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Revisiting the EKC hypothesis in South Asia: The role of Export Quality Improvement

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Abstract
Global climate change adversities have particularly sparked the urgency in mitigating carbon dioxide emissions across the world. Against this backdrop, the paper attempts to investigate the validity of the carbon dioxide emission-induced Environmental Kuznets Curve (EKC) hypothesis controlling for the impacts of export quality on the economic growth-carbon dioxide emission nexus in the context of selected South Asian economies: Bangladesh, India, Pakistan, Sri Lanka and Nepal. Using annual data from 1972 to 2014, the results from the panel data econometric analyses provide statistical validity to the EKC hypothesis while the country-specific results depict heterogeneity of the findings in this regard. The EKC hypothesis is validated only for Bangladesh and India while in the context of Pakistan the economic growth-carbon dioxide emission nexus portrays a U-shaped association. In contrast, economic growth is found to monotonically decrease carbon dioxide emissions in Sri Lanka and Nepal. Besides, the results from both the panel and time-series analyses suggest that improvement in export quality lead to lower levels of carbon dioxide emissions. Moreover, the statistical significance of the interaction term between economic growth and export quality implies that the overall impacts of economic growth on carbon dioxide emissions are conditional on the quality of the exports. Thus, enhancing the quality of the export products is pertinent with respect to ensuring environmental sustainability across South Asia.

Key words: EKC hypothesis; carbon dioxide emissions; export quality; renewable energy consumption; South Asia
JEL codes: B17; F18; F64; Q5; Q56

1. Introduction
In the contemporary era, apprehensions stemming from the exponentially aggravating climate change adversities, worldwide, have sparked the urgency in mitigating the global greenhouse emissions. Traditionally, the conventional development strategies were predominantly biased towards escalating the growth rate of the world economy, turning a blind eye to the environmental degradations that have simultaneously accompanied the growth achievements. However, this concept of '*growing up at present and cleaning up in the future*' has reached to a point of saturation whereby failure to address the critically important issue of environmental well-being, any longer, could go on to jeopardize the overall sustainability of the global economy. As a consequence, curbing greenhouse emissions has become a key agenda amidst policymakers across the globe. In this context, the modern-day environmental policies are often conceptualized to facilitate economic growth while simultaneously safeguarding the environmental welfare as well. More importantly, reducing the intensity of Carbon-dioxide Emissions (CO_2E), in particular, has become the core focus of such policies since CO_2E constitute more than two-thirds of the total global greenhouse emissions (Field 2014).

The relevance of mitigating CO_2E with respect to combating the climate change adversities and, more importantly, improving the environmental quality has been appropriately acknowledged in the global context. The implementation of the Kyoto protocol in 1997, under the United Nations Convention on Climate change, has specifically stressed for curbing CO_2E worldwide (United Nations 1997; Kyoto Protocol Summit 1997). Moreover, the United Nations' 2030 agenda of Sustainable Development Goals (SDG) has also highlighted the need for reducing CO_2E, particularly via augmenting renewable energy resources into the global energy mix (Murshed 2020a). On the other hand, several of the global economies have also pledged in the Paris Climate Change Conference, in 2015, to undertake effective measures in limiting CO_2E and have also committed to regularly report their respective progress in this regard (Horton, Keith and Honegger 2016). The central aim of this conference was to motivate the participating economies in reaching a consensus to reducing greenhouse emissions, thus, keeping the global temperature rise in this century well below 2°C, and try to reduce it further to 1.5°C, above the pre-industrial levels. In a recent report by the Intergovernmental Panel on Climate Change, it is estimated that to keep the global warming levels to the target of 1.5°C above the pre-industrial levels, the global CO_2E have to be brought down by about 45% from the 2010 levels by the end of 2030, while completely phasing it out by 2050 (IPCC 2018). However, despite the commitments, the CO_2E reduction strategies are yet to reap the desired outcomes. Recently, a report by the United Nations Environment Programme has predicted that the global emission levels to be higher by 27% and 38% than what is required to limit global warming to 2°C and 1.5°C, respectively (UNEP 2019). Thus, it is critically pertinent to explore the factors bottlenecking the prospects of mitigating the CO_2E to assist in the relevant policy making decisions concerning the sustainability of the global environment.

CO_2E have popularly been linked to economic growth which can apparently be understood from the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis postulates in favor of economic growth, in the early stages, attributing to environmental degradation via triggering greater volumes of CO_2E, which beyond a certain growth threshold, can be expected to decline (Narayan and Narayan 2010). Hence, this hypothesis explicitly refers to economic growth as both the cause and the plausible solution to the CO_2E-induced environmental hardships. However, although a plethora of the existing studies has probed into the economic growth-CO_2E nexus, in light of the EKC hypothesis, the relationship between these variables is said to be highly conditional on the impacts of other key macroeconomic aggregates. For instance, several of the existing studies have referred international trade to be one of the critically important factors affecting the economic growth-CO_2E nexus (Gozgor 2017; Pata 2019). More precisely, the impacts of rising export volumes (Salman *et al.* 2019) and export diversification (Liu, Kim and Choe 2019) on the EKC for CO_2E have been extensively explored in the literature. Although different studies have used different measures to quantify exports, the use of export quality in this regard has received minimal consideration. However, addressing the export quality aspects of international trade is pertinent not only from the perspective of the effectiveness of the export-led growth strategies pursued by the underdeveloped economies, in particular, but it could also linked to lower levels of CO_2E as well.

Improving the quality of exports, in general, is key to acquiring comparative advantage in the international markets, thus, facilitating the exporting economies to penetrate the world markets with ease (Henn, Papageorgiou and Spatafora 2013). Moreover, enhancing export quality is believed to generate higher revenues for the exporting economies which can be effective in mitigating their trade imbalances, particularly in the context of the underdeveloped nations across the globe (Hallak and Sivadasan 2013). In addition, it might also lead to diversification of the overall export basket, thus contributing to the national value-added figures as well (Bahar *et al.* 2017). Hence, it is pretty evident that higher quality of exports is likely to be translated into higher levels of economic growth (Hayakawa, Mukunoki and Yang 2020). Besides, improving the export product quality could also be foreseen to exhibit a key role in tackling the epidemics of climate change adversities through mitigation of CO_2E (Gozgor and Can 2017). This particular notion of export quality improvement and environmental betterment is grounded on the fact that technological innovation is often asserted to be one of the core determinants of higher quality of exports (Roper and Love 2002). Similarly, technological progress is also essential in influencing the levels of CO_2E (Fang *et al.* 2019). On the other hand, export quality is hypothesized to be conditional on investments in Research and Development (R&D) (Smith, Madsen and Dilling-Hansen 2002) which also is a requirement to undergoing the transition from non-renewable to renewable energy consumption[1], particularly to mitigate the CO_2E (Fernández, López and Blanco 2018). Thus, these complementing impacts of technological innovation and R&D investments, on export quality improvement and CO_2E, could plausibly be tapped to link export quality improvements to mitigation of the CO_2E.

Against this backdrop, this paper aims to explore the dynamic impacts of export quality on CO_2E, in light of the EKC hypothesis, across five South Asian economies, namely Bangladesh, India, Pakistan, Sri Lanka and Nepal, over the period spanning from 1972 to 2014.[2] The paper contributes to the literature in multiple aspects. Firstly, only a few existing papers have analyzed the CO_2E-induced EKC hypothesis exclusively for the South Asian region. However, extensive analysis of the economic growth-CO_2E nexus in the South Asian context is pertinent since the concerned nations have registered robust growth of their respective economies and have simultaneously accentuated the CO_2E levels as well. Secondly, to the best of knowledge, no preceding study has controlled for the quality of exports within the EKC analysis in the context of South Asia. Thirdly, this paper taps the cointegration approach

[1] For more information on renewable energy transition and its relevance to reducing CO_2E see Murshed (2018).
[2] The selection of the South Asian countries is based on data availability.

introduced by Gregory and Hansen (1996) which also has received nominal attention in the EKC literature. Finally, this paper is among the very few studies that have considered both panel and time-series estimators to perform the econometric analyses to evaluate the EKC hypothesis.

Moreover, the preliminary motivation behind this paper is sourced from the fact that the geographic topography of South Asia makes it extremely vulnerable to the atrocities of climate change particularly stemming from the escalating CO_2E trends across this region (USEPA 2019). Moreover, these emerging South Asian economies have persistently exhibited rising trends in the overall energy demand which, in most cases, is predominantly derived from the combustion of fossil fuels. Apart from Nepal, all the other four South Asian economies produce a lion's share of their respective national outputs using the non-renewable energy resources (World Bank 2019) which is hypothesized to be one of the central factors attributing to the aggravating volumes of CO_2E in South Asia. On the other hand, all these nations have also experienced persistent deficits in their respective trade balances whereby improvement in the quality of the export items, apart from mitigating CO_2E, can also be anticipated to mitigate the respective trade imbalances as well. Therefore, it can be said that export quality improvement can be expected to simultaneously safeguard the economic and environmental attributes of the South Asian economies.

The following questions are specifically addressed in this paper:

1. Is there any evidence of the EKC hypothesis for CO_2E across South Asia?
2. Does improvement in export quality affect CO_2E?
3. Are the findings homogeneous across the different South Asian economies?

The remainder of the paper is structured as follows. Section 2 provides an analysis of the trends in CO_2E across the selected South Asian nations. A review of the existing literature is presented in section 3. Section 4 introduces the empirical model and discusses the attributes of the dataset used. The methodology engulfing the econometric analyses is explained in section 5 while section 6 reports and discusses the corresponding results. Finally, section 7 concludes and recommends relevant policy interventions.

2. An overview of the trends in CO_2E across the selected South Asian economies

The historical trends in both the absolute and per capita volumes of CO_2E, between 1972 and 2014, across the selected South Asian economies, are tabulated in Table 1. It is apparent from the table that the aggregate CO_2E have increased significantly over the years. As far as the absolute volumes are concerned, the total volume of carbon dioxide emitted by these nations has surged by almost 7-fold, on average, over the aforementioned period. This can largely be attributed to the robust growth of most of these nations which have persistently aggravated the demand for energy, which has conventionally been met via the non-renewable electric power supplies. Among these five nations, the CO_2E in Nepal, on average, rose by more than 15 times followed by Bangladesh, India, Pakistan and Sri Lanka registering corresponding growths in CO_2E by 10.97, 6.98, 6.24 and 4.83 times, respectively. On the other hand, the total per capita CO_2E volumes, as shown in Table 1, are also seen to exhibit upward trends, increasing by almost 3.5 times between 1972 and 2014. Once again it is apparent that Nepal, despite sourcing a large portion of its national output from renewable energy resources (World Bank 2019), has performed the worst among the five South Asian economies considered in this paper. The nation registered a rise in its corresponding per capita CO_2E figures by more than 8 times. In contrast, the per capita CO_2E in Pakistan has escalated the least, by a little less than 2.5 times, on average, over the aforementioned time period.

Therefore, it is quite obvious from the trends in both the absolute and per capita CO_2E figures that the levels of CO_2E across the selected South Asian economies is persistently growing which is a matter of concern keeping the issues of environmental well-being and climate changes into cognizance. The worsening trends in the CO_2E across this region can be explained by the predominant reliance of most of these five nations on the consumption of non-renewable energy to generate the national output. Figure 2, in the appendix, illustrates the changes in the average shares of renewables, in the total final energy consumption figures, respectively across the concerned South Asian nations. It can be explicitly understood from the diagram that between the periods 1995-2000 and 2010-2015, the average renewable energy shares in all the five South Asian economies have declined which can be perceived from the changes in the color codes from yellow to orange for India, from light green to orange for Bangladesh, and from light green to yellow for Sri Lanka. Although the color codes did not change from yellow and dark green for

Pakistan and Nepal, respectively, the renewable energy consumption shares did go down. Between the two aforementioned time periods, the average shares of renewables declined the most in Bangladesh, by almost 23 percentage points, followed by India, Sri Lanka, Pakistan and Nepal registering corresponding declines by 14.90, 6.62, 5.03 and 4.33 percentage points, respectively (World Bank 2019). Hence, these figures explicitly point towards the rise in the non-renewable energy shares which have collectively played a decisive role in the aggravation of CO_2E across South Asia.

3. Literature Review

This section has two subsections discussing the theoretical framework engulfing the EKC hypothesis, along with the potential impacts of rising export quality on the growth-CO_2E nexus, and the empirical evidence in this regard, respectively.

3.1. Theoretical Framework

The EKC hypothesis is a variant of the Kuznets Curve hypothesis, originally put forward by Simon Kuznets (Kuznets 1955), which postulates in favor of the non-linear association between economic growth and income inequality. Keeping the non-linearity into consideration, the EKC hypothesis was first introduced in the seminal study by Grossman and Krueger (2011) which claimed a similar non-linear association between economic growth and environmental quality. Following Gross and Krueger (2011), a wide array of studies have statistically investigated the validity of the EKC hypothesis using different measures to quantify environmental quality. However, CO_2E is the most commonly used indicator of environmental well-being in the relevant EKC narrative. The core rationale behind the EKC hypothesis for CO_2E is that during the initial phases of growth the volume of CO_2E is expected to rise, thus, implicating towards a trade-off between economic growth and environmental degradation. However, beyond a threshold growth level, the relationship can be anticipated to be reversed whereby further growth of the economy is hypothesized to reduce the CO_2E, thus phasing out the initial trade-off between economic and environmental welfares. As a result, the EKC for CO_2E is asserted to depict an inverted-U shape, denoting a positive and negative correlation between economic growth and CO_2E in the early and latter stages of growth, respectively.

The inverted-U shape of the CO_2E-induced EKC, as shown in Figure 2, can be explained in terms of the scale, composition and technique effects that take place along the growth stream.[3] For instance, during the pre-industrial phase, the scale effect could be interpreted as the expansion of the agricultural activities resulting in CO_2E. Hence, several studies have explored the agricultural-induced EKC hypothesis in the literature (Gokmenoglu and Taspinar 2018). Then, as the economy progresses towards the industrialization phase, gradually transforming the traditional agrarian economy into a modern industrialized economy, both the scale and composition effects are expected to stimulate CO_2E further. The composition effect refers to the choice of the industrial inputs which, in the initial stages, are primarily fossil fuel-based, thus, explaining the corresponding rise in the CO_2E during the earlier phases of industrialization (Opoku and Boachie 2020). However, towards the end of the industrialization phase and throughout the post-industrialization era, the technique effect is likely to take strides whereby the CO_2E are likely to decline (Cherniwchan 2012). During this phase, technological innovation and infrastructure development are expected to influence the choice of the industrial inputs which are likely to be relatively more environment-friendly, whereby lower volumes of CO_2E can be anticipated.

Hence, the turning point of the EKC, at the growth threshold, is believed to be at the point where the technique effect starts to come into effect, which is most likely to take place over the late-industrialization and post-industrialization phases. This is where enhancing the quality of exports is thought to play a key role with respect to influencing the growth-CO_2E nexus. For instance, higher export quality is likely to contribute to the export-led growth strategies of the developing economies in particular (Berik 2000). As a result, the better quality of the export products can be expected to catalyze the growth rates within the concerned economies via contributing to the national value added (Krishna and Maloney 2011). Thus, improving export quality could be ideal in enabling the concerned economies to go past the respective growth threshold, in the context of the EKC for CO_2E, relatively faster. On the other hand, upgrading the quality of exports may directly contribute to lower levels of CO_2E as well; particularly via making use of the appropriate technologies to produce the exportables using renewable energy

[3] For in-depth understanding of the scale, composition and technique effects see Grether, Mathys and de Melo (2009) and Liobikienė and Butkus (2019).

inputs (Costantini and Crespi 2008). Therefore, improving the quality of exports, via facilitation of the renewable energy transition process, can plausibly be linked to lower levels of CO_2E.

3.2. Empirical Evidence

In the seminal paper addressing the EKC hypothesis, Grossman and Krueger (1991) investigated the responses of sulfur and smoke emissions along with the growth of the Mexican economy, following the execution of the North American Free Trade Agreement (NAFTA). Later on, Panayotou (1993) examined the EKC hypothesis in the context of 68 developed and developing economies by quantifying environmental degradation in terms of deforestation within these economies. The results confirmed the authenticity of the deforestation-induced EKC hypothesis. Since then the validity of the EKC hypothesis was statistically explored using different indicators of air pollution which included emissions of carbon dioxide (Murshed 2020b), methane (Benavides *et al.* 2017), nitrous oxide (Miah, Masum and Koike 2010) and particulate matter (Miah *et al.* 2011). Besides air quality, the authenticity of the EKC hypothesis was also checked in the context of indicators of water pollution (Lee, Chiu and Sun 2010), land degradation (Bimonte and Stabile 2017) and deforestation (Murshed 2020c) in particular. The recent studies on the EKC hypothesis have also used ecological footprints as a measure of environmental quality (Al-Mulali *et al.* 2015). However, among these diverse indicators of environmental well-being, most of the existing studies probing into the EKC hypothesis have predominantly focused on the rising CO_2E to quantify environmental deterioration.

In the context of the existing studies investigating the growth-CO_2E nexus, in light of the EKC hypothesis, the specific impacts of per capita national income on per capita CO_2E were studied by Romero-Ávila (2008) for a sample of 86 countries spanning across Asia, Africa, Europe and Oceania. However, the validity of the CO_2E-induced EKC could not be ascertained following the non-stationarity issue in the data. However, following the apprehensions regarding the potential omitted-variable biases involving such bivariate modeling approaches by Romero-Ávila (2008), successive studies have augmented critically important macroeconomic aggregates into econometric models to ascertain the conditional impacts of economic growth on CO_2E (Stern 2004). For instance, controlling for aggregate energy consumption, Shahbaz *et al.* (2019) concluded in favor of the statistical validity of the EKC hypothesis for CO_2E in the context of 64 high, middle and low-income economies across the globe. In contrast, Pablo-Romero and De Jesús (2016) found economic growth to exponentially aggravate CO_2E within 22 Latin American and Caribbean nations, largely alleging the growth in the energy demand being responsible for the invalidity of the CO_2E-induced hypothesis. Similar studies have also used disaggregated energy data to predict the nature of the growth-CO_2E nexus. In a study featuring 25 Organization for Economic Cooperation and Development (OECD) countries, Jebli, Youssef and Ozturk (2016) confirmed the CO_2E-induced EKC hypothesis controlling for both renewable and non-renewable energy consumption into the econometric analyses. The authors also highlighted the results which revealed that higher consumption of renewable energy led to lower levels of CO_2E while non-renewable energy consumption escalated CO_2E across the selected OECD member nations.

A large number of the existing studies have also controlled for the rate of urbanization in predicting the nature of the growth-CO_2E nexus. Saidi and Mbarek (2017) found urbanization to stimulate CO_2E across 19 emerging economies. Besides, the authors also failed to validate the EKC hypothesis since economic growth was seen to monotonically increase the levels of CO_2E within these economies. In contrast, Destek, Balli and Manga (2016) found urbanization to account for lower CO_2E in the context of 10 Central and Eastern European countries and also concluded in favor of the validity of the CO_2E-induced EKC hypothesis. In another study on 49 African economies, Effiong (2018), despite finding urbanization to reduce CO_2E, did not find statistical evidence regarding the validity of the EKC hypothesis for CO_2E across Africa.

Moreover, linking financial development to CO_2E, the EKC for CO_2E in the context of 24 transitional economies was validated in the study by Tamazian and Rao (2010). The authors opined that financial development deteriorates the environmental quality of these nations through stimulation of CO_2E. However, betterment of the institutional quality was claimed to be necessary for financial development to being effectively reducing the CO_2E. In another relevant study on the BRICS countries, Haseeb *et al.* (2018) found statistical evidence to validate the EKC hypothesis while financial development was found to stimulate the levels of CO_2E. The country-specific analyses, in this regard, showed that the EKC hypothesis holds only for Brazil, China and South Africa while for Russia and India the growth-CO_2E nexus was found to portray U-shaped associations. The authors also opined that financial development led to lower CO_2E in Russia and China while triggering emissions across Brazil and South Africa.

The role of Foreign Direct Investments (FDI) inflows on the growth-CO_2E nexus has also been explored in the existing literature. The relevant studies, along with the aim of investigating the validity of the CO_2E-induced EKC hypothesis, also focused on the Pollution Haven Hypothesis (PHH) which predicts that rising FDI inflows attribute to higher CO_2E within the recipient economies.[4] In a corresponding study on 14 selected Latin American countries, Sapkota and Bastola (2017) found statistical evidence to validate the existence of the EKC hypothesis while referring FDI inflows to contribute to higher CO_2E across the concerned economies. Similarly, in the context of 5 South-east Asian nations, Baek (2016) concluded FDI inflows to exert adverse impacts on the CO_2E levels, but no statistical support was found to prove the validity of the EKC hypothesis.

Last, but not the least, the impacts of international trade on the growth-CO_2E nexus were extensively studied as well. However, different studies have used diverse measures of international trade to ascertain the conditional impacts of economic growth on CO_2E. The trade openness index, measured in terms of the share of imports and exports in the national GDP, is the most commonly used proxy for international trade in this context. Zhang, Liu and Bae (2017) found statistical evidence of the EKC hypothesis for a panel of 10 newly industrialized economies, controlling for trade openness in the analysis. Moreover, the authors opined that higher trade openness led to reduction in the CO_2E. Other relevant studies have analyzed the impacts of exports on the growth-CO_2E nexus as well. In the context of a panel of 11 Asian countries, Rahman (2017) found exports to trigger CO_2E which ultimately could have played a key role in invalidating the CO_2E-induced EKC hypothesis for these nations. However, the country-specific analyses revealed that the EKC hypothesis was valid only for the Philippines. On the other hand, Zhang (2018) found imports to boost CO_2E in South Korea, only in the long-run, while concluding in favor of the validity of the EKC hypothesis as well.

Besides, some of the recent studies on the CO_2E-induced EKC hypothesis, have explored the impacts of export diversification on CO_2E. Apergis *et al.* (2018) found statistical validity of the CO_2E-induced EKC hypothesis in the context of a panel of 19 developed economies in which export product diversification was referred to effective in curbing CO_2E in the long-run. Moreover, using the results from the country-specific analyses, Apergis *et al.* (2018) found that the EKC hypothesis was valid for 13 out of the 19 developed economies in the long-run and in most cases export diversification was found to be reducing the CO_2E in the respective economies. Similarly, for a panel of 98 developed and developing nations, Mania (2019) also found statistical validity of the CO_2E-induced EKC hypothesis, both in the short and the long-runs. Besides, export diversification was found to reduce the levels of CO_2E within these economies.

Although these aforementioned indicators of international trade received a significant amount of emphasis across the existing studies focusing on the CO_2E-induced EKC hypothesis, the dynamic impacts of export quality improvement on the growth-CO_2E nexus are yet to be explored extensively. There is only a single study in the literature that controls for the quality of exports in investigating the EKC for CO_2E. Dogan *et al.* (2020), very recently, used annual data in the context of 63 developed and developing nations and found that improving the quality of the export items led to higher CO_2E whereby economic growth was affirmed to persistently boost CO_2E, thus, invalidating the EKC hypothesis. Against this existent gap in the literature, this paper aims to contribute, to the empirical literature, via exploring the impacts of export quality improvement on the EKC for CO_2E in the context of Bangladesh, India, Pakistan, Sri Lanka and Nepal over the period 1972 to 2014.

4. Empirical Model and Data

The CO_2E trends along the economic growth streams across the selected South Asian economies are modeled using a non-linear double-log function, controlling for key macroeconomic aggregates that are hypothesized to influence the overall nexus between economic growth and CO_2E. The corresponding empirical model, within a panel framework, can be specified as:

$$\boldsymbol{lnCO2_{it} = \partial_1 + \partial_2 lnRGDP_{it} + \partial_3 lnRGDP^2_{it} + \partial_4 lnENERGY_{it} + \partial_5 lnEQ_{it} + \partial_6 (lnRGDP * lnEQ)_{it} + \partial_7 lnURB_{it} + \partial_8 lnFD_{it} + \partial_9 lnFDI_{it} + \varepsilon_{it}} \quad (1)$$

where the subscripts i (i =1, 2, …, N) and t (t=1, 2, …, T) denote the individual cross-section (country) and the time period, respectively. ε stands for the error-term. The intercept and the elasticity parameters to be estimated are expressed as ∂_1 and $\partial_i (i = 2, 3, ..., 9)$, respectively. The variable CO2 refers to the emission of carbon dioxide

[4] For more information on the PHH see Al-Mulali and Tang (2013).

measured in terms of kilotons. RGDP and $RGDP^2$ stand for the real gross domestic product and its squared term, respectively, to evaluate the possible non-linearity of the economic growth-CO_2E nexus. The real GDP figures proxy for the real national income levels of the respective economies measured in constant 2010 US dollar prices. The econometric model is controlled for several key macroeconomic aggregates which include the total energy consumption (ENERGY) in terms of tonnes of oil equivalent; export quality (EQ) expressed in terms of the export quality index which ranges from 0 to 1 in the ascending order of the export product quality; the interaction term between real income level and export quality (RGDP*EQ) to account for the combined impacts of economic growth and export quality on the levels of CO_2E; the rate of urbanization (URB) expressed in terms of the percentage of the total population residing in the urban areas; financial development (FD) measured in terms of the ratio of the domestic credits, extended to the private sector, to the GDP; and the monetary value of the net inflows of foreign direct investments (FDI), measured as percentage shares in the GDP. Inclusion of the incoming FDI figures was based on the intention to investigate the validity of the PHH in the context of the selected South Asian economies.

4.1. Hypothesis building

In line with the principles of the EKC hypothesis, the signs of the elasticity parameters attached to *lnRGDP* and $lnRGDP^2$ are expected to be positive and negative, respectively, to implicate the initial trade-off between economic growth and higher CO_2E which eventually gets phased out beyond a threshold growth level (Romero-Ávila (2008). The sign of the elasticity estimator attached to *lnENERGY* is ideally expected to depict a positive sign (Pablo-Romero and De Jesús 2016), particularly due to almost all the five South Asian economies sourcing a significant portion of their respective energy demands from non-renewable sources (World Bank 2019) with Nepal being the only exception. However, the recent trends, shown in Figure 1 in the appendix, reveal that the renewable energy shares have been declining across all the five nations which further reason the hypothesized positive energy consumption-CO_2E nexus. The elasticity parameter attached to *lnEQ* can be anticipated to bear a negative sign assuming the quality improvement is based on modern technology that reduces the intensity of energy-use while simultaneously employing renewable energy inputs to produce the exportables. It is believed that reducing energy-use intensities (Sadorsky 2014) and the consumption of renewable energy (Roca and Alcántara 2001) could be associated with mitigation of the CO_2E. Moreover, the sign of the elasticity parameter attached to the interaction term *ln(RGDP*EQ)* is likely to be negative following the assumption that higher economic growth and export quality improvement, in the process, would attribute to lower levels of CO_2E.

On the other hand, the sign of elasticity parameter attached to *lnURB* could be ambiguous since the existing literature has documented equivocal evidence in this regard (Martínez-Zarzoso and Maruotti 2011). Financial development is also expected to exhibit ambiguous impacts on the CO_2E, thus, the sign of the corresponding elasticity estimator attached to *lnFD* could either be positive (Tamazian and Rao 2010) or negative (Shahbaz *et al.* 2013). Finally, the sign of the elasticity parameter attached to *lnFDI* can also be anticipated to exhibit ambiguity as well since the nature of the FDI and the industry in which the foreign funds are being invested (Tang 2015) determines the movements in the volumes of CO_2E. A positive sign of the elasticity parameter in this regard would provide validity to the PHH while the negative sign would refute it (Al-Mulali and Tang 2013).

For the robustness check of the findings in the context of the economic growth-CO_2E nexus, model (1) is re-estimated using the per capita CO_2E figures instead. The corresponding econometric model can be specified as:

$$\boldsymbol{lnCO2pc_{it} = \beta_1 + \beta_2 lnRGDP_{it} + \beta_3 lnRGDP^2_{it} + \beta_4 lnENERGY_{it} + \beta_5 lnEQ_{it} + \beta_6 (lnRGDP * lnEQ)_{it} + \beta_7 lnURB_{it} + \beta_8 lnFD_{it} + \beta_9 lnFDI_{it} + \varepsilon_{it}} \qquad (2)$$

where CO2pc abbreviates for the per capita emission of carbon-dioxide measured in terms of metric tonnes. β_1 and $\beta_i (i = 2, 3, \ldots, 9)$ are the intercept and the elasticity parameters to be estimated, respectively. The expected signs of the elasticity parameters are anticipated to conform to the corresponding signs of the elasticity parameters explained in the context of model (1). The abovementioned panel models are random-effects models due to the omission of time-invariant variables from the analysis.[5]

[5] The Hausman (1978) test also suggested the appropriateness of the random-effects model over the fixed-effects model. For brevity, the results are not reported but can be made available upon request.

Finally, in order to assess the possible heterogeneity of the overall findings considering the country-specific aspects, models (1) and (2) are respectively modeled using the time-series framework for the individual South Asian economies.

Annual data spanning across 1972 and 2014 is compiled to perform the econometric analyses. The data for export quality is sourced from the database of the International Monetary Fund while that for the rest of the variables are retrieved from the World Development Indicators database of the World Bank. All the variables have been transformed to their natural logarithms, as denoted by the prefix 'ln' in respective models, for the ease of estimating the long-run elasticities, thus, reducing the sharpness of the data to generate more reliable and consistent estimates. Table 2 in the appendix provides the descriptive statistics for all the aforementioned variables while the pairwise correlation coefficients concerning these variables are reported in Table 3 in the appendix. The correlation analysis, as shown in Table 3, reveals that the models are not subject to multicollinearity issues. Moreover, the high correlation between the absolute and per capita CO_2E figures justifies the use of the per capita CO_2E figures for the robustness check of the economic growth-CO_2E nexus.

5. Methodology

This paper employs both panel data and time-series econometric analyses to predict the validity of the CO_2E-induced EKC hypothesis across the selected South Asian countries.

5.1. Panel data econometric analyses

At first, the panel dataset is checked for Cross-Sectional Dependency (CD) since the presence of correlation across the panels could lead to the estimation of inconsistent stationarity and cointegrating properties (Dong, Sun and Dong 2018). The Breusch-Pagan (1980) Lagrange Multiplier (LM) and the Pesaran (2004) CD tests are tapped to ascertain the possible CD issues. The LM test statistic can be specified as:

$$\boldsymbol{LM = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} T_{ij}\,\hat{\rho}_{ij}^{2} \rightarrow \chi^{2}\,\frac{N(N-1)}{2}} \qquad \textbf{(3)}$$

where N is the number of countries, T is the time period and $\hat{\rho}_{ij}^{2}$ is the predicted correlation coefficient sourced from the residuals of the econometric model. Besides, the Pesaran (2004) CD test, ideally suited for handling datasets with small cross-sections and short time dimensions, is also employed. The Pesaran CD test statistic can be specified as:

$$\boldsymbol{CD = \sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} T_{ij}\,\hat{\rho}_{ij}^{2} \rightarrow N(0,1)} \qquad \textbf{(4)}$$

Both these test statistics are respectively estimated under the null hypothesis of cross-sectional independence against the alternative hypothesis of CD. The results from the CD analyses for models (1) and (2) are displayed in Table 4. The statistical significances of the Breusch-Pagan LM and the Pesaran CD test statistics reject the null hypotheses of cross-sectional independence, for the respective models, to validate the existence of the CD among the panel series. Hence, the application of the conventionally used first-generation panel unit root and cointegration techniques is no longer valid since these methods fail to account for the CD issues in the dataset.

In addition to CD analyses, it is pertinent to check the slope heterogeneity issue as well since ignoring the possible heterogeneity of the slope coefficients, across the cross-sections, could result in the elasticity estimations being biased. Thus, this paper uses the slope heterogeneity test proposed by Pesaran and Yamagata (2008) which estimates two test statistics, $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$, under the null hypothesis of slope homogeneity against the alternative hypothesis of slope heterogeneity. The corresponding results from the slope heterogeneity test, for models (1) and (2), are also reported in Table 4. The statistical significance of the test statistics, at 1% level, rejects the null hypothesis to predict the presence of the slope heterogeneity issues.

The panel data unit root analyses follow the CD and slope heterogeneity examinations. Since the CD tests revealed the problem of CD, the second generation panel unit root techniques are employed since the first generation tests do not account for CD across the panels. This paper taps the Cross-sectionally Augmented Dickey-Fuller (CADF) and the Cross-sectionally Augmented Im, Pesaran and Shin (CIPS) panel unit root estimation techniques proposed by Pesaran (2007). The CADF test statistic can be obtained from the generalized regression model given below:

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + \sum_{j=0}^{s} d_{ij}\, \Delta\bar{y}_{t-j} + \sum_{j=1}^{s} \delta_{ij}\, \Delta\bar{y}_{i,t-j} + e_{it} \quad (5)$$

where $\bar{y}$ and $\overline{\Delta y}$ are the cross-sectional averages of lagged levels and first differences, respectively, at time T for all cross-sections. The estimated t-statistic from equation (5) is then used to compute the CIPS statistic which can be specified as:

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \quad (6)$$

where $CADF_i$ is the t-statistic estimated from the CADF regression model shown in equation (5). Both the CADF and CIPS tests are performed under the null hypothesis of non-stationarity of the respective variable against the alternative hypothesis of stationarity.

Then, the long run associations between the variables are then ascertained using the appropriate panel cointegration methods. The conventionally employed panel cointegration methods namely the Pedroni (1999) residual-based cointegration technique does not take the CD across the panels into account. Thus, the Westerlund (2007) panel cointegration analysis, which is robust to handling cross-sectionally dependent panel datasets, is used. The CD is accounted for under the Westerlund (2007) cointegration approach via estimation of the probability values of the test statistics using bootstrapping methods. A total of two group-mean tests and two panel tests are performed under the null hypothesis of no cointegration against the alternative hypothesis of cointegration among at least one cross-sectional unit or cointegration among the whole panel, respectively. The four tests under the Westerlund (2007) panel cointegration approach are structured in the context of an error-correction model which can be expressed as:

$$\Delta y_{it} = \delta_i' d_t + \alpha_i\left(y_{i,t-1} - \beta_i' x_{i,t-1}\right) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{-q_i}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + e_{it} \quad (7)$$

where d_t stands for the deterministic components and p_i and q_i are the lag lengths and lead orders which are allowed to vary across individual cross-sections. The two group-mean test statistics G_t and G_a and the two panel test statistics P_t and P_a within the Westerlund (2007) cointegration analysis can be specified as:

$$G_t = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (8)$$

$$G_a = \frac{1}{N} \sum_{i=1}^{N} \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)} \quad (9)$$

$$P_t = \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (10)$$

$$P_a = T\hat{\alpha} \quad (12)$$

The statistical significance of these test statistics rejects the null hypothesis to suggest long-run associations between the variables included in the model. The presence of cointegrating relationships is a pre-requisite to estimating the long-run estimates using appropriate regression methods.

The panel regression analyses follow the cointegration analyses. Quite a few of the existing papers have tapped both the panel data cointegration and regression approaches to evaluate the authenticity of the EKC hypothesis (Aruga 2019; Liu *et al.* 2020; Jin and Kim 2020). It is pertinent to use both because the cointegration analysis provides evidence of the possible long-run associations between the variables of concern but does not unearth the sign of the correlative associations between the variables. However, from the perspective of evaluating the inverted-U shaped association between economic growth and CO_2E, under the EKC hypothesis, it is crucial for estimating the signs of the correlative properties.

The presence of CD issues in the dataset is likely to be translated into misspecification problems resulting in biased regression outputs (Damette and Marques 2019). Moreover, the slope heterogeneity issues are also likely to generate similar problems as well (Pesaran and Yamagata 2008). Although the most commonly used panel data regression techniques namely the Fully-Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) are claimed to be able to handle the cross-sectional correlations among the panels, such methods overlook the slope heterogeneity issues by inappropriately assuming the slope coefficients to be constant across all the cross-sections. To account for this problem, this paper uses three panel data regression estimators which, in addition to handling the CD issues, allow for the slope coefficients to vary across the cross-sectional units (Damette and Marques 2019).

The first of the three panel data regression techniques used in this paper is referred to as the Mean Group (MG) estimator developed by Pesaran and Smith (1995). The MG estimation primarily involves the prediction of the slope coefficients for each of the cross-sections, within the panel dataset, using the Ordinary Least Squares (OLS) method and then averaging them across the panel units. This allows for the possible heterogeneity of the slope coefficients, across the different cross-sections, to overcome the inefficiencies of the FMOLS and the DOLS techniques. The MG estimator can be specified as:

$$\widehat{\boldsymbol{\beta}}_{MG} = N^{-1} \sum_{i=1}^{N} \widehat{\boldsymbol{\beta}}_i \quad \textbf{(12)}$$

where $\widehat{\boldsymbol{\beta}}_{MG}$ is the simple mean of the individual estimates of the slope coefficients from each cross-sectional unit. However, a major limitation of this technique is that it fails to account for the CD in the data. Thus, the Common Correlated Effects Mean Group (CCEMG) estimator, proposed by Pesaran (2006), is also considered which basically is a cross-sectionally augmented version of the MG estimator. The CCEMG estimator corrects the limitations of the MG estimator by incorporating the time-variant unobserved common factors stemming from the CD issues into the estimation process via the augmentation of these unobserved common factors into the regression model before estimating the individual slope coefficients and then averaging them across the panel units. Much like the MG estimator, the CCEMG estimator can also be specified as:

$$\widehat{\boldsymbol{\beta}}_{CCEMG} = N^{-1} \sum_{i=1}^{N} \widehat{\boldsymbol{\beta}}_i \quad \textbf{(13)}$$

where $\widehat{\boldsymbol{\beta}}_{CCEMG}$ is once again the mean of the individual slope estimates from each cross-sectional unit. The only difference between the MG and the CCEMG estimators, respectively expressed in equations (12) and (13), is that the CCEMG estimator estimates and averages the individual slope coefficients via augmenting the common factors across the cross-sections into the empirical model which is not the case in the context the MG estimator.

Finally, for robustness check of the results across different panel regression techniques, the Augmented Mean Group (AMG) estimator proposed by Bond and Eberhardt (2013) is employed. The AMG estimator, much like the CCEMG estimator, also allows for slope heterogeneity and CD issues in the data. However, the AMG estimator augments the year dummies into the model and refers the time-variant unobserved common factors to exhibit a dynamic process whereas the CCEMG estimator includes the unobserved common factors in the error term (Mrabet *et al.* 2019).

5.2. Time-series econometric analyses

The time-series analysis starts off by checking the stationarity properties of the variables. It is pertinent to test for the existence of unit root in the data since non-stationary data is likely to result in spurious regression outputs. Moreover, the order of integration among the variables is also understood from the stationarity analysis which, in turn, determines the appropriate cointegration and causality estimation techniques to be applied. However, although the conventional time series unit root testing techniques such as the Augmented Dickey-Fuller (Dickey and Fuller 1979) and the Phillips-Perron (Phillips and Perron 1988) tests have been popularly used in the literature, these tests are said to produce biased estimates in the presence of Structural Break (SB) issues in the data (Perron 1989). Thus, accounting for the SB, the Zivot-Andrews (ZA) unit root estimation technique, proposed by Zivot and Andrews (2002), is employed. This method estimates the test statistic under the null hypothesis of non-stationarity against the alternative hypothesis of otherwise in the presence of one SB in the corresponding data. In addition to estimating the stationarity property, the ZA method also identifies the specific break year as well for each variable.

Once the order of integration, between the variables is ascertained it is important to evaluate the cointegration relationship between the variables as well. However, although the traditional time-series cointegration techniques developed by Engle and Granger (1987), Johansen (1991) and Johansen and Juselius (1990) are popularly tapped in the existing studies, these methods do not take into account the SB issues. All of these techniques are based on the incorrect assumption of the cointegrating associations being time-invariant. However, the SB in the data nullifies this erroneous assumption which makes their application inappropriate. Hence, this paper uses the Gregory-Hansen (GH) cointegration approach (Gregory and Hansen 1996) which is claimed to be robust to handling SB in the data. The null hypothesis in regard states no cointegration between the variables included in the econometric model against the alternative hypothesis of otherwise. Moreover, the break years are also ascertained from the GH cointegration analyses. Based on the identification of the break years from the cointegration exercises, the corresponding break date dummy variables are generated and augmented into the respective econometric models, prior to proceeding to the time-series regression analyses. Although the Bounds testing approach to cointegration is a preferred method for estimating the long-run associations, it is not tapped due to its limitation in terms of not being able account for the SB issues into account.

Then, the long-run elasticities for each of the models for the respective nations are estimated using the Fully-Modified Ordinary Least Squares (FMOLS) time-series regression technique. This estimation method is principally grounded on a non-parametric approach to regression analysis which provides estimates accounting for possible endogeneity and serial correlation issues in the data. Moreover, the FMOLS estimator is also believed to be ideally suited for estimations involving small sample sizes (Pedroni 2001), which further justifies the appropriateness of this method in the context of this paper. The FMOLS estimator ($\hat{\partial}_{FMOLS}$) can be shown by:

$$\left(\hat{\partial}_{FMOLS}\right) = N^{-1} \sum_{i=1}^{N} \widehat{\partial_{FMOLS,i}} \quad \textbf{(14)}$$

The corresponding t-statistic from the FMOLS estimator can be expressed as:

$$t_{\hat{\partial}_{FMOLS}} = N^{-1/2} \sum_{i=1}^{N} t_{\hat{\partial}_{FMOLS}} \quad \textbf{(15)}$$

6. Results and discussion

The panel unit root test results are reported in table 5. It is evident from the statistical insignificance of the test statistics, from both the CADF and CIPS tests, that all the variables are non-stationary at their respective level forms. However, they do become stationary at their first differences, thus, affirming a common order of integration [I(1)] among the variables. The statistical significances of the test statistics reject the null hypothesis of non-stationarity to confirm the stationarity properties of the concerned variables.

The panel unit root analyses are followed by the panel cointegration exercises and the corresponding results are presented in Table 6. The results from the Westerlund (2007) test reveal the presence of cointegrating equations in both the models. The statistical significance of the estimated test statistics, at 1% level, rejects the null hypothesis of no cointegration to confirm the long-run associations between the corresponding variables. Hence, it can be said that there are long-run associations between CO_2E, both in absolute and per capita terms, with economic growth, aggregate energy consumption, export quality, urbanization, financial development and FDI inflows in the context of the selected South Asian economies.

The long-run elasticity outputs from the panel regression analyses, in the context of models (1) and (2), are reported in Table 7. The overall results reveal that the elasticity estimates are robust across the three alternate panel data regression techniques used in this paper. The predicted signs and the corresponding statistical significances are found to be identical for all the three regression approaches.

In the context of model (1), the positive and negative signs of the statistically significant estimates of the elasticity parameters attached to *lnRGDP* and its squared term, respectively, indicate towards the validity of the CO_2E-induced EKC hypothesis in the context of the concerned South Asian economies. The results show that during the initial stages of economic growth, a 1% rise in the real national income level, proxied by the real GDP level, accounts for a rise in the CO_2E level by 3.09%-3.57%, on average, *ceteris paribus.* However, beyond a certain level, the marginal impact of growth results in a reduction in the CO_2E by 0.07%-0.08%, on average, *ceteris paribus.* Thus, the growth-CO_2E nexus in the context of the South Asian economies can be said to depict an inverted-U shape. The findings corroborate to those by Zhang, Liu and Bae (2017) and Rahman (2017) in the context of 10 newly industrialized and 11 Asian economies, respectively. The validation of the CO_2E-induced EKC hypothesis implies that the selected South Asian economies, much like all underdeveloped economies across the globe, accept the initial trade-off between economic welfare and environmental distress which is likely to be phased out gradually as these economies become more economically empowered to limit the CO_2E levels.

Besides, energy consumption is found to impose adverse environmental consequences via elevating the CO_2E. The corresponding elasticity estimates denote that a 1% rise in the aggregate energy consumption level stimulates a rise in the CO_2E by 1.96%-2.13%, on average, *ceteris paribus.* This tends to implicate towards the oil dependencies within these South Asian economies that have conventionally generated a large proportion of their respective national outputs using non-renewable energy resources, particularly in the form of the imported crude oils. The positive energy consumption-CO_2E association was also highlighted in the study by Pablo-Romero and De Jesús (2016) in the context of 22 Latin American and Caribbean nations. In line with the positive energy consumption-CO_2E nexus found in this paper, it is ideal for the selected South Asian economies to rapidly undergo renewable energy transition, via overcoming the associated limitations bottlenecking the generation and consumption of renewable power.

The negative signs of the statistically significant estimated elasticity parameters attached to *lnEQ* portray the beneficial role of enhancing export quality with respect to reducing CO_2E within the selected South Asian economies. The corresponding elasticity estimates reveal that an improvement in the export quality by 1% lowers down the volumes of CO_2E by 20.19%-28.19%, on average, *ceteris paribus.* Hence, it can be said that CO_2E across the selected South Asian economies are highly responsive to movements in the quality of their export items which justifies the need to enhance the quality of the exportables, particularly through the integration of renewable energy inputs within the production processes. This finding contradicts the positive export quality-CO_2E nexus put forward by Dogan *et al.* (2020) in the context of the 63 developed and developing nations. Furthermore, the statistical significance of the elasticities attached to the interaction term, between real GDP and export quality, implies that export quality along with growth joint affects the CO_2E levels. The negative signs of the elasticity parameters in this regard suggest that improvement in export quality alongside higher economic growth collectively account for lower CO_2E across the selected South Asian economies. These findings implicate that the overall impacts of economic growth on CO_2E are conditional on the quality of the exported products of the selected South Asian economies. Hence, it can be asserted that improving export quality is pretty much in line with the policies aimed at mitigation of CO_2E within the concerned economies.

As far as urbanization is concerned, the statistical insignificance of the elasticity parameters attached to *lnURB* denotes that urbanization is ineffective in explaining the movements in the levels of CO_2E in the context of the selected South Asian nations. This is an interesting finding from the perspective that most of these nations have had their unplanned urbanization issues which, to some extent, had been alleged to have contributed to high levels of CO_2E across the South Asian region (Siddique, Majeed and Ahmad 2016). On the other hand, financial development within these economies is found to be adversely affecting the environment, contributing to higher levels of CO_2E as well. The marginal impact of a 1% rise in the share of the domestic credit, extended to the private sector, in the GDP is found to be associated with a simultaneous rise in the CO_2E by 1.67%-1.93%, on average, *ceteris paribus.* Thus, it is ideal for the respective governments of these nations to incentivize the private sector stakeholders to adopt renewable energy technologies within their business process which can be anticipated to result in lower emissions of carbon dioxide. The negative impacts of financial development on CO_2E were also highlighted in the study by Tamazian and Rao (2010) which featured 24 transitional economies.

Finally, the inflow of FDIs into the South Asian economies was seen to aggravate the levels of CO_2E which affirm the validity of the PHH. The estimated parameters attached to *lnFDI* implicates that a rise in the level of FDI inflows by 1% elevates the CO_2E by 0.11%-0.21%, on average, *ceteris paribus.* Although the small magnitudes of these elasticities suggest that CO_2E are pretty inelastic to changes in FDI inflows, the positive signs seem to impose concerns in the context of these South Asian economies being targeted by foreign investors to outsource production of dirty commodities via exploiting the weak environmental laws and poor institutional qualities (Zakaria and Bibi 2019). This finding is also crucial from the perspective that the Chinese government, under its Belt and Road Initiative, plans to make hefty investments in all of these five South Asian economies which could be linked to higher volumes of CO_2E in the future. Hence, it is once again ideal for these nations to enhance their respective shares of renewable energy in total energy consumption figures to counter the potential adverse environmental impacts associated with rising levels of FDI inflows in the future.

The results in the context of per capita CO_2E, as perceived from the estimated elasticities in the context of model (2), are quite similar with respect to the predicted signs and their corresponding statistical significance. The long-run elasticity estimates in this regard, as shown in Table 7, once again confirm the validity of the EKC hypothesis for per capita CO_2E across the selected South Asian economies. Moreover, the other important findings reveal that the levels of per capita CO_2E are positively influenced by energy consumption, financial development and FDI inflows while export quality is found to reduce it. Hence, it can be asserted that the overall findings from the panel data analysis, concerning the economic growth-CO_2E nexus in the context of the five South Asian economies considered in this paper, are robust to different measures of CO_2E as well.

Keeping the possible country-specific heterogeneity of the findings from the panel data evidence, the econometric analyses are performed separately for each of the five nations using the appropriate time-series estimation techniques. Table 8 reports the time-series unit root results in the context of models (3) and (4) for each of the five South Asian economies. The results from the ZA unit root analyses also confirm a common order of integration among the variables, at the respective first differences, for all five economies. The statistical significances of the predicted t-statistics, considering both trend and trend and intercept, reject the null hypothesis of non-stationarity for all the variables in their respective first differences. Moreover, the results from the GH cointegration analyses, as reported in Table 9, confirm long-run associations of CO_2E/CO_2Epc with economic growth, export quality and other key macroeconomic variables controlled for in the econometric models. The statistical significance of the estimated test statistics, considering the SB in both the regime and regime and trend shifts, affirm these claims.

The country-specific long-run elasticity estimates using the FMOLS regression technique, for all the five South Asian economies, are reported in Table 10. The positive and negative signs of the statistically significant predicted elasticity parameters attached to $lnRGDP$ and $lnRGDP^2$, respectively, validate the CO_2E-induced EKC hypothesis only in the context of Bangladesh and India. Similar findings were reported for Turkey (Yavuz 2014) and Vietnam (Tang and Tan 2015). However, the results in the context of Pakistan reveal that the economic growth-CO_2E nexus depicts a U-shaped association which is not in line with the notion of the EKC hypothesis. This finding contradicts to the conclusion by Ahmed and Long (2012) for Pakistan between 1971 and 2008. These contrasting findings could well be due to the SB issues being overlooked in the study by Ahmed and Long (2012). Moreover, the two studies also differed in terms of the macroeconomic aggregates controlled for within the respective econometric models. Similar U-shaped growth-CO_2E nexuses were also reported by Haseeb *et al.* (2018) in the context of Russia and India.

On the other hand, economic growth is found to be monotonically decreasing CO_2E across Sri Lanka and Nepal, thus, invalidating the CO_2E-induced EKC hypothesis for these two economies. A particular reason behind this could be because of the fact that both Nepal and Sri Lanka, in comparison to the other three South Asian economies, have accounted for relatively higher renewable energy consumption shares in their respective aggregate final energy consumption figures (World Bank 2019) which could well have contributed to the predicted negative signs of the elasticity parameters attached to $lnRGDP$ and $lnRGDP^2$. The results are parallel to the findings by Annicchiarico, Bennato and Costa (2009) for Italy while contradicting those by Fodha and Zaghdoud (2010) for Tunisia. Therefore, these results collectively implicate towards the country-specific heterogeneity of the economic growth-CO_2E nexus which is evident from the ultimate finding that the CO_2E-induced EKC hypothesis holds true for only two of the five South Asian economies considered in this paper. The fact that the EKC hypothesis was authenticated for Bangladesh and India only because these two South Asian economies have outweighed Pakistan, Sri Lanka and Nepal with respect to enhancing the quality of their respective exportables. Between 2000 and 2015, the export quality indices of Bangladesh and India increased by 9.43% and 9.73%, respectively as oppose to export quality improvements in Pakistan and Sri Lanka by 3.94% and 5.53%, respectively. On the other hand, the Nepal's export quality between 2000 and 2015 had deteriorated by 7.45%. Hence, these contrasting trends further highlight the pertinence of improving export quality for curbing environmental degradation across the South Asian economies. Besides, both Bangladesh and India, among the selected South Asian economies, have also outperformed the others in terms of the per capita GDP levels. Between 2000 and 2017, the per capita GDP figures of Bangladesh and India rose by more than two-fold while that of Pakistan, Sri Lanka and Nepal increased by 1.31, 1.89 and 1.61 times, respectively. These trends imply that faster growth rate, alongside improvement in export quality, is a pre-requisite to mitigating the economic growth-environmental deterioration trade-off that takes place during the initial phases of growth. Hence, catching up in terms of these growth rates can resolve the adverse environmental impacts of growth in Pakistan, Sri Lanka and Nepal.

As far as energy consumption is concerned, the positive and statistically significant elasticity estimates, attached to *lnENERGY*, reveals that CO_2E across all the five South Asian economies are stimulated by their respective overall energy consumption figures, which in almost all the five countries is predominantly sourced from the non-renewable sources (World Bank 2019). Moreover, the declining shares of renewables in the respective final energy consumption figures across these nations justify the positive relationships between energy consumption and CO_2E. Thus, it is ideal for these nations to further incorporate greener energy sources into their respective national energy-mixes to account for the aggravating trends in CO_2E. The positive energy consumption-CO_2E nexus was also highlighted by Shahbaz, Mutascu and Azim (2013) and Al-mulali and Che Sab (2018) for Romania and the United Arab Emirates, respectively.

Improving export quality could be a potential means to curbing CO_2E across the five South Asian economies considered in this paper. The negative signs of the estimated elasticity parameters attaché to *lnEQ* support this claim. However, in comparison to the other four nations, the elasticity of reduction in CO_2E with respect to the rising quality of exports in Pakistan is the lowest which implicates the export woes of the nation, particularly due to its geopolitical disputes with the neighboring nations and internal terrorism issues (Garlick 2018). However, it is quite apparent from the negative correlations between export quality and CO_2E that technological innovation, particularly in the context of enhancing the energy-use efficiency levels and augmenting renewable energy into the production of the exportables, could reap dividends in the form of lower levels of CO_2E. Thus, it is pertinent for both the public and the private sector entities across the concerned South Asian nations to undertake R&D investments with respect to refining the quality of the export items, which, along with adding to the respective national value-added, would also foster the environmental sustainability goals across South Asia. This particular finding is of greater importance from the perspective that liberalization of trade barriers, which is synonymous to a rise in the trade openness index, has been alleged, in the existing literature, to trigger CO_2E within the five selected South Asian economies (Zakaria and BIbi 2019). Under such circumstances, improving the quality of exports could, to some extent, be ideal in countering the negative trade liberalization impacts put forward by Zakaria and Bibi (2019). Moreover, the statistical significance of the negative signs of the predicted elasticity estimators attached to the interaction term *ln(RGDP*EQ)* further justify the significance of quality improvement of the exportables, along with growth, to account for lower levels of CO_2E. Thus, once again it can be asserted that the nexus between economic growth and CO_2E is conditional on the respective quality of exports of the selected South Asian economies. However, it is to be noted that the absolute magnitude of the estimated elasticity parameter attached to the interaction term in the context of Pakistan is less than 1 while that of the other four nations is well above 1. This tends to imply that CO_2E in Pakistan is pretty inelastic to the joint impacts of economic growth and export quality improvement which is a matter of concern for the Pakistan government. This can once again be attributed to the nation's geopolitical tensions which have hampered the true potential of trade expansion in Pakistan, thus, possibly bottlenecking the scopes for export quality improvement as well.

The adverse impacts of urbanization on the CO_2E in the context of Bangladesh, India, Pakistan and Nepal are perceived from the statistically significant positive signs of the estimated elasticity parameters attached to *lnURB*. Hence, these findings, in contrast to the corresponding findings from the panel data analysis, tend to suggest that unplanned urbanization within these four countries have played a large role in boosting the respective volumes of CO_2E. Similar findings were found in the study by Liu and Bae (2018) in the context of China and Japan while Asumadu-Sarkodie and Owusu (2017) found urbanization to curb CO_2E in Senegal. In contrast, the corresponding elasticity estimates in the context of Sri Lanka despite exhibiting negative signs are found to be statistically insignificant. Thus, the impacts of urbanization on CO_2E in Sri Lanka can be referred to be inconclusive. This finding contradicts to the conclusion made by Gasimili *et al.* (2019) in which the authors opined in favor of urbanization reducing CO_2E in Sri Lanka between 1978 and 2014.

The long-run elasticities of CO_2E with respect to higher degrees of financial development are found to elevate the levels of CO_2E in Bangladesh, Pakistan, Sri Lanka and Nepal. This finding is parallel to the conclusion made by Zhang (2011) for China while contradicting the findings put forward by Shahbaz *et al.* (2013) and Shahbaz, Tiwari and Nasir (2013) for Malaysia and South Africa, respectively. On the other hand, only in the case of India, the corresponding elasticity estimates advocate in favor of financial development attributing to lower CO_2E. The fact that India is the largest amongst the five South Asian economies could well have had a scale impact which led to its negative correlation between financial development and CO_2E in the context of India. Thus, these country-specific results seem to provide support to the authenticity of the overall positive financial development-CO_2E nexus found from the panel data analyses reported earlier.

Finally, the positive signs of the statistically significant elasticity parameters attached to *lnFDI* validate the PHH in the context of Bangladesh, Pakistan, Sri Lanka and Nepal. However, in the context of Pakistan, the corresponding elasticity estimates although depicting the positive signs are found to be statistically insignificant which nullifies the authenticity of the PHH. Hence, these findings, along with the panel data evidence in this regard, imposes concerns for the governments of the concerned South Asian economies with regards to the incoming FDIs deteriorating the environmental quality. Therefore, it is crucial for the governments to closely monitor the sectors in which the foreign funds are being directed whereby effective measures to green the corresponding production process could be ideal in mitigating the CO_2E to a large extent. Empirical evidence regarding the existence of the PHH was also highlighted in earlier studies by Solarin *et al.* (2017) and Sun, Zhang and Xu (2017) for Ghana and China, respectively.

7. Conclusion and policy implications

The aggravation of the global volumes of CO_2E has triggered worldwide awareness regarding the pertinence of mitigating these emissions to safeguard environmental welfare, worldwide. Thus to ensure sustainability of the environment along the economic growth stream, it is pertinent to identify the possible factors that bottleneck the prospects of CO_2E mitigation. Against this background, this paper probed into the validity of the CO_2E-induced EKC hypothesis in the context of selected South Asian economies namely Bangladesh, India, Pakistan, Sri Lanka and Nepal, between 1972 and 2014. The results broadly implicated towards the validity of the EKC hypothesis for the panel of the five South Asian economies while country-specific examinations in this regard identified the heterogeneity of the economic growth-CO_2E nexus. The country-specific analyses provided statistical validity to the CO_2E-induced EKC hypothesis only in the context of Bangladesh and India, while refuting it for Pakistan, Sri Lanka and Nepal.

More importantly, this paper made a novel attempt to control for the quality of exports within the EKC-modeling in the context of the selected South Asian economies. The corresponding results, from both the panel and individual country-specific examinations, revealed that improving the quality of the export products can be linked to lower volumes of CO_2E within these countries. Moreover, the statistical significance of the interaction term between economic growth and export quality affirmed the economic growth-CO_2E nexus to be conditional on the quality of exports. However, the impacts are found vary across the South Asian nations which further add to the heterogeneity of the overall findings. Thus, keeping these statistical findings into cognizance, it is ideal for the concerned governments to incentivize quality improvement within the respective export industries which, along with boosting the economic growth levels, would also be effective in reducing the environmental impacts of growth, particularly via curbing the CO_2E across South Asia. Moreover, it is advisable for the private sector entities across these nations to undertake R&D investments which can be expected to portray key roles in improving the overall quality of the exported commodities.

Other relevant findings from the econometric analyses found positive correlation between aggregate energy consumption and CO_2E in the context of all the five South Asian economies. This calls for renewable energy transition within these economies whereby elevating the share of renewables in the respective aggregate energy consumption figures could be ideal in tackling the overall CO_2E-induced climate change adversities to a large extent. In addition, enhancing the energy-use efficiencies could also reduce the overall demand for energy which, in turn, could attribute to further declines in the volumes of CO_2E. Besides, statistical evidence regarding the PHH was also ascertained for the entire panel of the five South Asian economies as well as in the context of Bangladesh, Pakistan, Sri Lanka and Nepal. Hence, it is pertinent to green the industries in which the foreign capitals are being directed which could be a critically important policy move to address the CO_2E woes of these nations. Furthermore, the development of the financial sector should also be done in a systematic manner whereby domestic credit should ideally be provided to private sector entities that are relatively intensive in use of renewable energy inputs. In conclusion, it can be said that the governments of the selected South Asian economies must address the aggravating CO_2E phenomenon with grit and sheer determination, particularly via aligning the respective energy generation and consumption policies with the SDG of the United Nations. Moreover, quality management and improvement within the export sector should be included within policy making decisions across the concerned South Asian economies.

As far as the country-specific policy implications are concerned, since the statistical estimates suggested that the EKC hypothesis holds in the context of Bangladesh and India, both these countries can pursue their respective growth strategies without the fear of adversely impacting the environment in the process. However, the growth strategies need to further aligned with the environmental welfare policies whereby the macroeconomic factors attributing to environmental deterioration, CO_2E in particular, need to be handled with caution. From the perspective of energy consumption, Bangladesh is better-off minimizing its mono-tonic dependence on combustion of natural gas and imported crude oils for electricity generation purposes; rather the nation is ideally recommended to elevate its renewable energy consumption shares in the national energy consumption figures. On the other hand, India is predominantly reliant on the use of coal for electricity generation purposes which also is detrimental for the sustainability of the environment. Hence, keeping environmental welfare alongside economic growth into cognizance, the nation is also advice to undergo transition from non-renewable to renewable energy use. Thus, energy diversification with specific focus on phasing out of the conventional non-renewable energy consumption dependency and gradual adoption of the renewable alternatives should be an ideal policy agenda of the governments of Bangladesh and India. In contrast, the fact that the empirical estimates in this paper failed to establish the validity of the EKC hypothesis for Pakistan, Sri Lanka and Nepal, these countries are recommended to match Bangladesh and India in terms of expediting per capita economic growth rates and also with respect to the rate of improvement in the quality of their respective exportables. Although the rate of export quality improvement in Pakistan and Sri Lanka, in the recent times, has registered upward trends, it is still relatively lower than that compared to Bangladesh and India; whereas the quality of Nepal's export has rather declined. Hence, it is prescribed that Pakistan, Sri Lanka and Nepal, along with enhancing their renewable energy shares, adopt appropriate policy measures to escalate their respective quality of exports which would not only reap dividends in terms of enhancing their growth rates but would also be effective in curbing their respective levels of CO_2E.

As part of the future scope of research, this paper can be extended to augment renewable and non-renewable energy consumption figures into the respective models, instead of considering the aggregate energy consumption levels, with respect to investigating the heterogeneity of the results across different types of energy resources. Moreover, the impacts of export product diversification on the CO_2E-induced EKC hypothesis in the context of South Asia can also be explored for possible policy interventions.

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Appendix