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What drives carbon emissions in the long-run? The role of renewable energy and agriculture in achieving the sustainable development goals

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ABSTRACT

The South Asian economies encounter several issues for achieving the Sustainable Development Goals (S.D.G.s), global warming is one of the serious key issues facing these countries. For addressing this issue, a comprehensive policy framework is required at the context of South Asian Countries. In this view, the present study scrutinises the impact of renewable energy-consumption (R.E.C.p.), non-renewable energy consumption (R.E.n.), agriculture (A.g.), urbanisation (U.b.), and economic growth (E.G.) on CO₂ emissions for selected South Asian economies over period of 1990–2018. For this purpose, we apply fully modified ordinary least square technique and variance decomposition analysis. The empirical outcomes demonstrate that R.E.C.p. and agriculture reduces carbon emission while R.E.n. and U.b. increase environmental degradation. Moreover, the findings also confirm the E.K.C.-hypothesis in South Asian countries. Based on the results, a detailed S.D.G.-oriented policy framework has been suggested, which may help these economies towards achieving the main goals of S.D.G. 13, S.D.G. 07, S.D.G. 08, S.D.G. 11, and S.D.G. 02. This study contributes to the present literature by suggesting S.D.G. oriented policy framework.

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1. Introduction

After the approval of Sustainable Development Goals (S.D.G.s) by the United Nations in 2015 (Cf, 2015), all the countries are working to fulfill the S.D.G.s by 2030. While the developing countries of Asia are still some way off from implementing that S.D.G.s. To achieve the S.D.G.s, the developing Asian countries face a number of challenges, the most serious of which is environmental pollution (Sun et al., 2021). A growing consensus has emerged over the past few decades between scientists,

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environmental and energy scholars about the threatening effects of global warming on the quality of the environment and human health for upcoming generations (Anwar, Siddique et al., 2021; Awodumi & Adewuyi, 2020; Lingyan et al., 2021). Several researchers have emphasized that there should be a substantial decline in greenhouse gas emissions (G.H.G.), which is one of the critical sources of global warming, to keep away from global environmental catastrophe (Chien et al., 2021). Stern et al. (2006) pointed out that if no effort is made to reduce the alarming and ever-increasing amount of G.H.G., then there is a possibility that G.H.G. concentration in the atmosphere would be doubled its pre-industrial level till 2035, and the global average temperature increase of more than 2 °C (Sharif et al., 2020; Stern et al., 2006). This warning about the alarming condition was verified in 2016 by the Paris Agreement conference (2016); according to this conference, if no reasonable effort were made to reduce G.H.G. emissions, the global temperature would reach over 2 °C (Zhuang et al., 2021; Ling et al., 2021). Many environmental experts and institutions believe that it will be very thought-provoking if global temperature crosses this threshold level and will harshly affect human life (Ahmad et al., 2021; Deschenes, 2014; Sj).

In environmental literature, several empirical studies suggested that the rapid increase in G.H.G., especially CO₂ emissions (CO₂E) is the leading source of G.H.G. (Adedoyin et al., 2020; Salem et al., 2021). According to the Intergovernmental Panel on Climate Change (I.P.C.C.) report, the use of fossil fuels in industrial processes is responsible for 65% of CO₂ emissions in worldwide G.H.G. emissions (IPCC, 2014). Numerous studies suggested that energy consumption has a progressive influence on G.H.G. emanation (Anwar, Sharif et al., 2021; Salahuddin et al., 2018). In contrast, some studies documented that the energy conservative policies for improving environmental quality can reduce economic growth (Destek & Aslan, 2017; Salem et al., 2021). Therefore, all the countries face the challenge of formulating a suitable policy for sustainable development, which maintains the pace of growth and minimises environmental degradation (Nizetic et al., 2019; Sharif et al., 2021).

To tackle the problem of CO₂E, the green economy concept is presently attaining popularity among emerging economies (Nguyen et al., 2012). Several studies proved that renewable energy-consumption (R.E.C.p.) negatively influences carbon emanation (Sarkodie et al., 2020; Sharif et al., 2019). Moreover, few researchers claimed that unidirectional causality existed from green energy to CO₂ emanation (An et al., 2021; Khan et al., 2018; Nathaniel & Iheonu, 2019). An increase in urbanisation (U.b.) is related to industrial growth and technological progress, leading to migration and globalisation (Liddle, 2013). In the experience of modernisation and industrialisation, the demand for resources, i.e., Coal, steel, cement, timber, and iron, increases energy demand (Shen et al., 2005). When commercialisation starts, this modifies urban structure, encourages financial development, stimulates the need for raw material, speeds up migration of labourers from rural to urban sectors, and boosts economic growth (Anwar, Sinha et al., 2021; Shahzad et al., 2021). Several examinations, for instance, Zhang et al. (2015), Liddle (2013) pointed out that U.b. has a direct impression on CO₂ emissions. While Yao et al. (2018) suggest that U.b. is progressively linked with the environment.

The agriculture sector plays a central role in fulfilling the requirement of food for the masses. It also a significant source of economic growth (Funk & Brown, 2009).

Numerous studies have pointed out that the agriculture sector causes carbon emissions by releasing a substantial amount of G.H.G.s into the air that is augmented by land management (Johnson et al., 2007; Salem et al., 2021; Timilsina et al., 2019). On the other hand, few studies found a negative link between agriculture activities and CO₂E (Jebli & Youssef, 2017; Rafiq et al., 2016).

Figure 1 depict the trends of the time series data which we utilized to discover the connection between CO₂-emission, economic-growth (E.G.), U.b., energy-consumption (E.C.), non-renewable energy-consumption (R.E.n.) and agricultural productivity among the South Asian countries including: Pakistan, India, Sri Lanka, Bangladesh, and Nepal. All these economies are developing and in the process of conversion to development and industrialisation. For meeting the process of industrialisation, every developing country increases their energy-consumption multiple times. Though, the initial development stage of these countries is very important to study to understand their previous CO₂-emission pattern.

The aim of this study is to recommend the S.D.G.-oriented policy framework for Asian developing economies. For this purpose, this article investigates the dynamic relationship and causal connections among CO₂ emissions and R.E.C.p., R.E.n., U.b., A.g.-value added and E.G. for S.S.A. countries. The contribution of this study in existing literature is four-fold, First, as most of the existing literature utilises the cumulative energy consumption in their models and in this way neglects to recognise the separate effect of renewable as well as R.E.n.. The significance of this article lies at the core of considering both renewable and R.E.n. utilisation so we can distinguish the overall impact of each on CO₂ emission. Secondly, this study is using the fully modified ordinary least squares (F.M.O.L.S.) technique which may eliminate the issue of endogeneity in panel regression and also have ability to overcome the auto-correlation problems (Hu et al., 2018), which has been commonly viewed as better than the customary O.L.S. (Salahuddin et al., 2015). Thirdly, this study investigates country wise separate impact of underlying variables on CO₂ emission. So, the policy-makers may suggest a policy for a specific country in the light of empirical results of that country. Fourthly, the absence of significant definitive proof of the Environmental-Kuznets-Curve (E.K.C.) hypothesis and previously mentioned clarifications of the mixed existing empirical evidence inspire us to empirically re-examine the association between economic growth and environmental degradation in these economies. From empirical output of this study, we suggest policy implications to S.S.A. countries for achieving the S.D.G.s considering: goal no. 13 (Climate Action), S.D.G. goal no. 07 (Affordable and Clean Energy), S.D.G. goal no. 08 (Economic Growth), S.D.G. goal no. 11 (Sustainable Cities), and S.D.G. goal no. 02 (Sustainable Agriculture).

The second section discusses the literature review. Data and methodology are presented in section three and section four provides the results of our study. Section five presents the conclusion and policy implications of this study.

2. Literature review

There is a global consensus on the importance of sustainability in the planet and consumption of the available resources especially in the developing nations. At this brief,

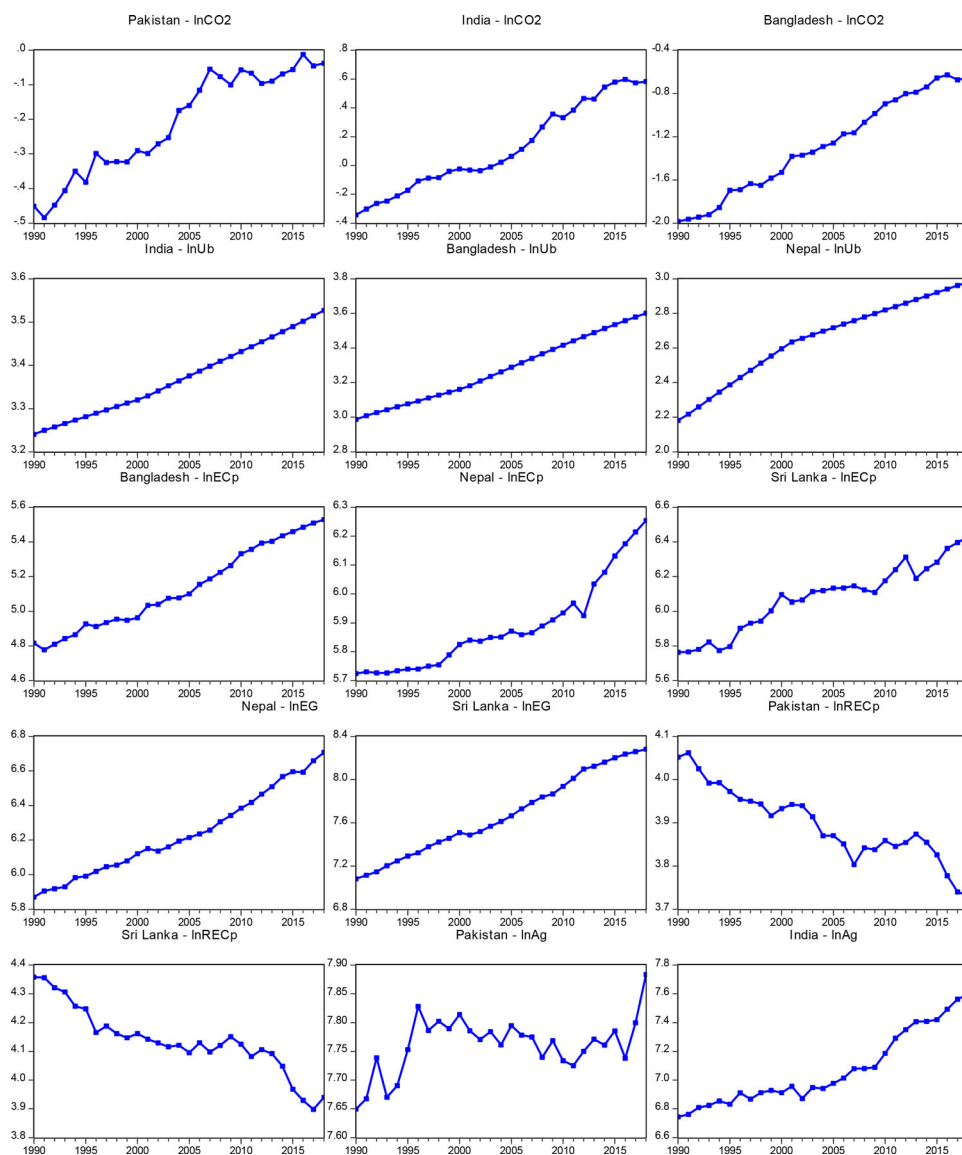


Figure 1. Trend in the variables.

Source: Authors' estimation.

it is imperative to remember that South Asian Economies were late in implementing Millennium Development Goals, however the last decades data and indicators regarding economic development, poverty reduction, unemployment, and G.D.P. in many Asia country shows positive move forward. The 17 S.D.G.s were addressed in the context of 169 targets in which some Asia countries could not efficiently focus on all targets because of structural and pressing needs. According to Khemka and Kumar (2020), the S.D.G.s are an enabling framework for action not just a static template. The South Asian countries including Bangladesh, India, Nepal and Pakistan account for approximately 30 percent of the world's population and a third of the world's poor. In fact, most of South Asian countries are not on track to meet S.D.G.s, or

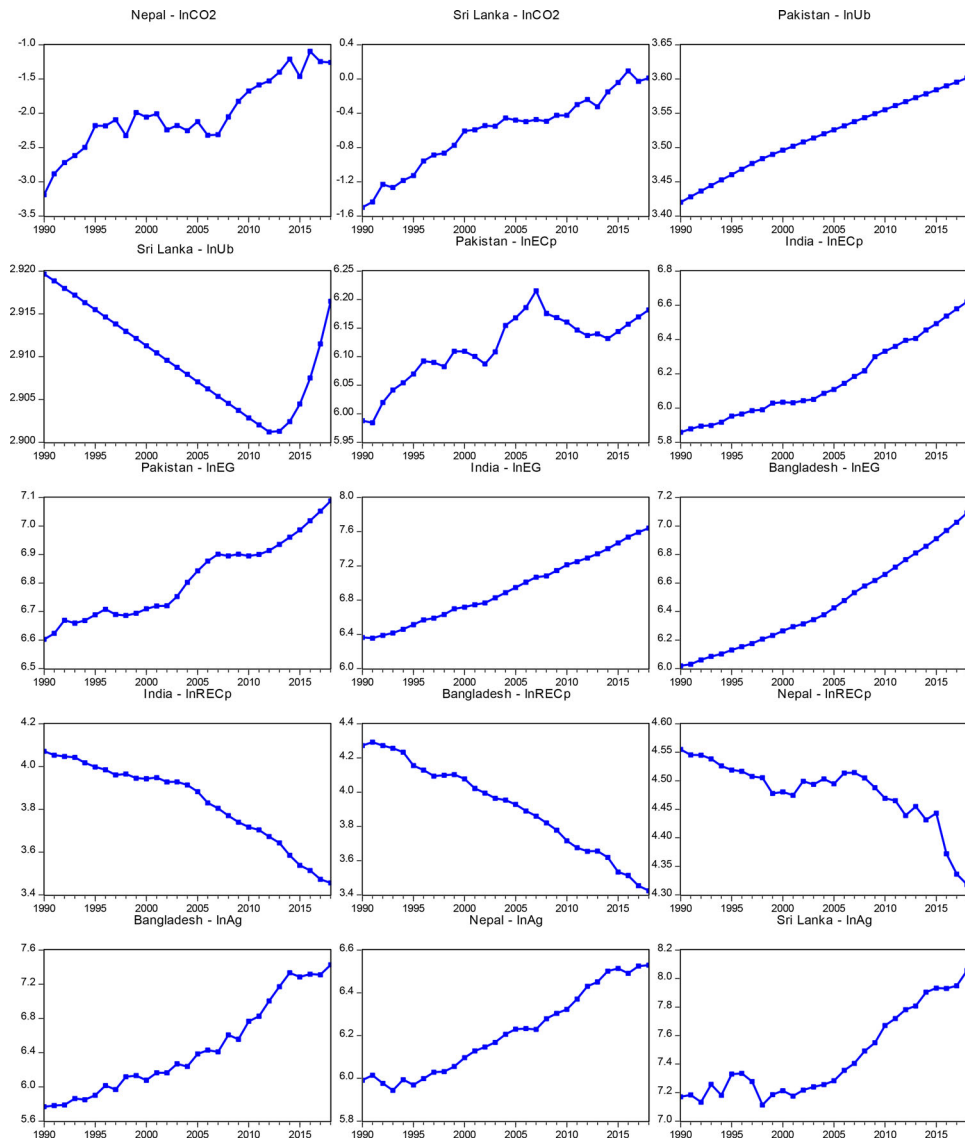


Figure 1. Continued

even no progress, and very inadequate progress on S.D.G. 13 (climate action) and S.D.G. 7 (affordable and clean energy). Meeting S.D.G.s is not a task for government while Servaes (2017) highlights a core goal of sustainable development concerning encouraging and convincing human beings to live in harmony with their environment not to control or destroy it but to preserve it accordingly. Based on what Sachs (2015) pointed out that the economic, social, and environmental objectives of the S.D.G.s would be only achieved if governments focus on the fourth objective as good governance to enable societies to prosper. *The Plundered Planet*, by Paul Collier (2010), stated that technology turns nature into an asset, while confirming that nature is priceless to point to the importance of protecting natural assets.

In the Sustainable Development Report 2021, Sachs et al. (2021) have addressed the significance of energy decarbonisation and energy transformation to assure universal access to modern energy sources, and targeting decarbonising energy system, while showing the necessity of government commitments for integrating the principle of climate neutrality in the national law and policies. There are numerous studies, which discussed the different indicators of S.D.G. (e.g. Anwar, Sinha et al., 2021; Razzaq et al., 2021; Wang et al., 2021). Global warming is a major hurdle for S.S.A. countries for attaining S.D.G.s. Climate change is a natural process. However, contemporary tendencies regarding climate change are shocking primarily due to anthropogenic causes. Khanal (2009) claimed that climate change inversely affects people, their ecosystem and livelihood. It is also a development challenge for the poor people of low-income countries as well as for the general global community. This article elaborates on the cause and effect of relationships among the E.C.p., U.b. and CO₂E. Anwar, Sinha et al. (2021) highlighted that U.b. plays an important role to influence the CO₂-emission in Asian (European) economies (Al-Mulali et al., 2015). Hossain, (2011) argued the analogous results in their respective research on the U.S.A. and selected newly industrialised countries. Jun et al. (2021) and Anwar, Sharif et al. (2021) suggested that E.C.p., U.b. and E.G. are the major cause of CO₂E. Furthermore, U.b. increases the E.C.p. which is mostly in the shape of non-renewable energy in developing countries, so it becomes a cause of CO₂E (Sharif et al., 2020).

Poumanyong et al. (2012) discovered that U.b. requires more transportation which leads to an increase in more energy-consumption (Zhang et al., 2021). In their study, Al-Mulali et al. (2012) discovered a long-run correlation between U.b., E.C.p. and CO₂E. Similarly, O'Neill et al. (2012) examined that the rapid U.b. augmented new labour supply, which led to boost largely E.C.p. and affected CO₂E in China. Besides, Zhu et al. (2012) found the inverted U-Curve association between CO₂-emission and U.b. among the 20-developing countries.

Bryant (2013) writes that the increase in U.b. is related to the pace of industrial growth and technological progress which may lead to migration and globalisation. The process of U.b. requires more agricultural output for food in urban and rural areas as well (Kalnay & Cai, 2003). In the experience of modernisation and industrialisation, the demand for resources, i.e., coal, steel, cement, timber and iron, increases, which lead to increased energy demand (Shen et al., 2005). When the process of commercialisation starts, this modifies urban structure, encourages financial development, stimulates need of raw material, speeds up migration of labour from rural sector to urban sector and boosts E.G. of the country (Madlener & Sunak, 2011; Sadorsky, 2013).

3. Data and methodology

3.1. Data

Secondary data is obtained to estimate the relationship among variables in this research study. This study explores the influence of U.b., R.E.C.p., E.C.p., A.g. and E.G. on CO₂E in selected south Asian economies. The required data is assembled for the period of 1990 to 2018 from World Development Indicators (W.D.I.) by World Bank (2021).

3.2. Model specification

We utilized the E.K.C.-framework proposed by Grossman and Krueger (1995), by using CO₂-emission as a dependent variable and U.b., R.E.C.p., non-energy-consumption (E.C.p.), agriculture (A.g.) as independent variables. Functionally, we can formulate above relationship as;

$$CO_2 = f(Ub, ECp, EG, EG^2, RECP, Ag) \quad (1)$$

where U.b. is calculated as percentage (%) of total population, R.E.C.p. as a percentage of total energy-consumption, total energy-consumption in kilogram of oil equivalent per capita, agriculture value added per worker (constant = 2010 \$) and E.G. percentage increase in real per capita G.D.P. (constant = 2010 \$). Our estimated model is as follows:

$$CO_{2it} = \beta_0 + \beta_1 Ub_{it} + \beta_2 ECp_{it} + \beta_3 EG_{it} + \beta_4 EG^2_{it} + \beta_5 RECP_{it} + \beta_6 Ag_{it} + \varepsilon_{it} \quad (2)$$

3.3. Estimation procedure

3.3.1. Unit root test

The unit-root test is widely used to reflect the usual measure in time-series analysis (Anwar, Sinha et al., 2021; Chang, 2010). Normally, the individual unit-root tests are unable to elaborate the determinants of each cross-sectional regression error. Therefore, following are the null (H₀) and alternative (H₁) hypotheses suggested by Levin-Lin-Chu (L.L.C.) unit root test; Null hypothesis (H₀); each time-series has non-stationary properties, whereas H₁ assumes that each time series is stationary. Furthermore, the lag operator (ohm- Ω) is Ω used to allow the dissimilarity across the cross sections. Lastly, the aforementioned procedure is trailed in the following steps:

Step-1; Augmented-Dickey-Fuller (ADF) test is helpful for separate cross sections in the following way:

$$\Delta \ddot{Y}_{i,t} = \alpha_{0i} + \Omega y_{i,t-1} + \sum_{L=1}^{pi} \theta_{iL} \Delta \ddot{Y}_{i,t-L} + \beta_{mid_{m,t}} + u_{it} \quad (1)$$

Since $i = 1$ to N and $t = 1$ to T

Step-2 utilises the two auxiliary regression equations:

1. $\Delta \ddot{Y}_{i,t}$ on $\Delta \ddot{Y}_{i,t-L}$ and $\zeta_{m,t}$, and get estimated residual $\acute{\epsilon}_{it}$ and,
2. $y_{i,t-1}$ on $\Delta \ddot{Y}_{i,t-L}$ and $\zeta_{m,t}$, and acquire residual $\hat{v}_{i,t-1}$.

In step-3, we obtain standardised-residuals by applying:

$$\acute{\epsilon}_{i,t} = \acute{\epsilon}_{i,t} / O_{Uit} \quad (2)$$

$$\hat{v}_{i,t-1} = \hat{v}_{i,t-1} / O_{Uit} \quad (3)$$

O_{Uit} represents the standard-error (S.E.) of each A.D.F.-tests

Finally, the augmented pooled-O.L.S. is run as:

$$\hat{e}_{i,t} = \Omega \hat{v}_{i,t-1} + U_{it} \tag{4}$$

The null hypothesis is $\Omega=1$. So, Levin et al. (2002) argue to make some adjustment for getting required values of t-statistics. For this purpose, the sufficient conditions are to be fulfilled such that $\sqrt{\frac{NT}{T}} \rightarrow 0$ and $\sqrt{\frac{NT}{T}} \rightarrow k$. Literature has witnessed that the L.L.C.-test is appropriate for large panels i.e.5 ... 250 in case of T and from 10 ... 250 in terms of N. If the panel is undersized, the smaller value of T will show the smaller power of the unit root while the larger value of T is useful to elaborate the separate unit root for each cross section. Along with the above-mentioned advantages of L.L.C., there are some disadvantages of this test. One of the drawbacks is that its null hypothesis restricts the perception that all cross sections have unit root problems whereas several have not. Another disadvantage of the L.L.C. test is that this test considers the all-cross sections autonomously. Therefore, we also employ the Breitung-Panel Unit to detour the weaknesses of the L.L.C. test. Moreover, this test is also useful to predict non-stationary panels (Breitung, 2002).

3.3.2. Panel cointegration test

Literature advocates that the development of co-integration to panel data is common in time-series econometrics. Pedroni (1999) and Pedroni (2004) recommend seven differentiated test-statistics to test co-integration (long-run association) in heterogeneous panels. These suggested-tests are presumed to rectify the biases in endogenous regressors. These tests are also termed as between and within dimension-statistics (Pedroni, 2004). The difference between these two are as follows: between-dimensions-statistics consider the group mean panel co-integration, whereas, within dimensions statistics only consider the panel cointegration (Razzaq et al., 2021a). Moreover, Engle and Granger (1987) proposed a two steps procedure to elaborate the cointegration test. For this purpose, the seven-phase approach is useful to track the residuals.

Finally, the suggested-model illustrates the required-test equation:

$$X_{i,t} = \alpha_{0i} + \hat{C}_i t + \beta_{1i} z_{1i,t} + \dots + \beta_{mi} z_{mi,t} + \mathfrak{m}_{it} \tag{5}$$

For, $i = 1 \dots N$; $t = 1 \dots T$; $\mathfrak{m} = 1 \text{ to } M$

where, T, N and M represent total observations, total cross-sectional units, and total number of regressors in the panel respectively. α_{0i} is termed as fixed effects which oscillate across the individual cross-sectional. This method is useful for slope-coefficients (h_{it}) in the third step.

In second step, the differences of each cross-section are estimated to obtain the residuals of separate regression:

$$DX_{i,t} = q_{1i}DZ_{1i,t} + \dots + q_{mi}DZ_{mi,t} + h_{it} \tag{6}$$

In third step, we obtain the long-run variance ($\square^2_{11,i}$) from residuals (h_{it}).

The step four is employed to acquire appropriate auto-regressive (A.R.) model by exhausting residuals (\mathfrak{m}_{it}) of actual co-integration.

At the end, the seven panel cointegration tests with appropriate means and variances are executed as follow:

1. Panel v-statistics:

$$Z_{v,N \& T} = T\sqrt{N^3 2} \left(\sum_{i=1}^N \sum_{t=1}^T \delta_{11i}^{-2} \mu_{it-1}^2 \right)^{-1}$$

2. Panel rho(p)-statistics:

$$Z_{p, N, T} = Z_{p, N, T} = T^2 \sqrt{N^3} \left(\sum_{i=1}^N \sum_{t=1}^T \delta_{11i}^{-2} \mu_{it-1}^2 \right)^{-1} \sum_{i=1}^N \sum_{t=1}^T \delta_{11i}^{-2} (\mu_{it-1}^1 \Delta \mu_{it} - \gamma_i)$$

3. Panel nonparametric t-statistics:

$$Z_{p, N, T} = \left(\sigma^2 \sum_{i=1}^N \sum_{t=1}^T \delta_{11i}^{-2} \mu_{it-1}^2 \right)^{-\frac{1}{2}} \sum_{i=1}^N \sum_{t=1}^T \delta_{11i}^{-2} (\mu_{it-1}^1 \Delta \mu_{it} - \gamma_i)$$

4. Panel-parametric t-statistics:

$$z^* t, N, T = \zeta_{N, T}^2 \left(\sum_{i=1}^N \sum_{t=1}^T \delta_{11i}^{-2} \mu_{it-1}^2 \right)^{-\frac{1}{2}} \sum_{i=1}^N \sum_{t=1}^T \delta_{11i}^{-2} (\mu_{it-1}^1 - \Delta \mu^* it)$$

5. Grouped rho (p)-statistics:

$$Z_{p, N, T} = \frac{T}{N^{\frac{1}{2}}} \sum_{i=1}^N \left(\sum_{t=1}^T \mu_{it-1}^2 \right)^{-1} (\mu_{it-1}^1 \Delta \mu_{it} - \gamma_i)$$

6. Grouped nonparametric t-statistics:

$$Z_{p, N, T} = \frac{1}{N^{\frac{1}{2}}} \sum_{i=1}^N \left(\sigma_i^2 \sum_{t=1}^T \mu_{it-1}^2 \right)^{-\frac{1}{2}} \sum_{t=1}^T (\mu_{it-1}^1 \Delta \mu_{it} - \gamma_i)$$

7. Grouped parametric t-statistics:

$$Z_{p, N, T} = \frac{1}{N^{\frac{1}{2}}} \sum_{i=1}^N \left(\sum_{t=1}^T \theta^2 \mu_{it-1}^2 \right)^{-1/2} \sum_{t=1}^T (\mu_{it-1}^1 \Delta \mu_{it})$$

where: $\gamma_i = (\sigma_i^2 - \theta^2)/2$ and $\theta^{*2}_{N,T} = 1/N \sum_{i=1}^N \theta^{*2}$

The following augmented term for mean and variances are utilised to comply with asymptotic distribution $(Y_{N,T} - \mu) / \Rightarrow \dot{N}(0, 1)$.

Here, $Y_{N,T}$ represents the consistency form of \dot{N} and T statistics. μ and V show Brownian Motion Movement-Functions (B.M.M.F.). This function assumes the null-hypothesis i.e., (H_0 : no cointegration) or as H_0 : $\rho_i = 1$, and $1 < \square i < \dot{N}$

Alternative hypothesis (H_1 : existence of cointegration) for all panel test-statistics is H_1 : ρ_i less than 1, and $\square i = 1 \dots \dot{N}$.

Similarly, the alternative hypothesis (H_1) is H_1 : $\rho_i = \rho$ less than 1, $\square i = 1 \dots \dot{N}$

3.3.3. Panel cointegration estimations

The co-integration test is helpful to check the long-run relationship among the variables. Since, fixed-effect (F.E.) and random-effect (R.E.) and Generalised Method of Movement (G.M.M.) may produce misleading and inappropriate in panel data. Therefore, fully modified ordinary least squares (F.M.O.L.S.) is suggested by Pedroni

(2001) to avoid this problem. F.M.O.L.S. method estimates consistent coefficients in smaller-samples. Moreover, this may not undergo large-size disturbances in the existence of endogeneity dynamics. Hence, panel F.M.O.L.S. estimator for the slope-coefficient (β) is represented as:

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

where:

$$Z_{it}^* = (z_{it} - Z) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \Delta y_{it}.$$

$$\hat{\eta}_i \equiv \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^0 - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \left(\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^0 \right)$$

\hat{L}_i represents the lower triangle decomposition of ($\hat{\Omega}_i$)

Thus, the relevant t-statistic generates:

$$t_{\hat{\beta}}^* = N^{-1/2} \sum_{i=1}^N t_{\hat{\beta},i}^*.$$

And

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

4. Results and discussion

Table 1 depicts the outcomes of descriptive statistics, which shows mean values of lnCO_{2it}, lnU.b., lnE.C.p., lnE.G., lnR.E.C.p., and lnA.g. as -0.800, 3.144, 5.874, 6.821, 4.051 and 6.988 respectively, similarly the maximum values of these indicators are as follows: 0.597, 3.601, 6.620, 8.280, 4.555 and 8.056 respectively.

The panel unit-root test is employed to confirm that all the examined variables are stationary at level (I_0) or first difference (I_1) before proceeding to the cointegration

Table 1. Descriptive statistics.

	lnCO _{2it}	lnUb _{it}	lnEcp _{it}	lnEG _{it}	lnREcp _{it}	lnAg _{it}
Mean	-0.800	3.144	5.874	6.821	4.051	6.988
Minimum	-3.191	2.180	4.778	5.870	3.424	5.768
Maximum	0.597	3.601	6.620	8.280	4.555	8.056
Median	-0.497	3.240	6.004	6.717	4.021	7.112
Kurtosis	2.412	2.651	3.345	2.790	2.332	1.724
Skewness	-0.569	-0.631	-1.048	0.612	0.052	-0.250
Std. Dev.	0.864	0.350	0.427	0.584	0.287	0.665
Observations	145	145	145	145	145	145

Source: Authors' estimation.

Table 2. Panel unit-root test-L.L.C.

Variables	At-Level				At 1 st -Difference			
	Const & Trend	Prob-value	Const.	Prob-value	Const & Trend	Prob-value	Const.	Prob-value
lnCO _{2it}	0.091	0.536	-1.763	0.138	-9.691	0.000	-10.609	0.000
lnECp _{it}	0.264	1.000	4.195	1.000	-9.747	0.000	-9.716	0.000
lnRECP _{it}	0.938	0.825	4.402	1.000	-6.112	0.000	-6.306	0.000
lnEG _{it}	0.748	0.772	5.359	1.000	-6.049	0.000	-5.288	0.000
lnUb _{it}	-2.335	0.009	-	-	-	-	-	-
lnAg _{it}	-0.439	0.330	3.076	0.999	-7.785	0.000	-8.844	0.000

Source: Authors' estimation.

Table 3. Co-integration tests.

A. Johansen-Fisher Co-integration Test.				
Tests	Fisher Stat.* (from Trace-test)	Prob-value	Fisher Stat.* (from max Eigen-test)	Prob-value
None (At most)	172.2	0.000	87.21	0.000
1	90.61	0.000	32.54	0.000
2	61.92	0.000	25.82	0.004
3	41.44	0.000	18.90	0.041
4	29.52	0.001	17.91	0.056
5	21.36	0.018	21.36	0.018
6	172.2	0.000	87.21	0.000
B. Kao residual cointegration test.				
	t-Statistic			Prob-value
Augmented Dickey-Fuller (ADF)	-3.475			0.000
C. Pedroni (2004) panel cointegration test results.				
Test (Panel)	Statistic	Prob-value	Statistic	Prob-value
rho-Stat	-1.033	0.150	0.640	0.739
ADF-Stat	-4.643	0.000	-3.364	0.000
PP-Stat	-4.863	0.000	-4.908	0.000
v-Stat	1.227	0.109	-1.872	0.969
Alter-hyp: individual-AR coefficients				
Tests		Statistic		Prob-value
ADF-Statistic		-2.669		0.003
PP-Statistic		-4.747		0.000
rho-Statistic		1.119		0.868

Source: Authors' estimation.

test. It comforts to evade the issue of spurious regression. Table 2 shows the findings of the Levin et al. (2002) unit-root test and it is clear from the results that U.b. is stationary at (I_0) and remaining all variables are at (I_1).

The result of the unit root test permits us to proceed to the next step to test long-run association between the variables.

Table 3A–C shows the result of the Pedroni (1999) panel cointegration test. The empirical outcomes verify the presence of long-term equilibrium association among CO₂E, A.g., E.G., E.C.p., R.E.C.p. and U.b. for S.S.A. economies.

The outcomes of Johansen-Fisher co-integration and Kao residual also verify the validity of the results of the Pedroni (1999) co-integration test. The outcomes are similar with the findings of Anwar, Siddique et al. (2021), Anwar, Sharif et al. (2021), Hossain (2011) who use the panel data of different income level economies.

The overall findings of all cointegration tests assist the elementary aim of this research and allow us to explore the long-run association among the variables of the study.

Table 4. F.M.O.L.S. grouped results.

Variables	LNCO _{2it} : Dependent-variable			
	Coefficients	St. Error	t-Stat	Prob-value
LNUb _{it}	0.649	0.272	2.384	0.018
LNECp _{it}	0.435	0.066	6.560	0.000
LNEG _{it}	1.022	0.070	14.420	0.000
LNEG ² _{it}	-0.329	0.050	-6.488	0.000
LNRECP _{it}	-1.114	0.063	-17.471	0.000
LNAg _{it}	-0.061	0.021	-2.807	0.005

Source: Authors' estimation.

The result of the cointegration test verifies the long-run relationship among the variables. Though, it is necessary to explore the long-term elasticity among the variables. F.M.O.L.S. methodology suggested by Pedroni (2001) is applied to estimate unbiased and consistent long-run coefficients.

The results of F.M.O.L.S. tests as a grouped and individual country are shown in the Table 4 and Table 5 respectively. It is clear from the grouped-long-run results that U.b., E.C.p., and E.G. have progressive and significant impact on CO₂E. As 1% rise in Ub raises the CO₂E by 0.649%. This result is similar to the outcomes of Anwar, Sharif et al. (2021), Mahmood et al. (2020) and Anwar, Sinha et al. (2021). This result shows that the U.b. pattern in S.S.A. countries is unsustainable, as expanding the urban infrastructure increases the pressure on the environment in terms of CO₂ emissions.

In case of energy consumption, a 1% rise in E.C.p. increases CO₂E by 0.435%, these results support the findings of Jun et al. (2021), Anwar, Siddique et al. (2021) and Javid and Sharif (2016). The high value of the coefficient of E.C.p. represents that S.S.A. countries majorly depend on fossil fuel energy which continuously increases the environmental pollution in these countries. Similarly, 1% rise in E.G. raises the level of CO₂E by 1.01%. This result is similar to the finding of The-Phan et al. (2021), Chien et al. (2021), Anwar, Malik et al. (2021) and Habiba et al. (2021), who argued that economic activities increase the demand of energy; therefore, more use of fossil fuel energy increases the CO₂ emissions. While the negative and significant sign of the coefficient of E.G.² depict the presence of E.K.C.-hypothesis in S.S.A. countries which postulate that after a certain level the further economic growth will be to reduce the environmental pollution.

Whereas R.E.C.p. reduces environmental deterioration, as 1% increase in R.E.C.p. leads to decrease CO₂E by 0.1.144%. This result is in line with Khattak et al. (2020), Cheng et al. (2019), who stated that R.E.C.p. reduces the CO₂E; therefore, the governments of S.S.A. countries should increase the portion of renewable energy in total energy consumption as a plan to target the S.D.G.s goals. Moreover, agricultural productivity also reduces environmental pollution. A 1% increase in A.g. decreases CO₂E by -0.061%. The negative value of the coefficient of A.g. shows the efforts of S.S.A. countries for sustainable agriculture. It is witnessed that E.C.p. and U.b. are key contributors to environmental-degradation. The square of G.D.P. (E.G.²) has a significant influence on CO₂E that shows the existence of the E.K.C. in the S.S.A. economies.

Table 4 shows the country wise results of the selected South Asian countries. The empirical outcome demonstrates that in Pakistan, E.G., U.b., E.C.p. are positively

Table 5. Country specific F.M.O.L.S. results.

Dependent variable: $\ln\text{CO}_{2it}$				
Economy/Variable	Coefficient	t-Stat	St. Error	Prob. Value
Pakistan				
$\ln\text{EG}_{it}$	0.236	3.355	0.070	0.0038
$\ln\text{Ub}_{it}$	4.281	21.49	0.199	0.0000
$\ln\text{ECp}_{it}$	1.428	6.156	0.232	0.0000
$\ln\text{RECp}_{it}$	-0.101	-2.385	0.262	0.0348
$\ln\text{Ag}_{it}$	-0.331	-4.724	0.070	0.0002
Constant	-10.826	-3.869	2.797	0.0012
India				
$\ln\text{EG}_{it}$	0.997	5.705	0.174	0.0000
$\ln\text{Ub}_{it}$	-1.229	-1.583	0.776	0.1317
$\ln\text{ECp}_{it}$	0.811	2.508	0.415	0.0176
$\ln\text{RECp}_{it}$	-0.684	-1.870	0.365	0.0787
$\ln\text{Ag}_{it}$	-0.040	-0.559	0.072	0.5833
Constant	12.907	3.384	3.813	0.0035
Bangladesh				
$\ln\text{EG}_{it}$	-0.866	-4.441	0.195	0.0004
$\ln\text{Ub}_{it}$	2.525	7.371	0.342	0.0000
$\ln\text{ECp}_{it}$	0.706	2.390	0.246	0.0320
$\ln\text{RECp}_{it}$	-1.504	-6.774	0.222	0.0000
$\ln\text{Ag}_{it}$	-0.166	-2.468	0.067	0.0244
Constant	14.284	7.539	1.894	0.0000
Nepal				
$\ln\text{EG}_{it}$	3.595	9.881	0.363	0.0000
$\ln\text{Ub}_{it}$	0.459	3.118	0.147	0.0062
$\ln\text{ECp}_{it}$	0.213	0.600	0.355	0.5561
$\ln\text{RECp}_{it}$	-6.901	-13.276	0.519	0.0000
$\ln\text{Ag}_{it}$	-3.615	-7.604	0.475	0.0000
Constant	36.460	13.191	2.763	0.0000
Sri Lanka				
$\ln\text{EG}_{it}$	0.376	2.059	0.183	0.0551
$\ln\text{Ub}_{it}$	-11.893	-1.575	7.550	0.1336
$\ln\text{ECp}_{it}$	0.857	5.995	0.142	0.0000
$\ln\text{RECp}_{it}$	-1.509	-7.783	0.193	0.0000
$\ln\text{Ag}_{it}$	-0.132	-1.408	0.094	0.1769
Constant	42.995	1.862	23.088	0.0800

Source: Authors' estimation.

associated with CO_2E , where 1% rise in E.G., U.b. and E.C.p. augment CO_2E by 0.23%, 4.28% and 1.43% respectively. On the contrary, R.E.C.p. and A.g. impede environmental pollution by 0.10% and 0.33% respectively.

In the case of India, E.G. and E.C.p. have a direct link with environmental deterioration, where 1% rises in E.G. and E.C.p. lead to an increase 0.99% and 0.81% in CO_2E . However, R.E.C.p. is negatively associated with CO_2E . As 1% intensification in R.E.C.p. reduces CO_2E by 0.68%. A.g. and U.b. have insignificant impact on environmental pollution. For Bangladesh, E.C.p. and U.b. increase environmental deterioration. A 1% rise in E.C.p. and U.b. augments CO_2E by 0.7% and 2.5%. And E.G., R.E.C.p. and A.g. are negatively associated with environmental pollution. 1% increase in these three indicators reduces CO_2E by 0.86%, 1.5% and 0.16%, respectively.

In Nepal, E.G. and U.b. are the major contributors of environmental-degradation. A 1% raise in G.D.P. and U.b. increases CO_2E by 3.59% and 0.45%, respectively. However, R.E.C.p. and A.g. reduce environmental pollution. A 1% increase in both of these indicators, reduces CO_2E by 6.9% and 3.9%, respectively. Moreover, in the case of Sri Lanka, E.G. and E.C.p. increase the environmental-degradation. A 1% rise in

Table 6. Variance decomposition analysis.

Period	S.E.	$\ln\text{CO}_{2it}$	$\ln\text{U}_{it}$	$\ln\text{ECp}_{it}$	$\ln\text{EG}_{it}$	$\ln\text{RECP}_{it}$	$\ln\text{Ag}_{it}$
Variance decomposition of $\ln\text{CO}_{2it}$:							
1	0.084	100.00	0.000	0.000	0.000	0.000	0.000
2	0.106	99.239	0.250	0.011	0.004	0.169	0.323
3	0.137	95.337	0.491	2.307	1.376	0.108	0.378
4	0.158	94.131	0.676	2.479	2.183	0.082	0.447
5	0.180	92.061	0.768	3.118	3.475	0.063	0.512
6	0.199	90.946	0.832	3.307	4.341	0.052	0.519
7	0.217	89.791	0.880	3.579	5.159	0.044	0.544
8	0.233	89.019	0.920	3.718	5.753	0.038	0.549
9	0.248	88.334	0.955	3.862	6.248	0.034	0.563
10	0.263	87.820	0.988	3.962	6.625	0.030	0.572
Variance decomposition of $\ln\text{U}_{it}$:							
1	0.001	7.634	92.365	0.000	0.000	0.000	0.000
2	0.004	9.497	90.344	0.007	0.080	0.058	0.012
3	0.007	11.889	87.501	0.190	0.251	0.111	0.055
4	0.010	13.123	85.908	0.383	0.401	0.114	0.068
5	0.014	14.081	84.674	0.583	0.479	0.106	0.074
6	0.018	14.756	83.801	0.743	0.523	0.095	0.079
7	0.022	15.283	83.125	0.882	0.539	0.085	0.084
8	0.027	15.691	82.604	0.995	0.543	0.075	0.089
9	0.032	16.021	82.185	1.092	0.537	0.067	0.095
10	0.037	16.291	81.845	1.173	0.527	0.060	0.101
Variance decomposition of $\ln\text{ECp}_{it}$:							
1	0.028	15.331	0.408	84.259	0.000	0.000	0.000
2	0.039	19.659	0.365	76.164	0.044	3.560	0.205
3	0.046	23.062	0.296	71.513	0.148	4.084	0.894
4	0.052	25.691	0.567	67.690	0.438	4.353	1.257
5	0.058	27.794	1.051	64.330	0.779	4.242	1.801
6	0.064	29.537	1.755	61.124	1.161	4.074	2.346
7	0.070	30.928	2.622	58.110	1.543	3.827	2.966
8	0.076	32.066	3.615	55.244	1.922	3.563	3.586
9	0.081	32.976	4.687	52.538	2.281	3.293	4.222
10	0.087	33.709	5.808	49.981	2.622	3.031	4.845
Variance decomposition of $\ln\text{EG}_{it}$:							
1	0.017	1.900	1.550	8.303	88.245	0.000	0.000
2	0.029	4.184	0.917	5.027	87.685	0.903	1.281
3	0.040	4.012	1.186	3.016	88.761	0.896	2.125
4	0.050	4.083	1.665	1.981	88.685	0.768	2.815
5	0.060	4.174	2.202	1.459	88.102	0.636	3.424
6	0.069	4.358	2.778	1.130	87.196	0.531	4.004
7	0.078	4.552	3.393	0.915	86.127	0.442	4.568
8	0.087	4.771	4.029	0.761	84.964	0.371	5.101
9	0.095	4.994	4.676	0.648	83.752	0.313	5.614
10	0.103	5.220	5.325	0.561	82.523	0.267	6.101
Variance decomposition of $\ln\text{RECP}_{it}$:							
1	0.022	11.268	0.281	2.406	0.273	85.769	0.000
2	0.032	12.653	0.757	1.463	0.315	84.804	0.005
3	0.041	13.376	1.990	1.685	0.190	82.753	0.003
4	0.048	14.237	3.601	1.712	0.155	80.282	0.010
5	0.055	15.315	5.283	1.927	0.232	77.200	0.041
6	0.061	16.284	7.064	2.003	0.348	74.143	0.154
7	0.068	17.240	8.895	2.106	0.529	70.909	0.318
8	0.074	18.100	10.74	2.150	0.726	67.715	0.558
9	0.079	18.902	12.584	2.187	0.946	64.538	0.839
10	0.085	19.619	14.384	2.200	1.169	61.457	1.168
Variance decomposition of $\ln\text{Ag}_{it}$:							
1	0.052	0.000	0.029	0.256	4.137	5.782	89.793
2	0.064	0.040	0.147	1.395	5.764	4.833	87.817
3	0.080	0.088	1.180	1.927	7.780	6.221	82.802
4	0.092	0.069	2.690	2.271	9.751	6.737	78.479
5	0.103	0.105	4.781	2.365	11.409	7.535	73.802

(continued)

Table 6. Continued.

Period	S.E.	$\ln\text{CO}_{2it}$	$\ln\text{U}_{it}$	$\ln\text{EC}_{pit}$	$\ln\text{EG}_{it}$	$\ln\text{REC}_{pit}$	$\ln\text{Ag}_{it}$
6	0.113	0.260	7.391	2.507	12.876	8.051	68.912
7	0.123	0.519	10.388	2.580	14.096	8.573	63.842
8	0.134	0.895	13.633	2.646	15.126	8.955	58.741
9	0.144	1.352	16.986	2.680	15.961	9.275	53.742
10	0.155	1.874	20.338	2.701	16.633	9.504	48.946

Cholesky Ordering: $\ln\text{CO}_{2it}$ $\ln\text{U}_{it}$ $\ln\text{EC}_{pit}$ $\ln\text{EG}_{it}$ $\ln\text{REC}_{pit}$ $\ln\text{Ag}_{it}$.

Source: Authors' estimations.

G.D.P. and E.C.p. augments CO_2E by 0.37% and 0.85%, respectively. On the contrary, R.E.C.p. has adverse effects on CO_2E . A 1% increase in R.E.C.p. reduces CO_2E by 1.5%.

In this study, Vector autoregression (V.A.R.) analysis is simulated and that method explores the causal correlation between CO_2E , U.b., E.C.p., R.E.C.p. and E.G. The results of V.A.R. are reported in Table 6. The calculation covers the period 1990–2018. Decomposition analysis of CO_2E shows that 87.820% change in CO_2E added due to its own shocks and 0.988%, 3.962%, 6.625%, 0.030%, and 0.572% added by U.b., E.C.p., E.G., R.E.C.p., and Ag respectively. It suggests that in the S.S.A. countries, the major contributor of CO_2E is E.C.p., E.G. and U.b. Likewise, E.C.p. is 49.981% and is self-contributed, and 33.709%, 5.808%, 2.622%, 3.031%, and 4.845% is added by the CO_2E , U.b., E.G., R.E.C.p., and A.g., respectively. While R.E.C.p., E.G., U.b. and A.g. is typically contributed to by CO_2E , as R.E.C.p. (19.619%), E.G. (5.220%), U.b. (16.291%) and A.g. (1.874%), whereas self-contributed was 61.457%, 82.523%, 81.845%, 48.946%, individually.

Moreover, F.E.V.D.M. results of $\ln\text{CO}_{2it}$, $\ln\text{U}_{it}$, $\ln\text{REC}_{pit}$, $\ln\text{EC}_{pit}$, $\ln\text{EG}_{it}$, and $\ln\text{Ag}_{it}$ are estimated. Figure 2 shows the graphical representation of Impulse Response Function (I.R.F.). The dual relationship between the basic variables is featured as an exogenous response. The variance-decomposition analysis (V.D.A.) result is showing consistency with long-run estimates, validating over-all econometric modelling. The separate figure (in the form of graph) represents the I.R.F. of numerical F.E.V.D.M. test results and ensures estimations robust and useful for policymaking.

5. Conclusion and policy recommendations

This study explores the relationship among U.b., EC., R.E.C.p., W.G., A.g. and carbon-emission in selected South Asian emerging economies for the period 1990–2018. For this purpose, we utilized an F.M.O.L.S. technique for long-run results. The empirical outcomes of the F.M.O.L.S. technique concluded that U.b., R.E.n. positively affect the environmental-degradation in the long-run. While R.E.C.p. and A.g. reduce environmental-degradation. The results of F.M.O.L.S. also confirm the E.K.C.

The basic aim of this study is to suggest the comprehensive policy framework for attaining S.D.G. no. 13, S.D.G. no. 07, S.D.G. no. 08, S.D.G. no. 11, and S.D.G. no. 02. The empirical outcomes suggest that U.b. increases the carbon emissions in S.S.A. economies. U.b. increases the industrialisation process as well. In developing countries like the South Asian region, many industries use outdated machinery and traditional energy sources, which are the leading cause of environmental deterioration.

Accumulated Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

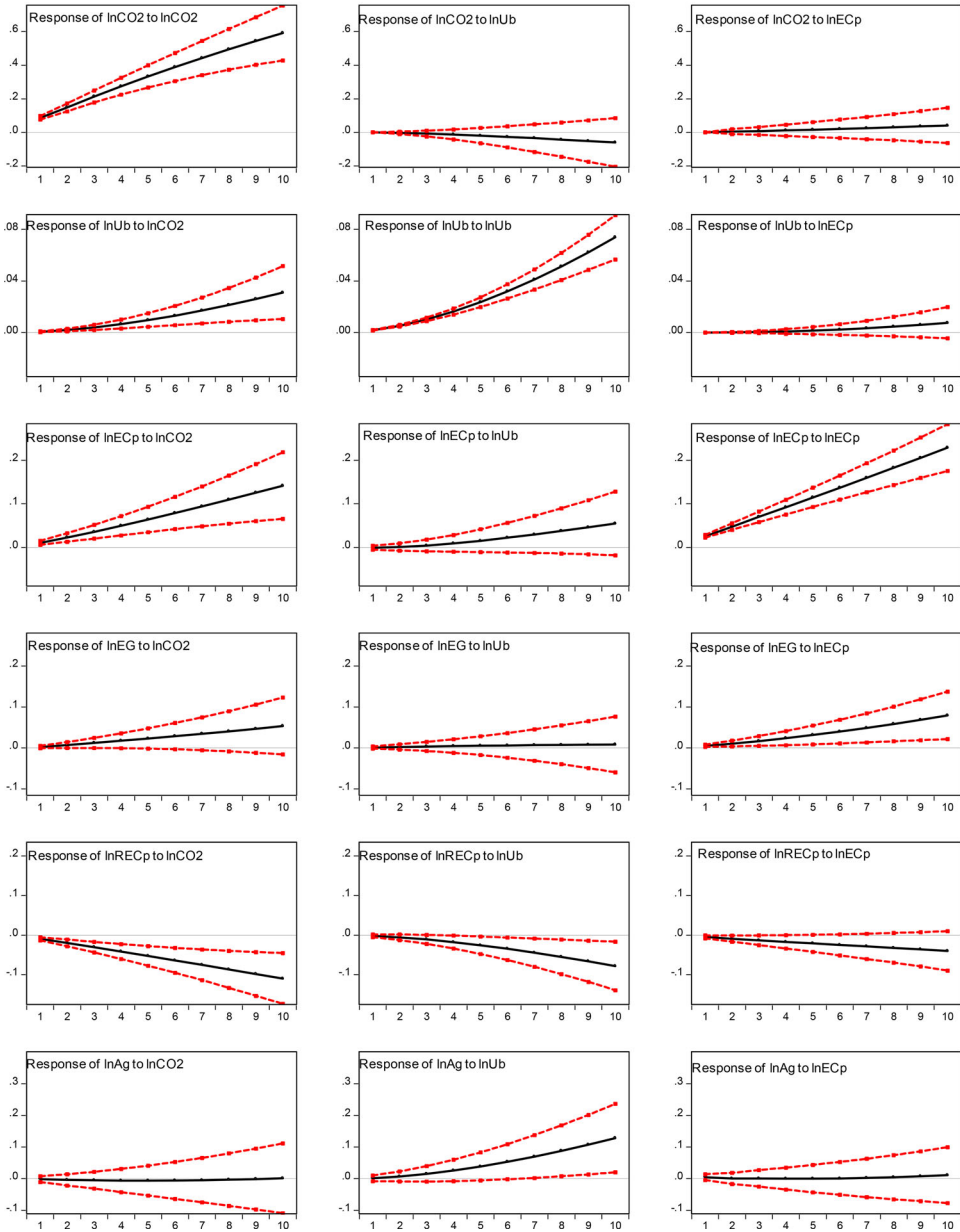


Figure 2. Impulse response function.
Source: Authors' estimation.

Consequently, to control environmental pollution, the governments of S.S.A. countries should assist the industrial sector in adopting environmental-friendly and advanced technology. The governments should also promote and subsidize green energy for the industrial sector. Besides, during the U.b. process, governments should also promote awareness regarding low-carbon development among urban residents through mass media and educational institutions. The governments of 15 S.A.

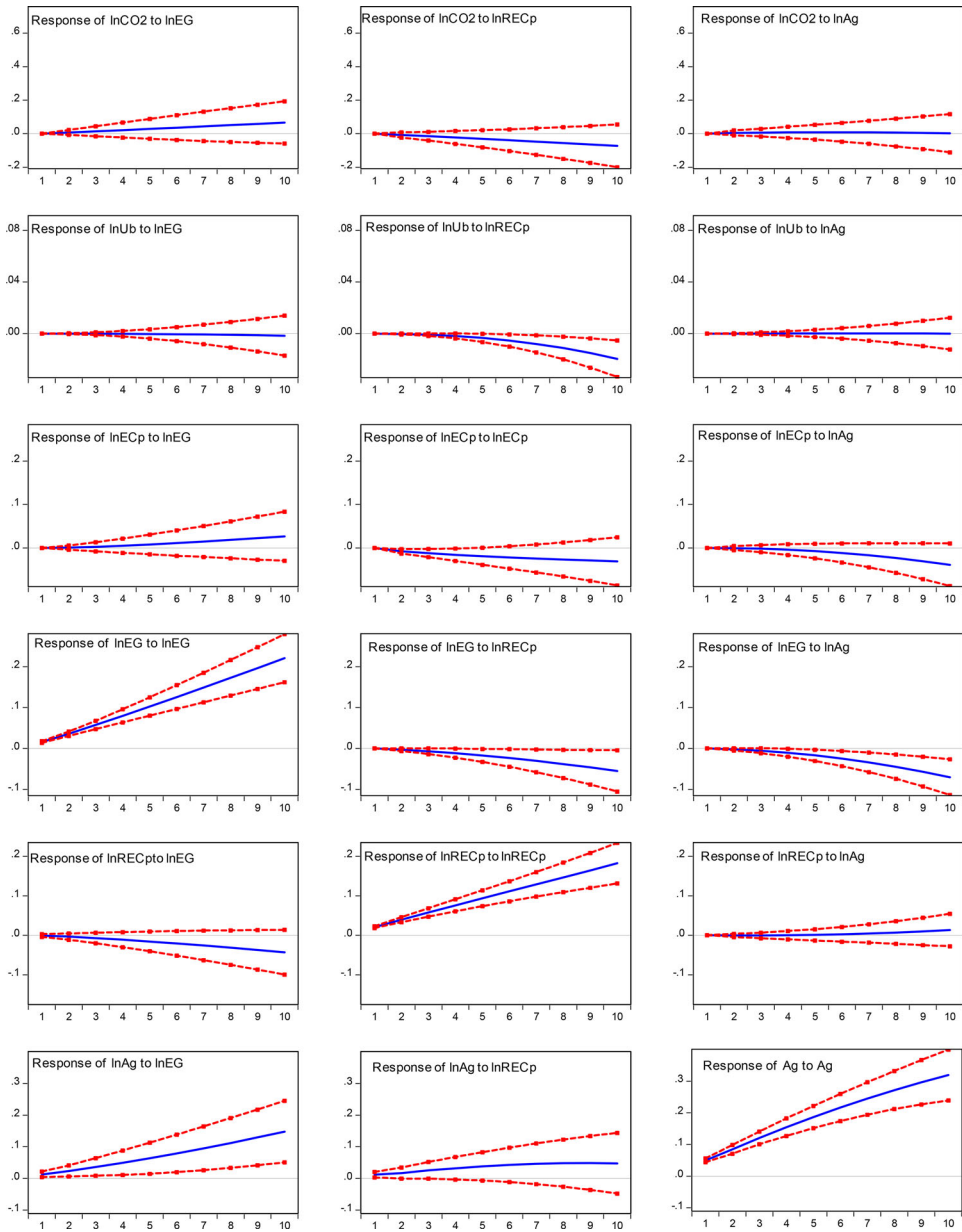


Figure 2. Continued

countries should promote renewable energy for transport vehicles, solar lighting, and heating system in urban areas.

The empirical findings also suggest that R.E.C.p. reduces carbon emission. Therefore, the government of S.S.A. countries must interfere and enable industries to adopt green technology in the near future. The governments of these countries should also provide subsidies or incentives for promoting the adoption of clean and green energy while implementing tax on emission could be another wise policy option

similar to the European Economies. Moreover, planting trees in urban areas may also be helpful in reducing environmental pollution.

Disclosure statement

No potential conflict of interest was reported by the authors.

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