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RESEARCH ARTICLE

Do carbon emissions impact Nepal's population growth, energy utilization, and economic progress? Evidence from long- and short-run analyses

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Abstract

Greenhouse gases are the major issues globally leading to climate change and increased pollution of the atmosphere. CO_2 emissions have divergent effect to the environment that also causes the economic performance of any country. The main motive of this analysis was to expose the influence of CO_2 emission on population growth, fossil fuel energy consumption, economic progress, and energy usage in Nepal by using time series data ranging from 1971 to 2019, and data stationarity was checked with the help of unit root tests. An autoregressive distributed lag (ARDL) method with cointegration test was employed to adjudicate the variable dynamics with short- and long-run evidence. Furthermore, variable causality was tested through the Granger causality test. Study findings show that during long-run analysis that fossil fuel energy consumption and energy utilization has constructive affinity with carbon dioxide emission that exposed the p-values (0.0000) and (0.1065) correspondingly, while population growth and economic progress uncovered an inimical relation to CO_2 emission. Similarly, the outcomes via short-run analysis also show that fossil fuel energy consumption and energy utilization have productive relation with CO_2 emission which shows the p-values (0.0000) and (0.1317), while population growth and economic progress demonstrate an adverse influence to CO_2 emission. The causality test results also validate a unidirectional linkage among variables. In attempt to participate in the global fight to clean up the atmosphere, the Nepali government and officials must take new measures to reduce CO_2 emissions.

Keywords Carbon emission · Environment · Fossil fuel energy · Pollution reduction · Economic progress · ARDL

Introduction

The association amid environmental sustainability and economic development ensures stability and also considered an important policy concern in the recent decade. Without prejudice to economic growth rates, policies aimed at building a cleaner environment are suggested with a view to decline the reliance on non-renewable sources, ensuring the energy stability and eliminating the poverty. Furthermore, a deeper consideration of connection among CO_2 emissions and economic progress delivers a treasured knowledge in order to execute the effective strategies for the environmental development. The effect of these policies will positively affect various empirical outcomes. Some studies affirm and claim that steps and policies are very sufficient to account for any economic losses incurred by the reduction of CO_2 emissions, while others show that they are immaterial because there is little, almost no proof of CO_2 emissions and economic progress (Chaudhry 2010; Joo et al. 2015; Magazzino 2016; Paramati et al. 2017).

The alternative source of fossil fuels and greenhouse gas emissions is renewable energy due to increasing concerns about environmental implications, and the reduction of CO_2 emissions and climate change regulation will inevitably entail reforming the energy sector (Alam et al. 2012; Carvalho et al.

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2013; Wang et al. 2014; Lorente and Álvarez-Herranz 2016). For the specification of the CO_2 emission context, the superior consideration of the linkage amid population growth, CO_2 emission, economic progress, and energy is especially convenient for government officials and policy makers who not only formulate short-term and long-term policies but also promote the CO_2 emissions and also encourage renewable energy consumption. Several studies has been explored and focusing on fundamental connection amid renewable energy and alternative energy usage, economic progress, and carbon emission, and demonstrating the dynamic effect of renewable energy use through an unexpected connection with international trade, foreign investment, urbanization, sustainable development, monetary policies, population growth, urban agglomeration, income inequality, production, and ecological footprint (Lee 2013; Sebri and Ben-Salha 2014; Bento and Moutinho 2016; Jebli and Youssef 2017; Goh and Ang 2018; Ehigiamusoe and Lean 2019; Nasrollahi et al. 2020; Hussain and Rehman 2021; Rehman et al. 2021a; Rehman et al. 2021b; Chishti et al. 2021; Rehman et al. 2021c; Ahmad et al. 2021a; Alvarado et al. 2021a; Ahmad et al. 2021b; Alvarado et al. 2021b), but the key focus of this study was to demonstrate the impact of CO_2 emission to fossil fuel energy consumption, population growth, economic progress, and energy usage in Nepal by applying an autoregressive distributed lag (ARDL) bounds testing technique through short- and long-term analyses. The study used the annual time series data to check the stationarity which is validated via unit root tests. The unidirectional relation among variables rectified through the Granger causality test.

Existing literature

An effective approach to contribution initiatives on resources and CO_2 emissions may have important political ramifications and help to resolve misrepresentation issues. However, huge work has been done on the connection amid energy usage and economic progress and the world environment has shifted considerably over recent decades (Knox et al. 2014). While economic growth has improved in many countries in separation standards and also has an obligation to increase CO_2 emissions and reduce natural resources, industrial, social, and economic influences and the emission of carbon dioxide are relatively similar and released in a number of ways, including gasoline, oil refining, natural gas, coal, and deforestation. Nevertheless, the connection amid economic progress and sustainable environment is related to the relation amid economic growth and energy utilization (Sanglimsuwan 2011; Adom et al. 2012; Javid and Sharif 2016; Alam et al. 2011). It is necessary to understand the correct nature of the relation amid economic efficiency and energy use in order to implement effective energy and environmental policies. Over the past few years, several studies have been done to confirm the correlation amid utilization of energy and high-impact of CO_2 emissions, as well as the association with non-renewable and renewable energy (Riti et al. 2017; Chaudhary and Bisai 2018; Han et al. 2018; Song et al. 2018; Antonakakis et al. 2017; Bekhet et al. 2017; Chiu 2017; Zhao et al. 2017; Irfan et al. 2020; Rehman et al. 2020b).

In the last few decades, exponential economic growth has taken place in the world due to the rapid progress of industrialization and urbanization. Demand for renewable energy is growing worldwide, including solar energy, geothermal electricity, hydropower, wind energy, and biomass. However, the increasingly rising demand for energy poses enormous environmental challenges, especially the global warming induced by CO_2 emissions. Changes due to increased pollution are mostly due to fossil fuel combustion (Jardón et al. 2017; Li and Su 2017; Dong et al. 2018). Renewable energy is the best mechanism for energy usage by replacing fossil fuels, resulting in fewer CO_2 emissions. Furthermore, renewable energy in the face of global warming has become a more efficient supernumerary for fossil fuels and a

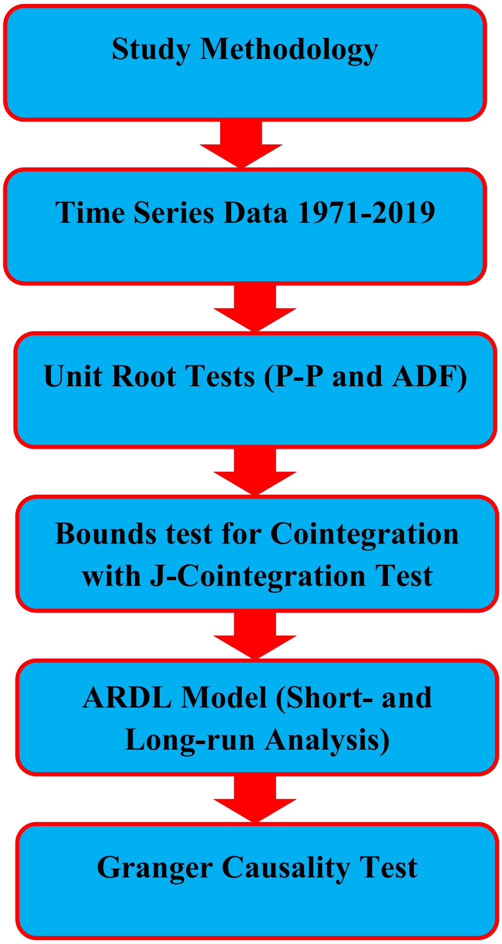

Fig. 1 Methodological roadmap of the study

totally related path to supportable growth (Bhattacharya et al. 2017; Dogan and Seker 2016).

The linkage amid economic progress and CO_2 emissions and energy has increased the growth significantly. Different authors used the time span data to check the casual connection using numerous strategies to contribute to this field. Although the results of these practices are far from conjunctural, it is not difficult to conclude that there are conflicts with old studies which have demonstrated the correlation of energy utilization and CO_2 emissions. Furthermore, some studies have surveyed the relation between clean energy and economic advancement in a single direction, while others have shown that this causative relation was reinvigorated. Other results indicate the reciprocal and neutral causality linkage of economic intensification and CO_2 emissions. However, some studies have established empirical problems and concluded that there are errors in the unit root test, cointegration, or missing compulsory variables (Hu and Lin 2008; Fodha and Zaghdoud 2010; Shabbir et al. 2014; Bilgili et al. 2016; Lv 2017).

There is increasing concern about renewable energy as a solution for increased greenhouse gas emissions. Many countries' energy policy is to encourage renewable energy in developing economies (Spetan 2016; Ghezloun et al. 2012; Alimi et al. 2017). Experts have recently begun using energy as a core problem for economic growth in labor and capital (Loizides and Vamvoukas 2005; Apergis and Payne 2010; Aïssa et al. 2014). Nevertheless, lawmakers and scientists have found out that coal is a prime source of carbon emissions in the global warming and climatic change. It is also recommended that policies on energy efficiency reduce CO_2 emissions to clean the atmosphere. At the other side, energy savings contribute to a decline in economic growth (Martinho 2016).

Greenhouse gasses have diverse impact on the environment and also in the earth's climate system. The average temperature of the snow melting in the glaciers is increasing globally, which is a testament to the heat of the atmosphere. Policymakers and environmentalists aim to create a linkage amid CO_2 emission progress intensification and also pay more attention to designing effective policies (Ziabakhsh-Ganji and Kooi 2012). Similarly, the connection between utilization of energy, CO_2 emission, and economic advancement has remained a main subject in current years concerning new policy goals and other environmental issues (Dinda 2008; Pao et al. 2011; Ohler and Fetters 2014; Salim et al. 2014). In this situation, the association amid energy, CO_2 emissions, and financial development can provide us with effective solutions, and CO_2 emissions can also contribute to economic growth. In such cases, a country must implement new policies to enhance economic growth (Arouri et al. 2012; Saidi and Hammami 2015).

Methodology and data

This study used data ranging from 1971 to 2019 and is based on time series. It was collected from the WDI (World Development Indicators). For the analysis, the following variables were used: CO_2 emission, population growth, fossil fuel energy consumption, economic progress, and energy usage. Figure 1 is illustrating the methodological roadmap of the study.

Specification of model with ARDL technique

The interaction amid variables including CO_2 emission, population growth, fossil fuel energy consumption, economic progress, and energy utilization can be demonstrated by following the Rehman et al. (2019) study and can be validated as:

$$\mathrm{CO2e_t} = \mathrm{f}(\mathrm{POPUG_t}, \mathrm{FOFUEC_t}, \mathrm{ECOGRO_t}, \mathrm{ENGU_t}) \tag{1}$$

Equation (1) can also be written as:

$$\mathrm{CO2e_t} = \mathrm{a_0} + \mathrm{a_1 POPUG_t} + \mathrm{a_2 FOFUEC_t} + \mathrm{a_3 ECOGRO_t} + \mathrm{a_4 ENGU_t} + \varepsilon_t \tag{2}$$

We can write above Eq. (2) as in its logarithmic form that follows as:

$$\mathrm{CO2e_t} = \mathrm{a_0} + \mathrm{a_1 LnPOPUG_t} + \mathrm{a_2 LnFOFUEC_t} + \mathrm{a_3 LnECOGRO_t} + \mathrm{a_4 LnENGU_t} + \varepsilon_t \tag{3}$$

where in Eq. (3) $\mathrm{LnCO2e_t}$ indicates the logarithm of CO_2 emission; $\mathrm{LnPOPUG_t}$ show the logarithm of population growth; $\mathrm{LnFOFUEC_t}$ display the logarithm of fossil fuel energy consumption; $\mathrm{ECOGRO_t}$ display the logarithm of economic progress; $\mathrm{ENGU_t}$ display the logarithm of energy utilization. ε_t is error term and t demonstrate the time for dimension and a_1 to a_4 demonstrate the coefficients of the long-run in the model.

Furthermore, this analysis utilized the ARDL method which is first developed by Pesaran et al. (2001) and Pesaran and Shin (1998) in directive to verify the association between variables. The cointegration order is either zero or one in the parameter illustration except for the order two. A long-run and short-run relationship using ARDL technique was seen via the UECM method. The exemplar is interpreted independently for short and long parameters. The characterization of the overall model between variables can be stated as:

Table 1 Summary statistics results

	LnCO2e	LnPOPUG	LnFOFUEC	LnECOGRO	LnENGU
Mean	7.341753	0.354032	1.867887	1.418933	5.799531
Median	7.719369	0.749416	2.146948	1.511401	5.740023
Maximum	9.116597	1.004017	2.739722	2.270179	6.074079
Minimum	5.288358	− 2.259228	0.503117	− 2.119071	5.693050
Std. Dev.	1.087113	0.885953	0.683598	0.718447	0.105350
Skewness	− 0.164093	− 2.166924	− 0.395638	− 2.852895	0.824167
Kurtosis	1.737185	6.642643	1.789846	14.01139	2.448090
Jarque-Bera	3.475746	65.43764	4.268288	314.0220	6.169124
Probability	0.175894	0.000000	0.118346	0.000000	0.045750
Sum	359.7459	17.34756	91.52648	69.52769	284.1770
Sum Sq. Dev.	56.72713	37.67582	22.43071	24.77598	0.532736

$$\begin{aligned}\Delta \mathrm{LnCO2e_t} = {} & \vartheta_0 + \sum_{i=1}^{b} \vartheta_{1i} \Delta \mathrm{i1iabl_{ti1}} + \sum_{i=1}^{b} \vartheta_{2i} \Delta \mathrm{i1iable_{ti1}} + \sum_{i=1}^{b} \vartheta_{3i} \Delta \mathrm{i1iables_{ti1}} \\ & + \sum_{i=1}^{b} \vartheta_{4i} \Delta \mathrm{LnECOGRO_{tnE}} + \sum_{i=1}^{b} \vartheta_{5i} \Delta \mathrm{LnENGU_{tnE}} + \psi_1 \mathrm{LnCO2e_{tnC}} \\ & + \psi_2 \mathrm{LnPOPUG_{tnP}} + \psi_3 \mathrm{LnFOFUEC_{tnF}} + \psi_4 \mathrm{LnECOGRO_{tnE}} \\ & + \psi_5 \mathrm{LnENGU_{tnE}} + \varepsilon_t \end{aligned} \quad (4)$$

In above Eq. (4), the variance operator is labeled by Δ, b express the lags sequence and error term is displayed through ε_t. The linkage of variables through long-run dynamics can be demonstrated as:

$$\begin{aligned}\Delta \mathrm{LnCO2e_t} = {} & \varphi_0 + \sum_{i=1}^{c} \varphi_{1i} \Delta \mathrm{i1\ be_{ti1}} + \sum_{i=1}^{c} \varphi_{2i} \Delta \mathrm{i1\ be\ d_{ti1}} + \sum_{i=1}^{c} \varphi_{3i} \Delta \mathrm{LnFOFUEC_{tnF}} \\ & + \sum_{i=1}^{c} \varphi_{4i} \Delta \mathrm{LnECOGRO_{tnE}} + \sum_{i=1}^{c} \varphi_{5i} \Delta \mathrm{LnENGU_{tnE}} + \varepsilon_t \end{aligned} \quad (5)$$

In Eq. (5), *c* indicates the order of lags. The ECM illustration of short-run analysis through ARDL method can be stated as:

$$\begin{aligned}\Delta \mathrm{LnCO2e_t} = {} & \zeta_0 + \sum_{i=1}^{d} \zeta_{1i} \Delta \mathrm{i1dica_{ti1}} + \sum_{i=1}^{d} \zeta_{2i} \Delta \mathrm{i1dicat_{ti1}} + \sum_{i=1}^{d} \zeta_{3i} \Delta \mathrm{LnFOFUEC_{tnF}} \\ & + \sum_{i=1}^{d} \zeta_{4i} \Delta \mathrm{i1ECOGRO_{tCO}} + \sum_{i=1}^{d} \zeta_{5i} \Delta \mathrm{LnENGU_{tnE}} + \alpha \mathrm{ECM_{tCM}} \\ & + \varepsilon_t \end{aligned} \quad (6)$$

where d presents the lags order in Eq. (6) through short-run dynamics amid the study variables.

Stationarity test persistence

In order to validate the consistency amid variables, a unit root test was used and can be specified as:

$$\Delta B_t = \lambda_\circ + \psi_\circ T + \psi_1 U_{t-1} + \sum_{i=1}^{m} \lambda_1 \Delta B_{t-1} + \mu_t \quad (7)$$

In Eq. (7) above, *B* describes the unit root variables to be evaluated, *T* displays the linear trend, Δ reveals the first difference between the operators, t represents time subscript, and μ_t is a stochastic error normally distributed.

Study outcomes and discussion

Summary and correlation analysis

The summary and correlation analysis outcomes are showed in Table 1 and Table 2. Results demonstrated that all study variables including CO_2 emission, population growth, fossil fuel energy consumption, economic progress, and energy utilization are normally distributed.

Stationarity test for the variables

This investigation used unit root tests including Phillips and Perron (P-P) (Phillips and Perron 1988) and ADF (Dickey and

Table 2 Correlation analysis results

	LnCO2e	LnPOPUG	LnFOFUEC	LnECOGRO	LnENGU
LnCO2e	{1.000000}	− 0.614339	0.980479	− 0.082337	0.880456
LnPOPUG	− 0.614339	{1.000000}	− 0.546951	0.056366	− 0.805145
LnFOFUEC	0.980479	− 0.546951	{1.000000}	− 0.044640	0.830719
LnECOGRO	− 0.082337	0.056366	− 0.044640	{1.000000}	− 0.065173
LnENGU	0.880456	− 0.805145	0.830719	− 0.065173	{1.000000}

Table 3 Unit root test results

	P-P test results		ADF test results	
Variables	At level (t-Statistic) [Probability values]*	First difference (t-Statistic) [Probability values]*	At level (t-Statistic) [Probability values]*	First difference (t-Statistic) [Probability values]*
LnCO2e	− 1.803844 [0.3743]	− 10.17583 [0.0000]	− 1.461146 [0.5445]	− 7.869722 [0.0000]
LnPOPUG	− 1.884269 [0.3368]	− 4.061708 [0.0026]	− 2.273111 [0.1847]	− 4.710430 [0.0004]
LnFOFUEC	− 1.796605 [0.3778]	− 9.135140 [0.0000]	− 2.040592 [0.2691]	− 3.435594 [0.0154]
LnECOGRO	− 7.020853 [0.0000]	− 32.74706 [0.0001]	− 7.009060 [0.0000]	− 7.019582 [0.0000]
LnENGU	− 0.637446 [0.8522]	− 8.113100 [0.0000]	− 0.637446 [0.8522]	− 7.307640 [0.0000]

*Indicates the p-values of MacKinnon (1996)

Fuller 1979) tests and outcomes are interpreted in Table 3 at level and at first difference in directive to measure the stationarity of series including CO_2 emission, population growth, fossil fuel energy consumption, economic progress, and energy utilization.

From Table 3 results, it is concluded that in the order of two none of the variables got integration and therefore autoregressive distributed lag (ARDL) model was used.

Cointegration in accordance with bounds testing

Table 4 illustrates the bounds testing to cointegration test outcomes. The F-statistics value is 10.78185. The values of lower bound at 10%, 5%, 2.5%, and 1% are 2.2, 2.56, 2.88, and 3.29. Furthermore, the upper bound values at 10%, 5%, 2.5%, and 1% are 3.09, 3.49, 3.87, and 4.37. Cointegration results demonstrate the linkage amid all study variables.

Similarly, the outcomes of the Johansen test (Johansen and Juselius 1990) are obtainable in Table 5 in directive to approve the robustness during long-run association. In the model, the zero hypothesis is rejected and no trace test statistics characterize cointegration. Trace metrics and maximum Eigenvalues show that they are above the average values.

The max eigenvalue statistics show 3 cointegrating eqn(s); *displays denial of hypotheses at rate 0.05; **indicates the MacKinnon-Haug-Michelis (1999) p-values

Long- and short-run dynamics

The consequences of short- and long-run dynamics amid variables are presented in Table 6 and Table 7.

The outcomes of Table 6 show that CO_2 emission has constructive interaction with fossil fuel energy utilization and energy usage via short-run analysis and have coefficients (0.770900) and (0.895044) with Prob-values (0.0000) and (0.1317) correspondingly, while the variables population growth and economic growth exposed an adversative association with CO_2 emission in Nepal having coefficients (− 0.029664) and (− 0.022996) with Prob-values (0.4816) and (0.4318), respectively, moving towards the consequences of Table 7 which reveal that fossil fuel energy consumption and energy utilization have constructive interaction with CO_2 emission through long-run with coefficients (1.314874) and (1.526618) having Prob-values (0.0000) and (0.1065). Likewise, outcomes also exposed that population growth and economic progress have an adverse association to CO_2 emission with coefficients (− 0.050595) and (− 0.039223) having Prob-values (0.4871) and (0.4247). However, excellent economic performance requires a lot of energy. The high demand, dependence, and ingesting of outmoded energy sources, mainly from natural gas, oil, and coal, have caused environmental problems, such as increased carbon dioxide emissions that cause the climatic change. Energy, especially from traditional resources such as gas, coal, and oil, has also

Table 4 Bounds testing for the confirmation of cointegration

F-B test		Null hypothesis: no levels relationship		
T-Statistic	Value	Signif.	I(0)	I(1)
F-statistic	{10.78185}	{10% }	{2.2}	{3.09}
K	{4}	{5% }	{2.56}	{3.49}
		{2.5%}	{2.88}	{3.87}
		{1% }	{3.29}	{4.37}

Table 5 Results of Johansen cointegration tests

NH	TS	P-values	NH	ME	P-values
$r \le 0$	85.60024	[0.0017]	$r \le 0$	36.62872	[0.0229]
$r \le 1$	48.97152	[0.0391]	$r \le 1$	29.03846	[0.0323]
$r \le 2$	19.93306	[0.4274]	$r \le 2$	13.57711	[0.4007]
$r \le 3$	6.355951	[0.6535]	$r \le 3$	5.085206	[0.7310]
$r \le 4$	1.270744	[0.2596]	$r \le 4$	1.270744	[0.2596]

Table 6 Short-run analysis results

Short-run Error Correction Regression

Variables	Coefficients	SE	TS	P-values
C	− 2.252673	3.154848	− 0.714036	0.4792
LnCO2e(-1)	− 0.586292	0.083150	− 7.050991	0.0000
LnPOPUG	− 0.029664	0.041775	− 0.710090	0.4816
LnFOFUEC	0.770900	0.117755	6.546623	0.0000
LnECOGRO	− 0.022996	0.028974	− 0.793688	0.4318
LnENGU	0.895044	0.582122	1.537554	0.1317
CointEq(-1)*	− 0.586292	0.068908	− 8.508374	0.0000

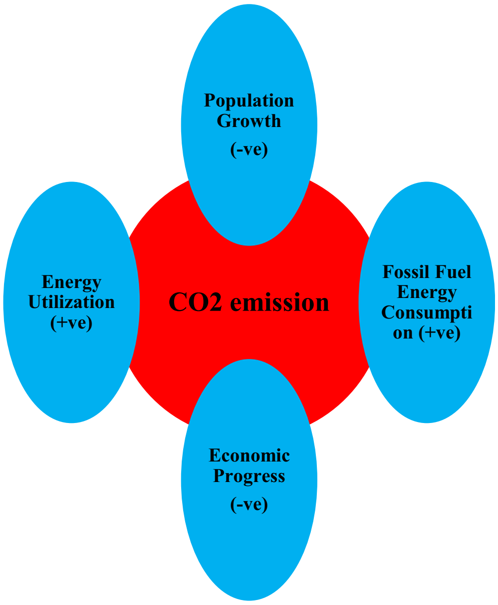

Fig. 2 Relation among CO_2 emissions and other variables

upsurges year by year. The close association amid per capita income and utilization of energy has led to a decline in environmental quality (Hasnisah et al. 2019; Khan et al. 2019; Kwakwa et al. 2020; Ulucak and Khan 2020).

The world's well-being and atmosphere are threatened by global warming. Due to the huge combustion of fossil fuels and the consequent explosive increase in CO_2 pollution, the main economic revolution in recent years has led to extreme global warming. Recent global warming and consequent climatic changes pose diversified challenges to the environment, prosperity, and biodiversity in the future. Other fatal conditions, such as increased sea level, changes in agriculture and water systems, often depends on adverse weather conditions, including floods, hurricanes, droughts, and heat waves (Perera 2018; Aye and Edoja 2017; Olale et al. 2018). Energy is seen as an economic and social cornerstone and a central element of potential climate change. Energy is sometimes referred to as the traditional variable of growth. Growth is not only energy-dependent, but also vital for sustainable economic progress, and can only achieve safe and clean energy sources. The connection among energy usage and economic efficiency is strong. In promoting the economy of any country, energy played a vital role (Koçak and Şarkgüneşi 2017; Wang et al. 2018; Maji et al. 2019; Azam et al. 2019).

The differentiation pollution of greenhouse gas from industrial activity is a major concern for economies, policymakers, and intellectuals. In developed countries which lack legislation and evaluation systems for regulating emission levels, this challenge is much more severe. In the first stage of pollution detaching from economic development, the different industries of the economy have an environmental incompetence whose output influences a country's overall environmental

Table 7 Long-run analysis results

Long-run interaction

Variables	Coefficients	SE	TS	P-values
LnPOPUG	− 0.050595	0.072170	− 0.701059	0.4871
LnFOFUEC	1.314874	0.103425	12.71335	0.0000
LnECOGRO	− 0.039223	0.048652	− 0.806189	0.4247
LnENGU	1.526618	0.925612	1.649307	0.1065
C	− 3.842237	5.241112	− 0.733096	0.4676
(R-squared)	(0.984099)	(Mean dependent var)	(7.384532)	
(Adjusted R-squared)	(0.982206)	(S.D. dependent var)	(1.056115)	
(S.E. of regression)	(0.140881)	(Akaike info criterion)	(− 0.965331)	
(Sum squared resid)	(0.833595)	(Schwarz criterion)	(− 0.731431)	
(Log likelihood)	(29.16795)	(Hannan-Quinn criter.)	(− 0.876940)	
(F-statistic)	(519.8563)	(Durbin-Watson stat)	(1.811702)	
Prob(F-statistic)	(0.000000)			

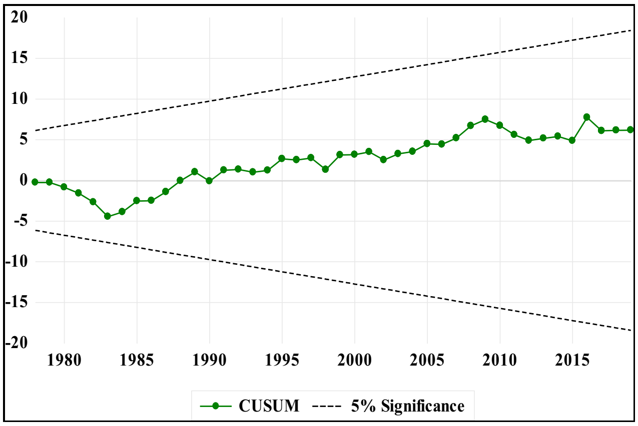

Fig. 3 Cumulative sum

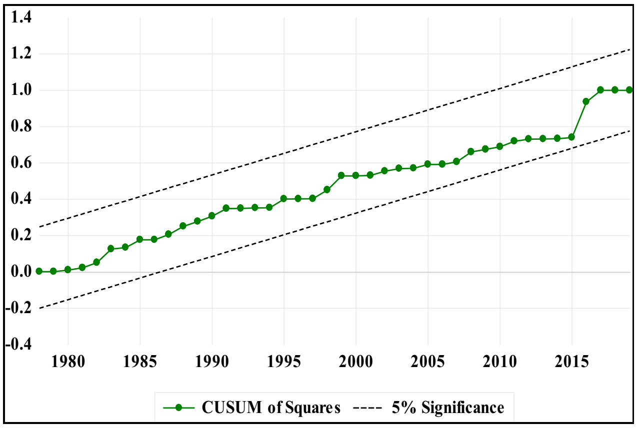

Fig. 4 Cumulative sum of squares

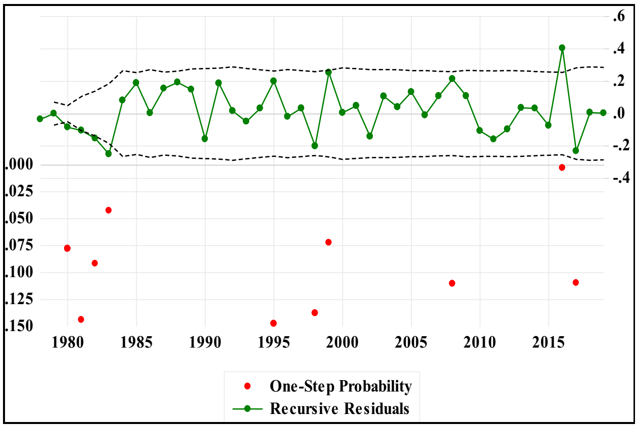

Fig. 6 One-step probability and recursive residuals

performance. The implementation of tailored policies aimed at improving the inefficiencies found should proceed. The explanation is that the environmental efficiency of any economy relies on the efficient utilization of resources by different industries in order to increase the development of ideal outputs such as products and services, thus reducing unwanted outcomes such as greenhouse gases (Younis et al. 2021; Shah and Longsheng 2020). For instance, a dual-way causal interaction exists between renewable energy investment and the sustainable development of all but the core groups, meaning that the central part is actually sustainable development is not a sustainable investment dependent on the energy market. Sustainable growth and environmental impacts are also mutually reinforcing. The energy industry framework must therefore be converted into a link between environmental impacts and sustainable growth (Ahmad et al. 2021c; Rehman et al. 2020a).

Furthermore, the outcomes of Table 7 also expose that R-squared value is (0.984099) that revealed a 98% discrepancy through the model. Similarly the value of adj-R^2 is (0.982206). Durbin–Watson value is (1.811702), indicating that the construct is not self-correlated and that it is necessary to disintegrate. Figure 2 illustrates the dynamic linkage amid CO_2 emission and all other concerned variables.

Figure 2 expresses the dynamic relation amid variables through long- and short-run analyses. In consequences of long- and short-run analyses, carbon dioxide has positive linkage to fossil fuel energy and energy utilization. The outcomes also revealed that CO_2 emission has adverse linkage to population growth and economic progress. Overall findings show the long-term linkage amid variables.

Figures 3 and 4 illustrate the graph of cumulative sum and cumulative sum of squares, which demonstrate structural stability through long- and short-run analyses. Both graphs show the level of significance at 5%. Similarly, Figs. 5, 6, and 7 also show the recursive residuals with one-step and N-step probability amid the variables.

Pair-wise causality test

The Granger causality method was used to assess the causality of CO_2 emission and all other concerned variables. Table 8

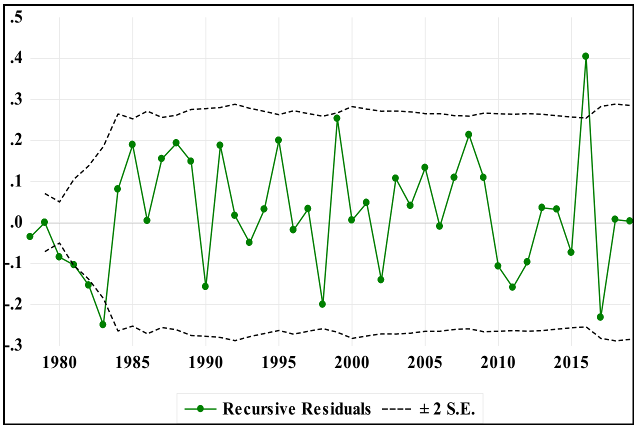

Fig. 5 Recursive residuals

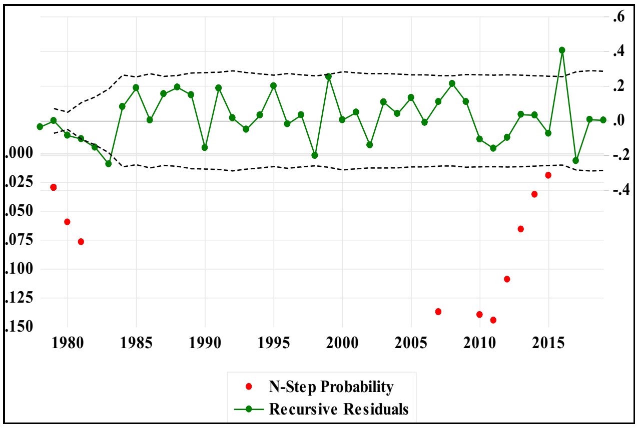

Fig. 7 N-step probability and recursive residuals

Table 8 Granger causality test

N-Hypothesis	F-Statistic	P-values
LnPOPUG is not showing Granger Cause to LnCO2e	0.15997	0.8527
LnCO2e is not showing Granger Cause to LnPOPUG	0.98256	0.3828
LnFOFUEC is not showing Granger Cause to LnCO2e	2.78503	0.0732
LnCO2e is not showing Granger Cause to LnFOFUEC	1.54152	0.2259
LnECOGRO is not showing Granger Cause to LnCO2e	0.29380	0.7469
LnCO2e is not showing Granger Cause to LnECOGRO	2.12459	0.1321
LnENGU is not showing Granger Cause to LnCO2e	0.21119	0.8105
LnCO2e is not showing Granger Cause to LnENGU	1.86298	0.1678
LnFOFUEC is not showing Granger Cause to LnPOPUG	0.80135	0.4555
LnPOPUG is not showing Granger Cause to LnFOFUEC	0.20185	0.8180
LnECOGRO is not showing Granger Cause to LnPOPUG	0.03317	0.9674
LnPOPUG is not showing Granger Cause to LnECOGRO	0.94560	0.3966
LnENGU is not showing Granger Cause to LnPOPUG	0.77600	0.4667
LnPOPUG is not showing Granger Cause to LnENGU	0.06195	0.9400
LnECOGRO is not showing Granger Cause to LnFOFUEC	0.32770	0.7224
LnFOFUEC is not showing Granger Cause to LnECOGRO	1.80715	0.1767
LnENGU is not showing Granger Cause to LnFOFUEC	0.08799	0.9159
LnFOFUEC is not showing Granger Cause to LnENGU	1.67953	0.1987
LnENGU is not showing Granger Cause to LnECOGRO	3.16550	0.0524
LnECOGRO is not showing Granger Cause to LnENGU	0.15557	0.8564

provides a unidirectional relation amid the variables, indicating the effects of a pair-wise Granger causality check.

Conclusion and policy recommendations

The key aim of this paper was to show the impact of CO_2 emission to population growth, fossil fuel energy consumption, energy utilization, and economic progress in Nepal by using time span data. All variables stationarity was verified by using the P-P and ADF unit root tests. An autoregressive distributed lag (ARDL) method and cointegration test were employed with long- and short-run analyses to check the relation among variables. Additionally, the Granger causality technique was also applied to determine the unidirectional linkage amid variables. Outcomes during long-run analysis show that CO_2 emission has constructive linkage to fossil fuel energy consumption and energy utilization, while exposed and had adverse linkage to population growth and economic progress in Nepal, moving towards the outcomes of the short-run dynamics which demonstrate that CO_2 emission has constructive linkage with fossil fuel energy consumption and energy usage, while exposed an adverse interaction with population growth and economic progress.

Global warming is increasing with the passage of time. As Nepal is fewer emitter of the CO_2 emission, possible initiatives are needed from the government of Nepal to diminish the CO_2 in order to boost the economic as well as agricultural growth. Carbon dioxide causes the climatic change and despite the potential risks posed by climate change and its effects to our biodiversity and socio-economic lifestyles, there is this cloud of despair and remains a glimmer of hope. Sustained pollution of greenhouse gasses would contribute to more warming and climate change. Nepal has been working to adapt the new policies regarding the climatic change. One of the major important points to consider is that most of the energy generated in Nepal is clean and comes from permanent energy sources. In the global greenhouse gas emission scenario, Nepal has low contribution, but also a negative carbon country, providing net carbon sinks through its dense green forests. Therefore, enhanced absorption and avoiding the release in the atmosphere of accumulated carbon are two of the most effective steps in the battle against global warming and securing the environment.

Abbreviations CO2e, Carbon dioxide emission; ARDL, Autoregressive distributed lag; WDI, World Development Indicators; POPUG, Population growth; FOFUEC, Fossil fuel energy consumption;

ECOGRO, Economic growth; ENGU, Energy use; UECM, Unrestricted Error Correction Model; P-P, Phillips-Perron; ADF, Augmented Dickey-Fuller; ECM, Error Correction Model

Availability of data and materials Not applicable.

Author contribution Kalpana Regmi: conceptualization, investigation, methodology, formal analysis, visualization, writing the original draft; Abdul Rehman: investigation, visualization, formal analysis, review, editing, and made suggestions to improve the quality of the manuscript.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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