.176**	0.014	− 4.076***	0.000
Panel ADF-statistics	− 3.556***	0.0002	− 5.462***	0.000
Alternative hypothesis: individual AR coefficients (between dimension)				
Regression	Statistics	Prob.		
Group rho-statistic	1.759	0.960		
Group PP-statistic	− 5.134***	0.000		
Group ADF-statistic	− 5.411***	0.000		
Results of Kao residual cointegration test				
H_0: no cointegration				
Statistic name	Statistic	Prob.		
ADF	− 2.085**	0.018		
Johansen Fisher panel cointegration test				
H_0: no cointegration				
Statistics names	Statistic	Prob.		
Fisher-stat (trace test)	143.1***	0.000		
Fisher-stat (Max-Eigen test)	71.22***	0.000		

***, ** and * means significance at 1%, 5% and 10% level respectively

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