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Nexus Between CO_2 Emissions, Energy Use and Economic Growth in Nepal

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Abstract

Background: Economic growth in different economies comes with a cost of environmental degradation. The environment-growth nexus has come to the spotlight since scientists as well as policy-makers point out the threat of climate change and global warming all around the world. Nepal faces problems of pollution day by day raising a question about sustainable growth in the country. Such sustainability can be achieved by exploiting the water resources of the country which can be further used to generate cleaner forms of energy.

Objective: This paper examines the interconnection between environmental degradation and economic growth in Nepal under the Environmental Kuznets curve's framework and causal framework. These frameworks also incorporate energy variables such as electricity production, electricity and oil consumption at a disaggregated level to understand the energy growth nexus in Nepal.

Method: The Auto-Regressive Distributed Lag model followed by TY Non-Granger Causality tests and variance decompositions are incorporated in the study to examine the EKC hypothesis and the nexus between energy and growth is analyzed through a multivariate framework.

Conclusion: Our result does not show the presence of the EKC hypothesis in the case of Nepal. However, the causal framework indicated that a percentage increase in electricity generation would lead to a reduction in carbon dioxide by 0.7%. The variance decomposition results showed that the impact of CO_2 on GDP would decrease with horizons getting longer. On the other hand, the impact of electricity generation on CO_2 on was found to be 78% in the longer horizon.

Implications: Nepal should harness its potential of generating hydroelectricity to reduce environmental pollution as well as increase economic growth. Substituting the cleaner form of energy such as hydroelectricity can help in reducing the consumption of fossils and fuels as well as help in mitigating the pollution level in Nepal. This will further allow Nepal to be self-reliant since it has huge potential for generating hydroelectricity.

Paper Types: Research Paper

Key Words: Environment, Growth, CO_2, Electricity

JEL Classification: Q43, Q54, Q56

Introduction

Human activities have affected the natural environment all over the world. The growth led development paradigm through rapid urbanization and industrialization resulted in severe pollution everywhere. According to IEA (2018), 14,766 metric tons (mt. tons) of CO_2 emissions are generated from coal, 11,415 mt. tons from oil, 7,104 from natural gas and remaining 228 mt. tons from other sources. NASA declared 2020 to be the hottest year posing more threats in the future. The rapid industrialization, urbanization and changing consumption habits have been the major drivers of the CO_2 emissions. The ever-increasing carbon emissions have accordingly put threats to nature's ecosystem and environment that have far bearing consequences for the economic prosperity and sustainable development (Epple et al., 2016). Climate change and global warming have been the immediate consequence of increasing CO_2 and other greenhouse gas emissions. Accordingly, there has been a surge in academic interest on examining the nexus between CO_2 emissions and economic growth in many countries.

Testing Environmental Kuznets's Curve (EKC) hypothesis in the context of emission and economic growth relationship has been an appealing approach (Dinda, 2004). The original hypothesis propounded by Kuznets (1955) asserted an inverted U-shaped relationship between economic growth and inequality. Following the similar framework, the literature that emerged in the 1990s especially test the hypothesis if the economic gains such as the increase in income or economic growth are coming at the expense of environmental degradation such as CO_2 emissions (Grossman & Krueger, 1995). Since CO_2 emissions and energy use pattern are closely related, the later literature also aimed to examine a relationship between energy consumption, CO_2 emissions and economic output related variables (Kaika & Zervas, 2013).

While there has been a considerable amount of literature available in the global and regional contexts, lesser is known especially in a country like Nepal where the abundance of natural resources and vulnerability of climate change. This paper aims to contribute to existing literature specifically testing the presence of the EKC hypothesis for Nepal as well as examining the energy consumption, CO_2 emissions and economic output in a multivariate regression framework. Generating such evidence on energy consumption, pollution and economic growth is important for a country like Nepal in several accounts.

First, Nepal is highly vulnerable and fragile to climate change and global warming. For example, it is ranked fourth, eleventh and thirtieth in terms of vulnerability to climate change, earthquake and flood risks respectively (UNDP, 2020). Home of several highest mountain peaks of the world, elevated geographic terrain with human settlements and intense diversities on its ecology makes Nepal not only unique in its geographical landscape but also prone to climate change and global warming. Glacier melting, increasing frequency of extreme natural calamities such as landslides, drought, and abnormal rains are already being documented in Nepal (Wester et al., 2019). It is, therefore, important to generate evidence on emissions-output nexus and bring it into the public and policy discourses as early as possible.

Second, Nepal possesses the potential for renewable energy production. Hydroelectricity, wind and solar powers have immense production possibilities (AEPC, 2014). The early evidence of growth–emission nexus may help Nepal accelerate the pace of clean energy production and substitute bio-mass and fossil fuels with the sources of clean energy. Evidence show bai-mass and fossil fuels can be substituted (Awasthi & Adhikari, 2019). These substitutions help Nepal on achieving economic growth from lesser emissions in general and reduce ever-increasing import bills of fossil fuels, lower energy bills to the households and gains in individual health in particular.

Third, it is also important to know to what extent the growth-emissions nexus are attributable to

Nepal's activities. It is now established that climate change and glacier melting happenings in Nepal are not only attributable to emissions and resource depletion in Nepal but are also closely connected with emissions in the region (Gurung et al., 2019). On the other hand, glacier melting, extreme events like floods, landslides, etc. have also implications for the livelihood of billions of individuals in the region, particularly in India. Therefore, evidence on the emissions-output nexus would help Nepal to put forward its climate change agenda on regional and global forums.

Despite such importance, the literature on the Nepalese context is quite limited. For example, Dhungel (2014) examines a causal relationship between energy consumption and economic growth in Nepal. This paper however does not take the CO_2 emissions into account. Bastola and Sapkota (2015) consider the energy consumption, pollution and economic growth relationship using Johansen and ARDL co-integration approach. Nepal and Paija (2018), with refinement in methodology, particularly using an augmented vector error correction model and addressing potential omitted variable biases by the inclusion of variables such as population, gross fixed capital formation among others, explored the relationship between real output, emissions and energy consumption in Nepal.

The second objective of the paper is similar to those of Bastola and Sapkota (2015) and Nepal and Paija (2018). We proceed with the twofold motivation for writing this paper. First, we explicitly test the EKC hypothesis in the Nepalese context. Second, we consider fossil fuel (oil) consumption, electricity consumption and electricity production into the model. The earlier notable studies of Bastola and Sapkota (2015) and Nepal and Paija (2018) for Nepal have taken the energy consumptions in aggregates. This disaggregation and inferences therein are particularly important for Nepal as electricity remains a viable option to substitute fossil fuel consumption implying that Nepal can accelerate economic growth with clean energy consumption. Our findings also confirm that CO_2 emissions get associated with fossil fuel consumption in particular.

The remaining section of this paper is organized as follows. Section 2 examines the available literature focusing both on theory, methods and empirical studies. Section 3 delineates the methodology with a focus on time series econometric analysis as this study aims to estimate the causal relationship between the variables of interest. Section 4 discusses the key results and discussions of the major findings. Finally, Section 5 concludes the study with a brief note on the implication.

Review of Literature

The oil price shock of the 1970s and the subsequent strong emergence of sustainable development arguments aroused the interest of economists in examining the relationship between energy consumption and economic output (Mandal et al., 2016). These interests were particularly helpful in designing new energy policies specifically aimed at gaining energy efficiency and promoting alternative energy production. With the extension and applications of the Kuznets Curve Hypothesis in the 1990s including in the environmental and ecological economics, the interest was also to include the environmental degradation variables such as carbon emissions into energy consumption-economic output nexus studies (Kaika & Zervas, 2013). The available literature on energy consumption-economic output relationship studies can be broadly summarized as i) study examining energy consumption and economic output relationship ii) examining environmental degradation measured by carbon emissions and other greenhouse gases and economic output relationship and iii) testing the relationship combining both (i) and (ii) i.e., examining energy consumption, emissions and economic output relationships (Nepal & Paija, 2018; Ozturk, 2010). In line with the objectives of the paper, we however limit our discussion to (ii) and (iii) set of literature. Indeed, Oztruk (2010) provides a comprehensive review of the first set of literature that typically looks into the energy consumption-growth nexus.

With growing environmental and ecological concerns, a set of literature in the1990s emerged examining the relationship between environmental degradation and economic growth. The carbon emission was considered as a proxy for environmental degradation owning to both data availability and significant contributor to environmental pollution. This set of literature particularly tests the EKC hypothesis. Dinda (2004) provides a comprehensive account of the mainstream EKC concerns while Mardani et al. (2017) review major empirical evidence.

The results from previous studies under the EKC framework can be categorized into three groups based on how economic growth and environmental degradation are associated in different countries or cross countries contexts. The first group includes the literature that confirms the EKC hypothesis. In their seminal paper, Grossman and Krueger (1995) estimated the environmental impacts of the North American Free Trade Agreement (NAFTA) and confirmed the presence of the EKC hypothesis. The authors found a positive relationship between output and environmental degradation variables such as S02, black soot and SPM (Suspended Particles) and a negative relationship in the later stage of development. Testing the EKC hypothesis was further amplified by a study by Shafik and Bandyopadhyay (1992) that supports the presence of the EKC hypothesis in both time series and cross-country analysis. The subsequent studies of Panayotou (1993), Selden et al. (1994) and Holtz-Eakin and Selden (1995) also favor the presence of EKC. The recent studies also support the presence of the EKC hypothesis the suggesting its testing is still a relevant academic concern. Examples include Al-Mulali et al. (2016), Hanif (2017), Ulucak and Bilgili (2018) and Shittu et al. (2018) among others. Not surprisingly, the extension over the years has been to examine country-specific cases, regional or group of economies and improvement in the estimation methodology.

The second group includes the studies which show that a U-shaped curve rather exists instead of an inverted U-shaped relationship in the EKC framework. For example, Lantz and Feng's (2006) study in Canada favors a U-shaped relationship between economic growth and CO_2 emissions contrary to an inverted U relationship asserted by the EKC hypothesis. Likewise, Twerefou et al. (2016) show that the economic growth was positive only when CO_2 emission also increased in Ghana. Moreover, they also modelled trade openness and energy consumption and established positive linkage with CO_2 emissions. Along with the existence of U-shaped curve, Park and Lee (2011) also established presence of N-shaped curve in some regions of Korea. They analyzed EKC hypothesis in 16 regions of Korea using panel data for 16 years and found the outcomes to be heterogeneous across the regions. Energy consumption was found to be the major cause of air pollution in Korea.

The third group indicates the non-existence of the EKC hypothesis. For example, Aung et al. (2017) investigated an association between economic growth and environmental pollution in Myanmar using time series data from 1970 to 2014. They incorporated greenhouse gases such as CO_2, CH_4 and N_2O as the proxy of environmental pollution and GDP as a measure of economic growth. Their findings indicated GDP and CO_2 to be positively associated to each other in short run as well as long run, thus refusing that environmental Kuznets curve exists in Myanmar. Likewise, Adu and Denkyirah (2019) used panel data for Western African countries to examine the EKC curve and concluded that CO_2 emissions increased economic growth in the short run. However, their relationship was not strong in the long run. Hence, they confirmed the non-existence of the EKC curve in the West African countries.

However, simply looking at pollution-economic growth nexus was criticized on several grounds. These mainly include omitted variable bias, time-series properties of data and spurious regression, and identification of time effects (Stern, 2017). Accordingly, a multivariate time series analysis has been widely used to examine the emission-growth nexus. The emission variable is added into the energy consumption-growth nexus as a primary cause of environmental pollution.

For example, Soytas et al. (2007) explored the Granger causality between income, energy consumption and carbon emissions with the inclusion of growth affecting variables such as labor and gross fixed capital formation. Based on the Granger causality analysis, the paper found that energy consumption granger-causes carbon emission while income does not. Halicioglu (2009) also followed a casual time series analysis to examine the relations between CO_2 emissions, trade, energy use and income for Turkey. The study finds a cointegrating relationship from energy consumption, income and foreign trade to carbon emissions followed by a long run casuality from carbon emissions, energy consumption and foreign trade to income. Likewise, Alshehry and Belloumi(2015) analyzed the link between per capita energy consumption, per capita GDP, price of crude oil and CO_2 emission per capita in Saudi Arabia for the period of 1971-2010. Bidirectional causality was detected between CO_2 emissions and economic growth in the long run. Moreover, unidirectional causality was detected from energy consumption to CO_2 emissions. However, variance decomposition analysis showed very less contribution of economic growth to CO_2 emissions. One standard deviation shock in CO_2 explained economic growth by 4.918%. The impact of CO_2 on economic growth kept decreasing in the longer horizons as per the forecast error variance decomposition. Mohiuddin et al. (2016) analyzed connections between economic growth, energy and CO_2 using time series spanning from 1971- 2013. The VEC model showed that there was no granger causality between GDP and CO_2 in any direction. However, results showed that a percentage increase in energy production led to 13.7% rise in CO_2 emissions in the long run. The impulse response analysis showed that energy production, electricity consumption and GDP contributed to CO_2 emissions.

In Nepal, less literature has examined the energy growth nexus. Dhungel (2008) examined a relationship between energy consumption and GDP indicating a unidirectional casual running from GDP to energy consumption. However, this paper ignored the emission variable taking into account. Bastola and Sapkota (2015) included an emission variable and found a long-run relationship when CO_2 emissions and electricity consumptions were dependent variables in the case of Nepal. They found long run relationships when CO_2 emissions and energy consumptions were dependent variables. They found two-way feedback between CO_2 and energy consumption and one-way causality from GDP to CO_2 and energy consumption from the Granger causality test. Nepal and Paija (2018) also looked into emission, energy consumption and growth nexus with the inclusion of growth accounting variables such as gross fixed capital formation population. They found that carbon dioxide emission Granger causes economic growth. However, there was no feedback from electricity consumption to economic growth.

Despite all the existing studies, the EKC hypothesis has not been tested in the case of Nepal yet. Further, existing studies take energy consumption aggregates whereas the disaggregation of such energy consumption could provide better inferences as discussed in the introduction section. This study aims to bridge this literature gap.

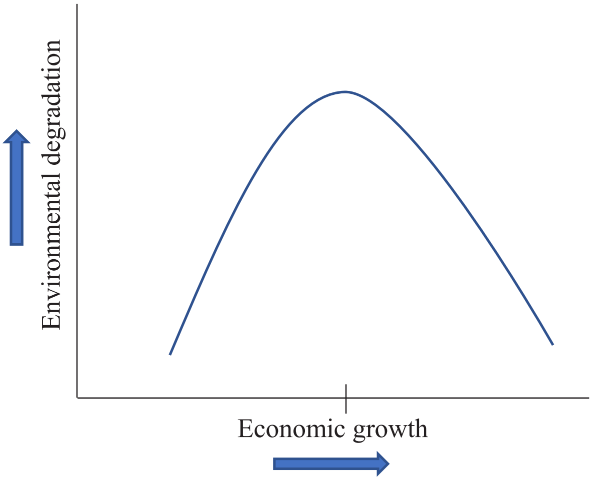
Research Methods

Theoretical Framework

Kuznets (1955) initially postulated the connection between income inequality and economic growth. An increase in the GDP of a country does not necessarily uplift the living standards of all its citizens. The economic growth might benefit the richer segments of the society, while the living standards of the poorer counterparts get deteriorated. Kuznets argued that such income inequality increases during the initial stage of development of a country. Whereas in the long run, income inequality declines along with economic growth when an economy achieves a threshold level of income. He expressed that the rise in economic growth worsens income inequality due to urbanization and industrialization in the early stages of development of the country. Whereas, in the later stages, income inequality declines along with economic growth. Such a relationship forms a bell-shaped curve or an inverted U-shaped curve which has been established as the Kuznets curve.

From the 1990s onwards, Kuznets' contribution took a new dimension. The empirical studies showed the same relationship in the case of environmental degradation and per capita income. The evidence showed that environmental degradation worsens along with the economic growth in the short- run. Meadows et al. (1972) argued that the natural resources are finite and such finiteness would prevent a country from growing economically if the environmental degradation continues. The EKC hypothesis suggests that environmental degradation should decline for an economy to achieve economic growth in the long run. Therefore, previous studies suggest that the relationship between environmental degradation and per capita income would form a similar kind of an inverted U-shaped curve.

Figure 1. Environmental Kuznets Curve



Empirical Strategy

We examine the existence of the EKC hypothesis in the case of Nepal employing time series data spanning from 1990 to 2018. Along with the EKC hypothesis, we also estimate the relationship between energy, economic growth and environmental pollution in a multivariate causal framework. The variables in the study include CO_2 emissions measured in kilotons (kt.), electricity production (EP) and electricity consumption (EC) measured in gigawatt hours (Gwh), oil consumption (OC) measured in kilotons oil equivalent (ktoe) and real Gross Domestic Product (GDP) in million rupees. The data of real gross domestic product is obtained from the quarterly bulletin of Nepal Rastra Bank. Time series data on CO_2 emissions, electricity production, electricity consumption and oil consumption are extracted from the data bank of the International Energy Agency. Although the data on other energy variables were available before 1990, the data on electricity generation was not available before 1990.

Many of the studies include the squared and cubed terms of GDP to capture the parabolic nature of the EKC curve. The problem of multicollinearity might exist in such modeling specifications (Narayan & Narayan, 2010). However, multicollinearity is not taken into account by most of the studies although it is one of the concerns. Literature argued that multicollinearity was not a problem while estimating the EKC curve (Attari et al., 2016; Lieb, 2002). Moreover, several studies examined the EKC curve in various nations using a time series approach incorporating growth and energy variables (Adebayo, 2020; Mohiuddin et al., 2016; Usman et al., 2019). Usually, the time series are highly correlated to each other and also high R^2 value is normal in time series analysis. Along with including squared term to capture the turning points of the EKC curve, the studies also model relevant energy variables such as electricity consumption and electricity production to establish a causal relationship between growth and energy variables (Jiang et al., 2021; Kong & Khan, 2019).

Since we want to test the presence of the EKC curve as well as estimate causal links between the variables, we conduct two linear models with and without the inclusion of the squared term in this paper. The former allows us to test the existence of the EKC curve in Nepal, whereas the latter helps us understand causal links among the variables. Following the linear model specified by Aung et al. (2017) in their study, the CO_2 emission can be expressed as a function of its determinants as follows:

$$CO_{2_t} = f(GDP_t, GDP_t^2\ EP_t, EC_t, OC_t,) \qquad [1]$$

$$CO_{2_t} = f(\ GDP_t, EP_t, EC_t, OC_t,) \qquad [2]$$

The linear relationship among the variables is established by taking logarithms on both sides of the equation. Such transformation allows us to calculate elasticities of CO_2 concerning the explanatory variables.

$$lnCO_{2_t} = \alpha_1 + \phi_1 lnGDP_t + \phi_2 lnGDP_t^2 + \phi_3 lnEP_t + \phi_4 lnEC_t + \phi_5 lnOC_t + \epsilon_t \qquad [3]$$

$$lnCO_{2_t} = \alpha_2 + \beta_{1i} lnEP_t + \beta_{2i} lnEC_t + \beta_{3i} lnOC_t + \beta_{4i} lnGDP_t + \epsilon_t \qquad [4]$$

The causal relationships among the variables are tested using a multivariate framework for which different functional relationships as presented in the next section. The ARDL bounds testing framework followed by Toda & Yamamoto's (1995) Granger-causality approach is incorporated to assess long-run relationships and direction of causality among the time series respectively.

$$EP_t = f\left(CO_{2_t}, EC_t, OC_t, GDP_t\right) \qquad [5]$$

$$EC_t = f\left(CO_{2_t}, EP_t, OC_t, GDP_t\right) \qquad [6]$$

$$OC_t = f\left(CO_{2_t}, EP_t, EC_t, GDP_t\right) \qquad [7]$$

$$GDP_t = f\left(CO_{2_t}, EP_t, EC_t, OC_t\right) \qquad [8]$$

Unit Root Testing

The unit root testing procedure is a prerequisite in any time series analysis. If the time series is not stationary, the regression may lead to spurious results. The unit root test allows us to pinpoint the order of integration for each time series. To proceed with the ARDL model, the order of integration of the time series should either be I(0) or I(1). Thus, the ADF test, P-P test and KPSS test are used to detect the order of integration of time series in this study. Moreover, Zivot & Andrew's (2002) stationarity test is also conducted to detect the order of integration in the presence of structural breaks in the time series. The Z-A unit root test pinpoints the break date in time series where the t-statistic from the ADF test is minimum.

ARDL Model

The ARDL method is utilized to test whether there is any long-run association among the time series due to several reasons (Pesaran et al., 2001). First, since the sample size is very low due to the unavailability of data, the ARDL method is employed since it is the most suitable method in the small sample size providing more robust results. The small size also provides robust results given that the diagnostic tests pass all the tests (Akbota & Baek, 2018). Secondly, the order of integration, whether I(0) or I(1), would not make any difference while estimating the equations under the ARDL model. However, the estimation process would crash in the presence of I(2) series. The ARDL (p, q_1, q_2, q_3, q_4) equation formulation of the equation (2) is presented as follows:

$$\Delta lnCO_{2_t} = a_1 + \sum_{i=1}^{p} \beta_{1i}\Delta lnC0_{2_{t-i}} + \sum_{i=0}^{q1}\beta_{2i}\Delta lnEP_{t-i} + \sum_{i=0}^{q2}\beta_{3i}\Delta lnEC_{t-i} + \sum_{i=0}^{q3}\beta_{4i}\Delta lnOC_{t-i} + \sum_{i=0}^{q4}\beta_{5i}\Delta lnGDP_{t-i} + \gamma_{11}lnCO_{2_{t-1}} + \gamma_{12}lnEP_{t-1} + \gamma_{13}lnEC_{t-1} + \gamma_{14}lnOC_{t-1} + \gamma_{15}lnGDP_{t-1} + U_{1t} \quad [9]$$

$$\Delta lnEP_t = a_2 + \sum_{i=1}^{p}\beta_{1i}\Delta lnEP_{t-i} + \sum_{i=0}^{q1} \beta_{2i}\Delta lnC0_{2_{t-i}} + \sum_{i=0}^{q2}\beta_{3i}\Delta lnEC_{t-i} + \sum_{i=0}^{q3}\beta_{4i}\Delta lnOC_{t-i} + \sum_{i=0}^{q4}\beta_{5i}\Delta lnGDP_{t-i} + \gamma_{21}lnCO_{2_{t-1}} + \gamma_{22}lnEP_{t-1} + \gamma_{23}lnEC_{t-1} + \gamma_{24}lnOC_{t-1} + \gamma_{25}lnGDP_{t-1} + U_{2t} \quad [10]$$

$$\Delta lnEC_t = a_3 + \sum_{i=1}^{p}\beta_{1i}\Delta lnEC_{t-i} + \sum_{i=0}^{q1} \beta_{2i}\Delta lnC0_{2_{t-i}} + \sum_{i=0}^{q2}\beta_{3i}\Delta lnEP_{t-i} + \sum_{i=0}^{q3}\beta_{4i}\Delta lnOC_{t-i} + \sum_{i=0}^{q4}\beta_{5i}\Delta lnGDP_{t-i} + \gamma_{31}lnCO_{2_{t-1}} + \gamma_{32}lnEP_{t-1} + \gamma_{33}lnEC_{t-1} + \gamma_{34}lnOC_{t-1} + \gamma_{35}lnGDP_{t-1} + U_{3t} \quad [11]$$

$$\Delta lnOC_t = a_4 + \sum_{i=1}^{p}\beta_{1i}\Delta lnOC_{t-i} + \sum_{i=0}^{q1} \beta_{2i}\Delta lnC0_{2_{t-i}} + \sum_{i=0}^{q2}\beta_{3i}\Delta lnEP_{t-i} + \sum_{i=0}^{q3}\beta_{4i}\Delta lnEC_{t-i} + \sum_{i=0}^{q4}\beta_{5i}\Delta lnGDP_{t-i} + \gamma_{41}lnCO_{2_{t-1}} + \gamma_{42}lnEP_{t-1} + \gamma_{43}lnEC_{t-1} + \gamma_{44}lnOC_{t-1} + \gamma_{45}lnGDP_{t-1} + U_{4t} \quad [12]$$

$$\Delta lnGDP_t = a_5 + \sum_{i=1}^{p}\beta_{1i}\Delta lnGDP_{t-i} + \sum_{i=0}^{q1} \beta_{2i}\Delta lnC0_{2_{t-i}} + \sum_{i=0}^{q2}\beta_{3i}\Delta lnEP_{t-i} + \sum_{i=0}^{q3}\beta_{4i}\Delta lnEC_{t-i} + \sum_{i=0}^{q4}\beta_{5i}\Delta lnOC_{t-i} + \gamma_{51}lnCO_{2_{t-1}} + \gamma_{52}lnEP_{t-1} + \gamma_{53}lnEC_{t-1} + \gamma_{54}lnOC_{t-1} + \gamma_{55}lnGDP_{t-1} + U_{5t} \quad [13]$$

First, equations (9) to (13) are estimated using OLS and respective F-statistics computed to check the joint significance of the lagged variables in the ARDL method. Next, the calculated F-statistics is compared to the two sets of asymptotic critical values namely lower bound and upper bound values (Pesaran et al., 2001). The hypothesis for the bounds test can be set as follows:

$$H_0: \gamma_{1i} \neq \gamma_{2i} \neq \gamma_{3i} \neq \gamma_{4i} \neq \gamma_{5i}$$

$$H_1: \gamma_{1i} = \gamma_{2i} = \gamma_{3i} = \gamma_{4i} = \gamma_{5i}$$

The calculated F-statistic is compared with lower and upper bound critical values. The first level value is calculated assuming that time series are integrated of order zero while the latter is calculated assuming that time series is integrated of order one. If the F statistic lies below the lower bond critical values, the null hypothesis of no cointegration cannot be rejected. The test is inconclusive if the F statistic lies between the lower bound and upper bound values. If the F statistic is greater than the upper bound critical values, the null hypothesis is rejected concluding that there is a long-run relationship among the variables. If the cointegration is established, the conditional ARDL (p,q_1,q_2,q_3,q_4) model is estimated as follows:

$$lnCO_{2_t} = a_1 + \sum_{i=1}^{p} \beta_{1i}lnC0_{2_{t-i}} + \sum_{i=0}^{q1}\beta_{2i}lnEP_{t-i} + \sum_{i=0}^{q2}\beta_{3i}lnEC_{t-i} + \sum_{i=0}^{q3}\beta_{4i}lnOC_{t-i} + \sum_{i=0}^{q4}\beta_{5i}lnGDP_{t-i} + \epsilon_{1t} \quad [14]$$

$$lnEP_t = a_1 + \sum_{i=1}^{p}\beta_{1i}lnEP_{t-i} + \sum_{i=0}^{q1} \beta_{2i}lnCO_{2_{t-i}} + \sum_{i=0}^{q2}\beta_{3i}lnEC_{t-i} + \sum_{i=0}^{q3}\beta_{4i}lnOC_{t-i} + \sum_{i=0}^{q4}\beta_{5i}lnGDP_{t-i} + \epsilon_{2t} \quad [15]$$

$$lnEC_t = a_1 + \sum_{i=1}^{p} \beta_{1i} lnEC_{t-i} + \sum_{i=0}^{q1} \beta_{2i} lnC0_{2_{t-i}} + \sum_{i=0}^{q2} \beta_{3i} lnEP_{t-i} + \sum_{i=0}^{q3} \beta_{4i} lnOC_{t-i} + \sum_{i=0}^{q4} \beta_{5i} lnGDP_{t-i} + \epsilon_{3t} \quad [16]$$

$$lnOC_t = a_1 + \sum_{i=1}^{p} \beta_{1i}\, lnOC_{t-i} + \sum_{i=0}^{q1} \beta_{2i} lnC0_{2_{t-i}} + \sum_{i=0}^{q2} \beta_{3i} lnEP_{t-i} + \sum_{i=0}^{q3} \beta_{4i} lnEC_{t-i} + \sum_{i=0}^{q4} \beta_{5i} lnGDP_{t-i} + \epsilon_{4t} \quad [17]$$

$$lnGDP_t = a_1 + \sum_{i=1}^{p} \beta_{1i} lnGDP_{t-i} + \sum_{i=0}^{q1} \beta_{2i} lnC0_{2_{t-i}} + \sum_{i=0}^{q2} \beta_{3i} lnEP_{t-i} + \sum_{i=0}^{q3} \beta_{4i} lnEC_{t-i} + \sum_{i=0}^{q4} \beta_{5i} lnOC_{t-i} + \epsilon_{5t} \quad [18]$$

ECM Model

The error correction terms of cointegrated equations in the form of residuals are estimated from the conditional ARDL models in the previous section and their lagged values are plugged in the equation (19) to obtain short-run dynamics.

$$\begin{bmatrix} \Delta lnCO_{2_t} \\ \Delta lnEP_t \\ \Delta lnEC_t \\ \Delta lnOC_t \\ \Delta lnGDP_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} + \sum_{i=1}^{p} \Delta \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} & \beta_{35} \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} & \beta_{45} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & \beta_{55} \end{bmatrix} \times \begin{bmatrix} lnCO_{2_{t-i}} \\ lnEP_{t-i} \\ lnEC_{t-i} \\ lnOC_{t-i} \\ lnGDP_{t-i} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \\ \epsilon_{3t} \\ \epsilon_{4t} \\ \epsilon_{5t} \end{bmatrix} \quad [19]$$

Where $\Delta lnCO_{2t}$, $\Delta lnEP_t$, $\Delta lnEC_t$,$\Delta lnEC_t$ and $\Delta lnGDP_t$ capture short-run dynamics and δ_i represents the speed of adjustment showing the error correction to converge back to the original equilibrium. The ECT_{t-1} is the error correction term obtained from the long-run cointegration equation. The error terms represented by ϵ_{it} are serially uncorrelated stochastic terms.

TY Non-Granger Causality Test, Impulse Response and Variance Decomposition

The estimated ARDL model avoids spurious regression and provides robust results, however, it does not detect the direction of causality. Hence, the Granger Causality test modified by Toda and Yamamoto (1995) is employed. The TY Non-Granger Causality test has several advantages over the standard Granger Causality testing procedure. First, it can be applied in the case of non-stationary time series, unlike the standard Granger Causality test. Second, it can be applied even when the time series has a mixed order of integrations. This model is performed under the VAR framework as presented in the following equations:

$$X_t = a_i + \sum_{i=1}^{k} \alpha_{1i} X_{t-i} + \sum_{j=k+1}^{k+d_{max}} \alpha_{1j} X_{t-j} + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{1j} Y_{t-j} + v_{1it} \quad [20]$$

$$Y_{it} = a_i + \sum_{i=1}^{k} \alpha_{2i} Y_{t-i} + \sum_{j=k+1}^{k+d_{max}} \alpha_{2j} Y_{t-j} + \sum_{i=1}^{k} \beta_{2i} X_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{2j} X_{t-j} + v_{2it} \quad [21]$$

Where X_t represents the carbon dioxide ($lnCO_2$) and Y_{it} represents the vector of independent variables used in the study. The K represents optimal lag length chosen by the criteria and d_{max} represents the maximum order of integration of the time series. The variance decomposition and impulse responses graph are estimated using the T-Y approach which uses augmented VAR.

Data Analysis and Result

Descriptive Statistics

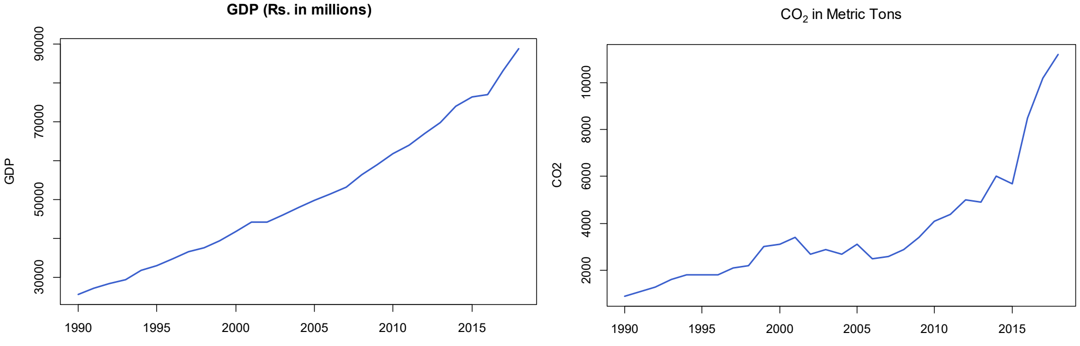
Table 1 presents summary statistics of the variables used in this study. CO_2 represents carbon dioxide emissions in metric tons (mt.). EP represents electricity production and EC represents electricity consumption both measured in Gigawatt hours (Gwh.). OC represents oil consumptions measured in kilotons oil equivalent (Ktoe.) and GDP stands for Gross Domestic Product in million rupees.

Table 1: Descriptive Analysis

Statistics	CO_2	EP	EC	OC	GDP
Mean	3686.2069	2390.0345	2310.34	885.172	51045.263
Median	2900	2404	1900	720	48100.432
Maximum	11200	4898	6500	2657	88781.666
Minimum	900	839	700	243	25650.89
Std. Dev.	2551.8514	1236.4783	1553.42	579.726	18090.565
Skewness	1.6219	0.3061	1.1478	1.7256	0.4318
Kurtosis	5.0481	1.9669	3.6107	5.5329	2.1061
Jarque-Bera	17.7843	1.7425	6.8192	22.1452	1.8668
Probability	0.0001	0.4184	0.0331	1.55E-05	0.3931
Observations	29	29	29	29	29
Correlations					
CO_2	1				
EP	0.8846	1			
EC	0.9723	0.9585	1		
OC	0.9948	0.8821	0.9699	1	
GDP	0.9083	0.9843	0.9694	0.9004	1

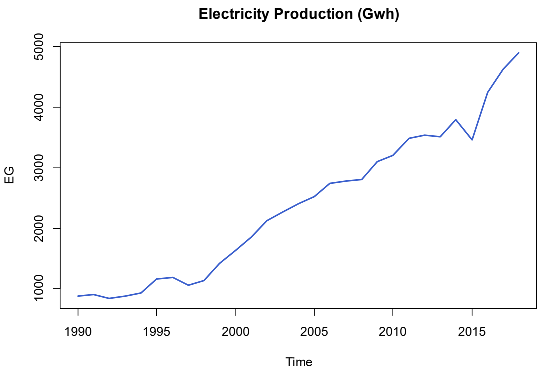
Table 1 shows the descriptive statistics of all the macroeconomic variables with a sample size of 29. The null hypothesis of normality is rejected for CO_2, EC and OC whereas the null hypothesis of normality cannot be rejected for EP and GDP. Every time series except EP and GDP exhibit right-tail (positive skewness). The CO_2, EC and OC have heavier tails following platykurtic distribution, while the remaining variables follow a leptokurtic distribution with lighter tails. The correlation analysis shows that all the coefficients are greater than 0.8, indicating a very strong association among all the time series variables. The plots in figure 1 show that all the endogenous variables are rising with time. The plots of carbon dioxide and oil consumption reveal a sharp increase in the year 2015.

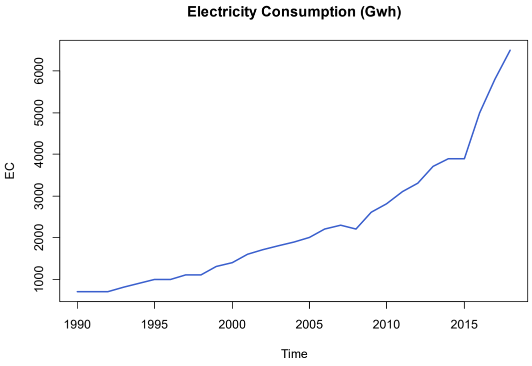
Figure 2: Time Series Plots

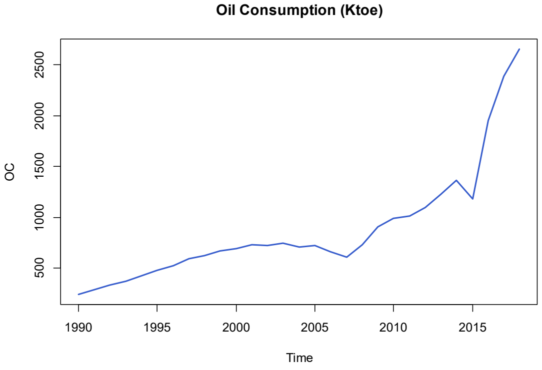


GDP (Rs. in millions)

CO_2 in Metric Tons







Unit Root Test

The order of integration of time series is checked by employing different unit root testing techniques. Since the bounds testing procedure can be applied only in the presence of I(0) or I(1) time-series, it is important to assess the stationarity property of the time series using the unit root testing approach.

Table 2: Unit Root Tests (t- statistic)

	ADF	PP	KPSS
Level			
$lnCO_2$	-1.6011	-1.6011	0.1157
lnEP	-1.9519	-2.0744	0.1282*
lnEC	-2.1773	-2.3552	0.1793**
lnOC	-1.2657	-1.5002	0.1177
lnGDP	-3.1295	-3.0373	0.1160
First Difference			
$\Delta lnCO_2$	-2.5757	-5.5385***	0.1520
ΔlnEP	-4.7462***	-4.7705***	0.1159
ΔlnEC	-5.8101***	-5.5875***	0.3320
ΔlnOC	-4.7635***	-4.7635***	0.1898
ΔlnGDP	-5.3873***	-6.7243***	0.1476

Notes: *, ** and *** represent significance levels at 10%, 5% and 1% respectively. ADF = Augmented Dickey-Fuller; (P-P) = Phillips-Perron; KPSS = Kwiatkowski–Phillips–Schmidt–Shin

In Table 2, the null hypothesis of having unit-roots for all-time series can be rejected in their first differences as per P-P and KPSS tests whereas, the ADF tests show non-stationary of CO_2 in its first difference. Such discrepancy is common and evident in several of the available studies (Frimpong & Oteng-Abayie, 2007). On top of that, the P-P and KPSS tests have an advantage over the standard ADF test since these tests correct for a coefficient from AR(1) and test the null hypothesis of stationarity respectively (Ibrahim et al., 2011). Moreover, the correlogram, as well as the graph in Figure 2, does not refute that CO_2 is non-stationary in its first difference.

Table 3: Zivot-Andrews Structural Break Unit Root Test

Variables	ZA Test for Level			ZA Test for First Difference		
	T-statistic	**Break**	**Outcome**	**T-statistic**	**Break**	**Outcome**
lnCO_2	-3.4656**	2006	Stationary	-4.8180***	2002	Stationary
lnEP	-4.1877***	1999	Stationary	-5.2398***	1999	Stationary
lnEC	-2.8604	2005	Non-Stationary	-5.5734***	1999	Stationary
lnOC	-2.5804**	2004	Stationary	-5.9311**	2008	Stationary
lnGDP	-4.0208	2002	Stationary	-6.7446***	2002	Stationary

Notes: *, ** and *** represent significance levels at10%, 5% and 1% respectively.

The null hypothesis of having unit-roots may not get rejected due to the presence of structural breaks in the time series. Therefore, a structural break unit root testing procedure is followed to test the unit root test hypothesis in the presence of structural break. The unit root test method developed by Zivot and Andrews (2002) is undertaken so that the structural break date in the series can be exogenously determined. The test concludes that all the time series are integrated of the order less than 2.

Bounds Test

The bounds testing procedure developed by Pesaran et al. (2001) is a prerequisite to determining the long-run association among the time series. However, it is necessary to determine the optimal lag length before proceeding with the test. Table 4 shows the lag length as per various criteria under the VAR model. In this paper, the lag length of 1 is selected based on SIC criteria and the bounds test is carried out further. The bounds test gives two sets of values at I(0) and I(1). The calculated upper and lower bound statistics are then compared to the set of critical values (Pesaran et al., 2001).

Table 4: VAR Lag Selection

Lag	Log Likelihood	LR Statistic	Final Predictor Error	Akaike Information Criterion	Schwarz Information Criterion	Hannan-Quinn Information Criterion
0	204.141	NA	1.53E-13	-15.319	-15.077	-15.249
1	323.99	184.383*	1.08e-16*	-22.615	-21.163*	-22.197
2	342.423	21.269	2.28E-16	-22.109	-19.448	-21.343
3	384.135	32.086	1.32E-16	-23.395*	-19.524	-22.280*

Note: * indicates lag selected according to various criteria.

The lag selection is vital in any time series analysis to avoid the problem of autocorrelation. The SIC value was found to be the lowest when the lag is 1 period as suggested by Table 4. The SIC lag is used since it is robust in the case of small sample sizes. Hence, a maximum lag of 1 period is selected before proceeding to the bounds testing method.

Table 5: Bounds Test Results

Dependent Variable	**SIC Lags**	**F-Statistics**	**Outcome**
$f(lnCO_2 \| lnGDP, lnGDP^2, lnEP, lnEC, lnOC)$	(1,0,0,0,1,0)	3.6974	Cointegration
$f(lnCO_2 \| lnEP, lnEC, lnOC, lnGDP)$	(1,1,0,0,0)	3.9210	Cointegration
$f(lnEP \| lnCO_2, lnEC, lnOC, lnGDP)$	(1,0,1,0,0)	0.4553	No
$f(lnEC \| lnCO_2, lnEP, lnOC, lnGDP)$	(1,0,0,1,0)	7.5573	Cointegration
$f(lnOC \| lnCO_2, lnEP, lnEC, lnGDP)$	(1,0,0,0,0)	5.5238	Cointegration
$f(lnGDP \| lnCO_2, lnEP, lnEC, lnOC)$	(1,0,1,0,0)	24.5305	Cointegration
Critical Values (Pesaran et al., 2001a)		***I*(0)**	***I*(1)**
1% significance level		3.29	4.37
5% significance level		2.56	3.49
10% significance level		2.2	3.09

Table 5 presents the results of the bounds test that shows that there are four co-integrating equations out of five at a 5% significance level. The F-statistics of lnCO_2, lnEC,lnOC and lnGDP are greater than the upper bounds at a 5% level of significance. However, the F-statistic for lnEP is 0.4553 which is less than the lower bound at a 5% level of significance. Therefore, there is no co-integration when lnEP is a dependent variable. Except for electricity production as the dependent variable, all other variables show that there are long-run relationships among the time series. Hence, ARDL long-run and error correction models can be estimated.

Table 6: Long Run Coefficients

The EKC Framework

Variables	**Coefficient**	**t-statistic**
lnGDP	-11.063	-1.268
$lnGDP^2$	1.367	1.354
lnEG	0.168	0.420
lnEC	-1.039	-1.102
lnOC	0.956	4.450***
C	25.337	1.274
R^2	0.626.	

Causal Framework

Variables	**$lnCO_2$**		**lnEC**		**lnOC**		**lnGDP**	
	Coeff.	**t-stat**	**Coeff.**	**t-stat**	**Coeff.**	**t-stat**	**Coeff.**	**t-stat**
lnCO_2	-	-	0.317	1.332	0.767	5.034***	0.241	1.374
lnEG	-0.501	-2.009**	0.432	2.615***	-0.230	-1.052	0.165	1.040
lnEC	0.363	0.917	-	-	0.653	1.565	0.242	1.037
lnOC	0.692	3.853***	0.095	0.437	-	-	-0.067	-0.4
lnGDP	0.7	1.144	0.546	1.305	-0.569	-0.980	-	-
C	-1.312	-0.751	-2.071	-1.948*	1.501	0.883	2.766	17.982***
R^2	0.44		0.59		0.40		0.31	

Model 1 presents long-run coefficients from the EKC framework. The coefficients for GDP and GDP^2 are found to be insignificant. Moreover, the coefficients of GDP should be positive and that for the squared term should be negative for the EKC hypothesis to be validated. In model 2, the causal relationship between the growth and energy variables is determined. The results reveal that electricity generation and oil consumption are significantly associated with the carbon dioxide emissions in Nepal. One percent rise in oil consumption results in a 0.7% increase in carbon dioxide level. Since Nepal is heavily dependent on fuel and renewable sources of energy, this result is plausible in the case of Nepal. Similarly, a one percent increase in electricity generation can be attributed to a 0.5% decrease in carbon dioxide emission at a 5% level of significance. This result corresponds to the conclusion drawn by Suman (2021) which argues that the adoption of a renewable form of energy reduces greenhouse gas emissions. The negative coefficient of lnEG when lnOC is dependent variable reveals that there is a negative association between electricity generation and oil consumption. Thus, the level of carbon dioxide emissions can be reduced if Nepal produces more electricity in the long run. The EC model shows that there is a positive relationship between electricity generation and electricity consumption in Nepal. However, there is misspecification of the functional form in this model as shown by Table 9 that estimates from the EC cannot be considered robust. The relationship between economic growth and electricity consumption is insignificant. This result is similar to the findings of Nepal and Paija (2019) that examined the relationship between energy and growth under classical production function. Both the EKC and causal frameworks confirm that there is no relationship between GDP and the level of carbon dioxide in the long run. Since Nepal is yet in the developing phase, the EKC hypothesis might not hold in the present scenario.

Table 7: Short Run Coefficients

EKC Framework

Variables	Coefficient	t-statistic
ΔlnGDP	-7.665	-0.884
ΔlnGDP^2	0.978	1.047
ΔlnEG	0.311	1.297
ΔlnEC	-0.012	-0.039
ΔlnOC	0.620	4.519***
ECT(-1)	-0.771	-4.708***

Causal Framework

Variables	ΔlnCO_2		ΔlnEC		ΔlnOC		ΔlnGDP	
	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
ΔlnCO_2	-	-	0.134	1.600	0.614	5.528***	0.085	2.867***
ΔlnEG	-0.066	-0.299	0.266	2.584***	-0.017	-0.084	-0.050	-1.163
ΔlnEC	0.398	1.370	-	-	0.393	1.503	-0.012	-0.200
ΔlnOC	0.574	3.955***	0.200	2.114**	-	-	-0.017	-0.475
ΔlnGDP	0.683	1.612	0.213	0.930	-0.490	-1.17	-	-
ECT(-1)	-0.77	-4.25***	-0.524	-4.38***	-0.618	-3.45***	-0.264	-10.86***

In the short run, a one percent increase in carbon dioxide emission leads to an increase in GDP by 0.09% under the causal framework. However, the feedback is not significant from lnCO_2 to lnGDP. The error correction terms in all four models are negative and significant which implies that any kind of disequilibrium in the short run due to shocks converges back to the equilibrium in the long run.

All the coefficients of the error correction term are between 0 and -1 which shows that the short-run disequilibrium tends to converge back to the long-run equilibrium. The GDP is seen to have the lowest speed of adjustment of 26.4% and CO_2 level to have the highest speed of adjustment of 77% per annum.

Table 8: Diagnostics and Stability Tests

EKC Framework

Diagnostics	Statistics
Normality (J-B)	1.039 [0.595]
Serial Correlation χ^2 (1)	0.238 [0.154]
Ramsey RESET (F_{stat})	0.132 [0.719]
ARCH Test χ^2 (1)	0.769 [0.758]
B-G test	0.773 [0.096]

Causal Framework

Dependent Variables	$lnCO_2$	lnEC	lnOC	lnGDP
Diagnostics				
Normality (J-B)	0.993[0.609]	0.279[0.870]	0.341[0.843]	0.649[0.723]
Serial Correlation χ^2 (1)	0.010[0.919]	1.938[0.164]	0.873[0.320]	0.181[0.671]
Ramsey RESET (F_{stat})	0.633[0.436]	8.102[0.01]	0.076[0.786]	0.009[0.924]
ARCH Test χ^2 (1)	0.538[0.463]	0.483[0.487]	0.018[0.892]	0.297[0.586]
B-G test	10.065[0.122]	6.078[0.415]	8.425[0.134]	2.199[0.901]

The diagnostic tests show that all the models are normally distributed. There is no serial correlation in all the time series. Similarly, all models are free from heteroscedasticity which ensures unbiased estimates. There are no misspecifications of functional form in all the models except when lnEC is the dependent variable. Therefore, estimates from all empirical models except for lnEC are found to be unbiased. The CUSUM and CUSUMQ tests check overall stability and structural breaks in the models. The cumulative sum of recursive residuals of the models are calculated and they are plotted against lower and upper bounds of the 95% confidence interval. If the plots fall between the 5% critical bands, the model is deemed to be stable and vice-versa. The CUSUM plots in Fig. 3 and 4 reveal that all the models are stable. There are structural breaks according to the CUSUMQ plots in CO_2, Electricity Consumption and Oil Consumption. However, the plots return to the 5% confidence interval after the breaks in the series.

Table 9: TY Non-Granger Causality Test of Causal Framework

The direction of non-Granger causality	N	χ^2	Prob.
$lnEG \nRightarrow lnCO_2$	27	24.0195	0.0000
$lnCO_2 \nRightarrow lnEG$		3.8540	0.0496
$lnEC \nRightarrow lnCO_2$	27	3.7732	0.0521
$lnCO_2 \nRightarrow lnEC$		3.8734	0.0491
$lnOC \nRightarrow lnCO_2$	27	0.0711	0.7897
$lnCO_2 \nRightarrow lnOC$		0.4737	0.4913
$lnGDP \nRightarrow lnCO_2$	27	5.7565	0.0164
$lnCO_2 \nRightarrow lnGDP$		0.5065	0.4767

The direction of non-Granger causality	N	χ^2	Prob.
$lnEC \nRightarrow lnEG$	27	2.5510	0.1102
$lnEG \nRightarrow lnEC$		3.2533	0.0713
$lnOC \nRightarrow lnEG$	27	0.9131	0.3393
$lnEG \nRightarrow lnOC$		18.5163	0.0000
$lnGDP \nRightarrow lnEG$	27	4.3203	0.0377
$lnEG \nRightarrow lnGDP$		3.4204	0.0644
$lnOC \nRightarrow lnEC$	27	2.4720	0.1160
$lnEC \nRightarrow lnOC$		4.2869	0.0384
$lnGDP \nRightarrow lnEC$	27	10.0144	0.0016
$lnEC \nRightarrow lnGDP$		6.0065	0.0143
$lnGDP \nRightarrow lnOC$	27	2.8671	0.0904

Apart from the findings of the long-run cointegrating relationships in a multivariate framework, the causality among the variables is presented in table 10. The TY non-Granger causality test results show that bidirectional causality exists between electricity generation and carbon dioxide emissions at a 5% level of significance. This result is in line with the long-run coefficient of the $lnCO_2$ model that shows a negative relationship between carbon dioxide emissions and electricity generation. Shrestha and Shakya (2012) has also examined the implication of reduction of CO_2 emissions in Nepal and found that such policy would lead to electricity generation and rise in domestic employment of the country. Therefore, electricity generation can help in reducing the environmental pollution in Nepal. Similarly, there is two-way causality feedback between electricity consumption and GDP. However, there is a unidirectional causality from GDP to electricity generation. The development of hydroelectricity plants can help Nepal to meet its energy demand as well as become independent in energy production (Poudyal et al., 2019). Such independence can also allow Nepal to export its energy resources to other countries. Although there is no long-run relationship between carbon dioxide emissions and economic growth, the results also show that economic growth Granger causes carbon dioxide emissions in Nepal.

Generalized Impulse Response and Variance Decomposition

The Granger causality test shows if there is any relationship between the trends of two variables. However, it does not depict the innovations in one variable due to the changes in another variable. The variance decomposition and impulse response allow us to analyze how one variable reacts to the shock in another variable. A percentage standard deviation shock in the Gross Domestic Product of Nepal explains carbon dioxide emissions by 10.79% in shorter horizons and by 1.33% in the longer horizons. The impact of carbon dioxide emissions on the Gross Domestic Product of Nepal is found to decline along with horizons getting longer as per the Impulse Response Function (IRF) graph whereas the impact of forecast error variance decomposition of electricity generation on carbon dioxide emissions was about 4% in shorter horizons and gradually increased to 78% in the longer horizons. The gradual increase in the impact can be seen in the second period as depicted by the impulse response in Figure 4. However, energy consumptions including both oil and electricity were found to be almost the same in all horizons.

As for the forecast error variance decomposition of GDP, the innovations in GDP are explained mostly by themselves up to the 6th period. However, 46% of the forecast error variance in GDP is explained by electricity generation in the longer horizons. Hence, electricity generation has a strong influence on the GDP in the long run. The impact of changes in carbon dioxide emissions on the changes in GDP was found to be increasing in the shorter horizons. However, the influence of carbon dioxide emissions on GDP is found to be declining in the longer horizons. This result is also indicative of a positive linkage between environmental pollution and economic growth only in the short run as shown by the short-run coefficients of the ARDL model. The impulse response also shows the response of GDP due to changes in CO_2 emissions to be declining in longer horizons. Therefore, carbon dioxide emissions have a positive effect on economic growth only in the short run but not in the long run.

Conclusion

This paper intends to examine the relationship between energy production and use, environmental degradation and economic growth at a disaggregated level. In line with the existing methodologies and studies, we used the EKC hypothesis as well as a multivariate framework to observe such relationships. The study found that there was no long-run relationship between carbon dioxide emissions and the economy in Nepal. Hence, the EKC hypothesis does not hold in the case of Nepal as of now. The results were in line with several studies which found the non-existence of the EKC hypothesis in many countries (Mazzanti et al., 2011; Wang & Lu, 2011). On the other hand, the causal framework showed that an increase in electricity production reduces carbon dioxide emissions in the long run. The forecast error variance of carbon dioxide emissions and declining trend of impulse response graph also shows that it is greatly influenced by electricity generation in the long run. Moreover, two-way feedback between oil consumption and carbon dioxide emissions was found in the long run. Therefore, Nepal should adopt a cleaner form of energy such as hydroelectricity instead of fossils and fuels to mitigate the problem of environmental pollution. Production of hydroelectricity can help Nepal reduce the CO_2 level and increase economic growth at the same time. Although CO_2 level and economic growth are positively related in the short run, Nepal has the potential to reduce the pollution level through electricity generation in the long run.

One of the major limitations of this study includes a small sample size because of the unavailability of the data. However, the diagnostics show that the estimations of the EKC framework and multivariate models are stable overall. Despite such limitations, the results are quite notable in the context of Nepal where fossils and fuels are used heavily as an energy source and have huge potential of generating cleaner forms of energy on the flipside. The threat of environmental pollution can be mitigated if Nepal can harness the potentiality of producing hydroelectricity. Substituting hydroelectricity for fossils and fuels not only benefits the environment but also helps Nepal to become a self-reliant country in terms of energy production. This will further boost the economic growth of Nepal.

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Annex:

Figure 2: Difference and Correlogram Graphs of $lnCO_2$

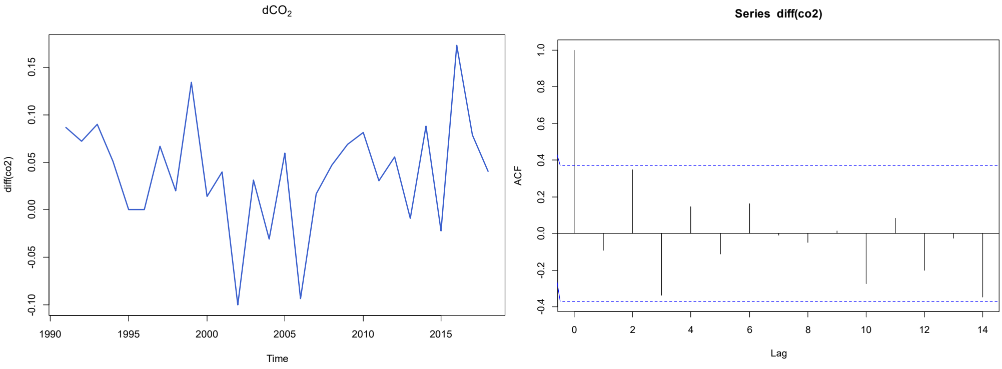


Figure 3: CUSUM and CUSUMQ for EKC Framework

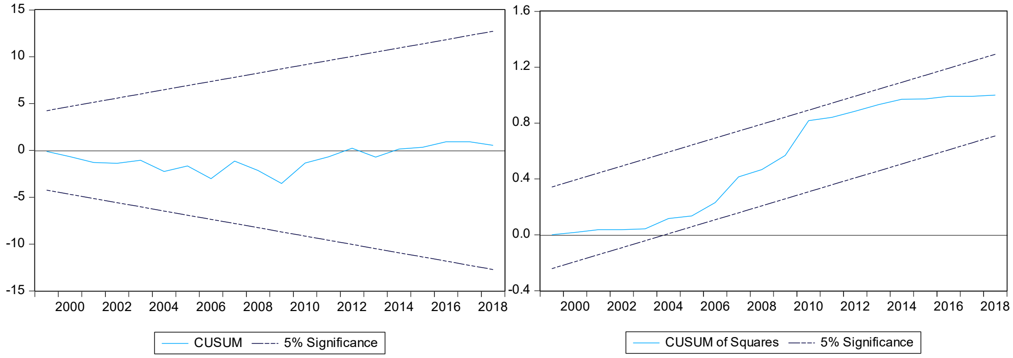
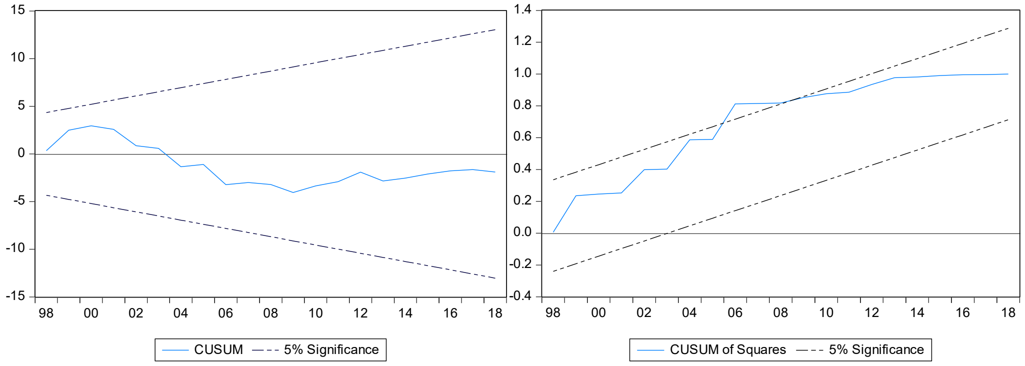
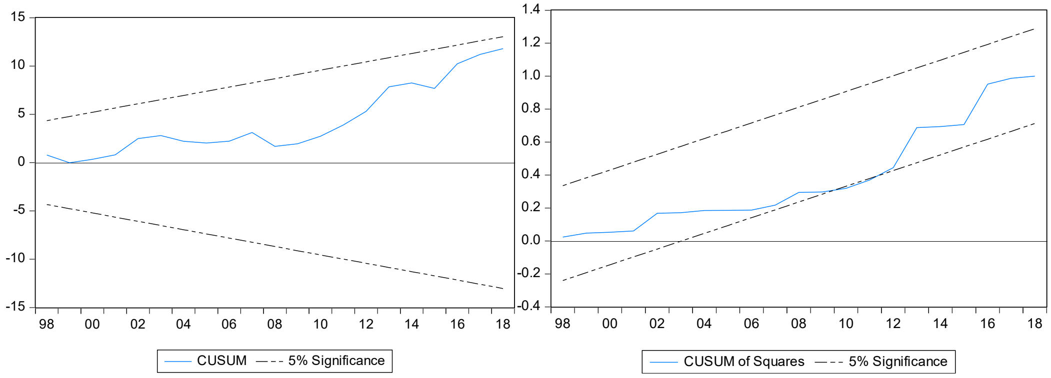


Figure 4: CUSUM and CUSUMQ for Causal Framework

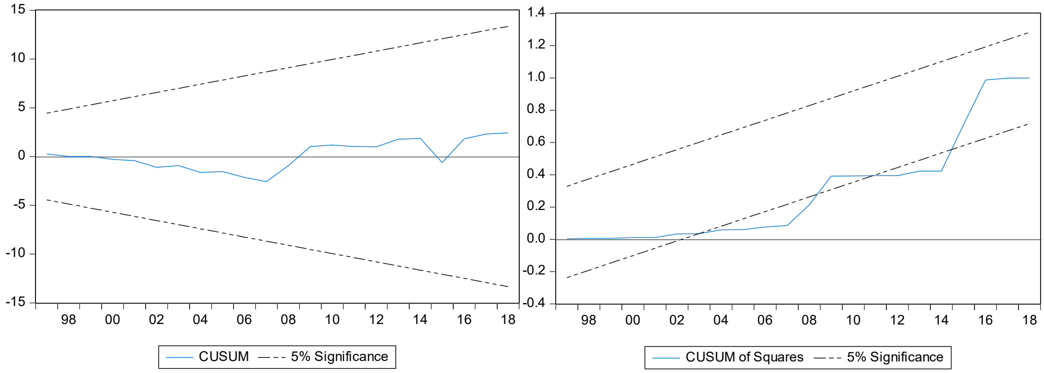
Carbon-dioxide (CO_2)



Electricity consumption



Oil Consumption



Gross Domestic Product

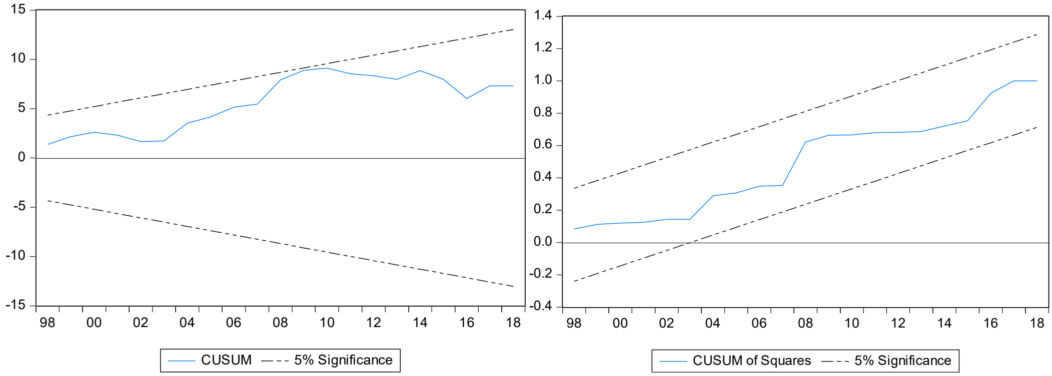


Table 10: Variance Decomposition

Period	S.E.	$\ln CO_2$	lnEG	lnEC	lnOC	lnGDP
Variance Decomposition of $\ln CO_2$						
1	0.04171	100	0	0	0	0
2	0.04982	82.4169	3.82428	0.10973	2.85506	10.7941
3	0.06668	55.3428	31.2221	0.28334	4.79275	8.35896
4	0.08777	34.4639	57.1888	0.16503	3.11002	5.07227
5	0.10274	25.4946	67.8767	0.37586	2.33921	3.91357
6	0.12165	23.3567	70.5185	1.45927	1.85418	2.81139
7	0.1377	19.9373	74.467	1.56804	1.80377	2.22392
8	0.15484	19.0828	75.5592	1.71966	1.76468	1.87369
9	0.16966	17.5303	77.3719	1.89654	1.61276	1.58851
10	0.18519	17.1869	77.7997	2.11454	1.5654	1.33351
Variance Decomposition of lnEG						
1	0.03822	7.80729	92.1927	0	0	0
2	0.05328	12.3991	86.4683	0.00071	1.1255	0.0064
3	0.06529	21.7445	72.6832	0.08541	5.32428	0.16265
4	0.07678	25.1078	67.077	0.45074	5.93041	1.43405

5	0.08425	27.8489	64.0673	0.62632	5.53618	1.92124
6	0.0898	28.5233	63.8765	0.84895	5.02318	1.7281
7	0.09766	28.9298	64.354	0.88755	4.34697	1.48172
8	0.10425	28.8672	64.5948	0.82078	4.28812	1.42913
9	0.11056	29.7589	63.4969	0.84366	4.47538	1.4252
10	0.11624	30.2036	62.9657	0.89531	4.4939	1.4415
Variance Decomposition of lnEC						
1	0.02034	0.16596	47.5548	52.2793	0	0
2	0.02651	3.95063	40.9513	46.4349	0.84595	7.81727
3	0.03443	9.29255	25.971	35.4396	15.7455	13.5513
4	0.03658	8.38045	23.4266	34.5881	19.9243	13.6806
5	0.03894	7.50014	24.4267	36.8941	18.7304	12.4488
6	0.04271	9.86669	22.3505	39.071	16.5497	12.1622
7	0.04526	9.37083	20.9621	41.3481	16.2947	12.0244
8	0.04887	11.6201	20.2446	41.4297	16.2542	10.4515
9	0.05139	11.0891	20.1845	42.745	16.3192	9.66233
10	0.05515	11.7509	19.6091	43.0003	16.1715	9.46815
Variance Decomposition of lnOC						
1	0.0402	25.6509	23.0125	2.55235	48.7842	0
2	0.04649	19.4852	17.5092	8.38587	50.0262	4.59345
3	0.04984	17.0538	25.9609	8.8765	43.9855	4.12332
4	0.06507	21.2428	40.0143	7.27645	26.7337	4.73278
5	0.0873	20.4012	51.9713	8.22695	16.1285	3.27205
6	0.11005	25.0734	53.2359	9.01412	10.6058	2.0708
7	0.12889	27.4727	53.9934	8.80953	8.10762	1.61676
8	0.14915	29.8516	53.3529	8.50049	6.38647	1.90855
9	0.16554	30.5124	53.3556	8.82534	5.42768	1.87901
10	0.18149	31.4269	53.2159	9.20121	4.56675	1.58924
Variance Decomposition of lnGDP						
1	0.00718	8.85704	19.2193	9.30879	11.5934	51.0214
2	0.00904	15.2267	12.3555	8.23925	17.0845	47.0941
3	0.00933	16.2143	13.3121	7.78126	17.3195	45.3729
4	0.01089	11.9916	28.7799	6.71534	12.7626	39.7506
5	0.01242	9.21015	31.694	6.40964	11.7591	40.9271
6	0.01354	7.9652	34.7844	5.39806	12.3016	39.5508
7	0.01467	7.38522	39.8192	4.60499	11.1897	37.0009
8	0.01569	6.78131	42.0211	4.16867	10.2922	36.7367
9	0.01679	6.3393	43.5799	3.68602	9.67769	36.7171
10	0.01782	5.96744	45.8823	3.27545	9.12561	35.7492

Figure 5: Impulse Response