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Closing the Evidence Gap: Energy Consumption, Real Output and Pollutant Emissions in a Developing Mountainous Economy

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Abstract

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Keywords

economic growth, granger causality, energy consumption, carbon emissions

JEL Classification

C32, O55, Q20, Q43

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1. Introduction

The mainstream theories of economic growth have paid little or no attention on the role of energy or other natural resources in promoting or enabling economic growth (Stern, 2004; Aghion and Howitt, 2009; Stern, 2011). Numerous empirical studies now exist validating the potential and actual linkages between energy and economic growth. However, the empirical evidences on the role that natural resources such as energy play on economic growth are limited for mountain economies. This is concerning considering that these economies are essential for global sustainable development as bearers of crucial ecosystem goods and services. Investigating the strength of the linkages between energy and economic growth in mountain economies is also necessary as increasing demands on ecosystem goods and services are adding more pressure on natural resources and environment of these economies (Schild, 2008).

Mountain economies occupy 24% of the global land surface area and provide shelter to 12% of the world's population (Schild and Sharma, 2011). About 10% of the world's population depends directly on the use of mountain resources for their livelihoods and wellbeing. Additionally, an estimated 40% depends indirectly on them for water, hydroelectricity, fuelwood, biodiversity and mineral resources. However, mountain economies are often overlooked in the global sustainable development agenda despite their important economic, energy and ecological contributions. Such lack of attention in sustainable policy agenda calls for an in-depth study on the linkages between economic growth, energy consumption and environmental degradation focussing on mountain economies.

These economies are also highly vulnerable to the risks of climate change owing to a matrix of drivers such as population growth, fossils based energy use and increasing economic activities although their current contribution to global Green House Gas (GHG) emissions is low (Shrestha, 2013). The demand for primary energy is increasing in these economies due to growing population and structural changes, which can engender potential adverse repercussions on their economy and the natural environment (Beniston, 2016). Climate change, now established as a prominent force of global change, will affect the world's mountain regions and may jeopardize the important services provided by mountains such as drinking water supplies, hydropower generation, agricultural suitability and risks of natural hazards (Kohler at al. 2014). Yet, studies directly addressing these environmental challenges in mountain economies that are guided towards understanding the linkages between energy consumption and economic growth while offering sustainable development related policy solutions are scarce. What is the nature of the relationship between energy use and GDP in these economies when time-series analysis generally show that energy use Granger causes GDP when capital and other production inputs are included in the vector autoregression (VAR) model?

This study attempts to close the current knowledge gap by exploring on the relationship between energy consumption and economic growth focusing on a recognized mountainous economy of Nepal with capital, population and emissions as additional variables. Hence, our analysis naturally borrows the insights from the classical and neo-classical theories of economic growth (Malthus, 1798; Solow, 1956). Nepal is an interesting case study as the nation is a recognized mountainous South Asian economy, homing eight of the ten tallest mountains in the world, and fully belongs to the Hindu Kush Himalaya region. Mountains and rugged hills almost cover 75% of Nepal's land area. Environmental protection and conservation policies is gaining more attention in this mountainous economy as climate change deepens as a major global environmental issue (Environment statistics of Nepal 2013). Community based initiatives along with sustainable use of forests are prescribed for effective conservation to prevent biodiversity loss although not much focus has been garnered towards energy consumption and its associated impacts. The lack of adequate attention towards energy consumption and its impact on economic growth and carbon emissions adequately merits this study considering that biomass and fuelwood cater for more than 80% of final energy consumption in Nepal.

The landlocked growing economy is one of the lowest per capita energy consuming countries in the world and remains well below the world average. Nepal's per capita energy consumption was 412.72 kg of oil equivalent in 2014, the lowest among the South Asian nations, while the world's average being 1920.724 kg of oil equivalent (World Bank, 2014). However, energy sector in Nepal has a substantial influence in the economy and the environment, thereby garnering heightened attention from policy makers. Petroleum products are the major imported commodities in terms of value, which is greater than the total value of all the commodities exported by the country (Trade Policy, 2013). Nepal is hugely dependent on the environmentally costly imported fossil fuel, despite the massive hydropower potential in the country (Parajuli, 2011). Increasing domestic demand for the petroleum products and its escalating international market price indicate more debasing of the country's foreign currency reserves and the natural environment. Such a high import of fossil fuels, together with poor performance of the export sector, has created a serious concern on trade deficit in the country (Bastola & Sapkota, 2015), which may have supreme implications for the country's economic growth. At the same time, insufficient energy supply may also have affected the growth of the economy. Hence, there is a strong national policy interest to emphasize on national energy consumption and study the associated impacts on the economy and the environment.

This study specifically considers the theory behind the emissions–growth nexus in Nepal and examines the relationship between energy consumption and real output in a multivariate framework with population, investment in fixed capital, and emissions as additional variables. We employ the well-established time series technique based on the Toda–Yamamoto (TY) procedure (Toda and Yamamoto, 1995) to test for long run Granger causality given the finite sample size[1]. It is also a standard practice in the energy and economic growth literature to employ the econometric notions of Granger causality to test the presence of and direction of causality between the variables (Stern, 2004a). The appeal of the TY test is such that it is valid regardless the time-series is cointegrated or non-cointegrated of any arbitrary order while also allows the possibility of testing for causality between integrated variables based on asymptotic theory. The TY tests avoids

[1] The lack of quality macroeconomic data is a common problem faced by developing economies like Nepal.

the difficulties encountered in testing for Granger causality such as the power and size properties under the conventional unit roots and cointegration tests in finite samples (Zapata and Rambaldi, 1997). We additionally employed innovation accounting methods known as generalized impulse response (IR) functions to study the effect of a policy shock to one variable on another variable and how long the effect lasts in the short run.

This study is a first time attempt to empirically investigate the inter-temporal links in the energy–environment–income nexus for Nepal applying a multivariate framework. The paper shows how the growth process is affected by energy consumption when combined with other important economic variables like environmental degradation, population and capital; potentially mitigating the impacts of variables omissions. The findings of this study are important for ecological and resource economists since the mainstream theory of economic growth have always undermined the role of energy towards economic growth (Stern, 2011). We undertake a country-specific case study using modern advances in time-series econometrics to find acute solutions for the problems faced at hand, as studies conducted at the aggregate level cannot capture and account for the economic, environmental and institutional complexity of each individual country. The econometric techniques conducted in this study can be readily extended to include other developing economies even though the findings of this analysis may be unique to Nepal due to its specific institutional and development characteristics. As it is important to note " *mixed evidence and differences in results can be inevitable due to differences in econometric approaches, institutional characteristics in specific countries, model specification, variable selection and time*" (Smyth and Narayan, 2015).

The remainder of the study is structured as follows. Section 2 gives an overview of literature and section 3 describes the econometric methodology used in the study. Section 4 presents the data while section 4 reports the empirical analysis from unit root tests, Granger causality results, and generalized impulse responses function. Section 5 of the paper concludes with important policy implications.

2. Literature Review

Greenhouse gas levels have been increasing since the start of the Industrial Revolution although the growth has been particularly fast over the last few decades. For instance, the GHG emissions grew more rapidly between 2001 and 2010 than during the previous decade in spite of international frameworks on climate change like the UNFCCC (United Nations Framework Convention on Climate Change) and the Kyoto Protocol. The ever-increasing amount of atmospheric CO_2 has placed more attention on the underlying global energy usage patterns and their impacts (see Menyah and Wolde-Rufael, 2010). Consequently, the relationship between income and energy consumption, as well as income and carbon emission, have been the subject of intense studies over the past few decades (Soytas et al. 2007; Zhang and Cheng 2009; and Ghosh 2010). However, the empirical evidence remains scarce to date especially in the context of mountain economies.

Ample reference seems to be on *three research strands* in the literature on the relationship between economic growth and environmental pollutants. The *first strand* focuses on the environmental pollutants and economic growth nexus and is closely related to testing the validity of the so-called Environmental Kuznets Curve (EKC) hypothesis. The EKC postulates an inverted U-shaped relationship between the level of environmental degradation and income growth (Selden and Song, 1994). That is to say, environmental degradation increases with per capita income during the early stages of economic growth, and then declines with per capita income after arriving at a threshold. However, the EKC model is severely criticized for lack of feedback from environmental damage to economic production as income is assumed to be an exogenous variable indicating mixed results (see Arrow et al., 1995; Stern, 2004b; Hung and Shaw, 2002; among others). Hill and Magnani (2002), Stern (2017), and Dinda (2004) have provided extensive reviews of this EKC research. Earlier research, following Grossman and Krueger (1995), mostly tested the existence and/or shape of an environmental Kuznets curve (EKC) without considering energy consumption.

Hypothesis 1: There is a relationship between economic output and environmental degradation such as pollutant emissions.

The *second strand* focuses on the link between output and energy consumption following on the original empirical research by Kraft and Kraft (1978). An increasing body of literature has studied the association between economic output and energy consumption and is summarized in four testable hypotheses: *growth*, *conservation*, *feedback* and *neutrality*. Ozturk (2010) provided a comprehensive literature review on the empirical results from causality tests.

Hypothesis 2: There is a relationship between energy consumption and economic output.

The *third strand* remains an emerging area of research and combines the earlier two approaches by examining dynamic relationship between carbon emissions, energy consumption and economic growth. For instance, Menyah and Wolde-Rufael (2010) examined the long-run and the causal relationship between economic growth, pollutant emissions and energy consumption for South Africa for the period 1965–2006 using bound test approach to cointegration. They found a unidirectional causality running from pollutant emissions to economic growth; from energy consumption to economic growth and from energy consumption to CO_2 emissions all without a feedback in South Africa.

Soytas et al. (2007) investigated energy consumption, output and carbon emission nexus for USA using augmented vector autoregression (VAR) approach of Toda and Yamamoto (TY) (1995). They found non- causality between income and carbon emission and between energy use and income. Zhang and Cheng (2009) examined the Granger causality between economic growth, energy consumption, and carbon emissions in China using the TY procedure, controlling for capital and urban population. They found that a unidirectional Granger causality running from GDP to energy consumption, and energy consumption to carbon emissions. Soytas and Sari (2009) also established unidirectional Granger causality from carbon emission to energy consumption in the long- run based on the TY procedures in the case of Turkey.

Lack of consensus on the direction of causality under the *third strand* based on time-series econometrics is also obvious in the literature[2]. Ang (2008), using vector error correction model (VECM), found that pollution and energy use were positively related to output in the long-run with strong support for causality running from economic growth to energy consumption, both in the short-run and long-run in Malaysia. In the case of China, Ang (2009) showed that more energy use, higher income and greater trade openness tend to cause more CO_2 emissions using the traditional Autoregressive Distributed Lag (ARDL) approach. In contrast, Jalil and Mahmud (2009) found that carbon dioxide emissions were mainly determined by income and energy consumption in the long-run based on the ARDL methodology. Halicioglu (2009) found that there was a bi-directional Granger causality (both in short- and long-run) running between carbon emissions and income in Turkey using the bounds testing to cointegration procedure.

Hypothesis 3: There is a relationship between energy consumption, economic output, labour, capital and pollutant emissions.

In *all research strands*, there are no studies that extensively investigate the relationship between energy consumption, income, and carbon emission accounting for the influences of capital formation and population using robust time series econometrics in the context of Nepal. A prior study by Bastola and Sapkota (2015) strictly examined the relationship between just three variables: economic growth, energy consumption, and CO_2 using both Johansen cointegration and ARDL bounds tests. They found a bi-directional causality running from energy consumption to carbon emission and vice-versa and a unidirectional causality running from economic growth to both carbon emissions and energy consumption in Nepal. However, the results are questionable due to the concerns relating to the problems of omitted variables bias in the absence of a multivariate framework. Our study uses a multivariate framework for which Stern (2004a) underscores the need while Payne (2010) and Smyth and Narayan (2015) discuss the advantages.

[2] We do not discuss the results from the panel data analysis on energy consumption, economic growth and emissions since our study uses time-series econometrics. However, using panel data does not necessarily solve the lack of consensus issue. See Smyth and Narayan (2015) for the reasoning.

3. Econometric Methodology

Unit root tests and cointegration technique has been abundantly applied to test the presence of and direction of causality among the economic, energy and environmental variables in the nexus literature (Stern, 2004a). However, short-run and long-run Granger causality based on conventional unit root and cointegration tests rely on the pre-tests of variables in diagnosing if they are integrated, cointegrated, or (trend) stationary. As an alternative, Toda- Yamamoto (TY hereafter) (1995) suggested a test procedure which can be applied regardless of whether a series is non-cointegrated or cointegrated of an arbitrary order (see Rambaldi and Doran, 1996). Toda and Yammato (1995) showed that the pre-tests for cointegration ranks in Johansen type Error Correction Model (ECM) are very sensitive to the values of the nuisance parameters in finite sample. Hence, causality inference in conventional granger causality tests such as ECM suffering from severe pretest biases is avoided by applying TY. In addition, if the system contains unit roots, standard Wald statistics based on ordinary least-squares (OLS) estimation of level VAR model for testing coefficient restrictions have non-standard asymptotic distributions that may involve nuisance parameters (see, e.g., Sims et al., 1990; Toda and Phillips, 1993) and is problematic to assume.

The pre-tests for unit root and cointegration might suffer from size distortions, which often imply the use of an inaccurate model for the causality test (Clarke and Mirza, 2006). For instance, the ECM procedures tend to have larger size distortion than TY procedure, as the actual size of the TY procedure based test is stable for sample sizes that are typical for economic time series data. Therefore, the TY procedure is more appealing for its small size distortion in finite samples since the serious size distortion may not be acceptable. As such, the TY test is appropriate for analysis in developing economies since they often lack quality time series data consisting of longer periods.

We, therefore, apply the TY tests procedure to capture the underlying long-run Granger causality among the variables used in this study. The novelty of the TY procedure is that it does not require pre-testing for the cointegrating properties of the system and thus avoids the potential bias associated with unit root and cointegration tests. The augmented

VAR modelling approach proposed by Toda and Yamamoto (1995) and Dolado and Lutkepohl (1996) has much practical appeal because it can be applied for any arbitrary level of series integration. The TY procedure has a high power of the test in finite samples (Zapata and Rambaldi, 1997). The TY tests procedure is also reliable to perform when there is uncertainty about the order of integration for each individual time series.

The TY approach fits a standard VAR model on levels of the variables and therefore allows for the long-run information that are often ignored in systems that require first differencing to be revealed (Clarke and Mirza, 2006). Following Soytas et al. (2007), Soytas and Sari (2009), and Zhang and Cheng (2009), we apply TY Granger causality procedure to examine the income–energy– environment nexus in Nepal. It is however clear from the literature review that the application of the TY tests procedure in testing the long-run Granger causality also seems limited in the nexus literature despite its appeal. The TY tests procedure is summarized under five steps:

(i) Employing unit root tests to find the maximal order of integration '*d*' of variables.

(ii) Determining the optimum lag length '*p*' of a VAR. Since the true lag length '*p*' is rarely known in practice, we can estimate it by several criteria.

(iii) Estimating the lag-augmented VAR (*p* + *d*) (where '*p*' is the optimum lag length and '*d*' is a highest integration order) model:

$$v_t = \alpha_v + \beta_1 v_{t-1} + \beta_2 v_{t-2} + \ldots.. + \beta_p v_{t-p} + \ldots.. + \beta_{p+d} v_{t-p-d} + \varepsilon_{vt}$$

where, v_t = (lnY_t, lnE_t, lnK_t, lnG_t, lnP_t)', α_v is a (5 × 1) vector of constant, $\beta_{1,2,..,p+d}$ are (5×5) coefficient matrices, and ε_{vt} denotes white noise residuals, lnY_t, lnE_t, lnK_t, lnG_t, lnP_t denotes income, energy consumption, capital formation, emissions and population series used in our analysis in logarithms. For example, the following system of equations are estimated for a VAR (*4*):

$$\begin{bmatrix} \ln Y_t \\ \ln E_t \\ \ln K_t \\ \ln G_t \\ \ln P_t \end{bmatrix} = \alpha_v + \beta_1 \begin{bmatrix} \ln Y_{t-1} \\ \ln E_{t-1} \\ \ln K_{t-1} \\ \ln G_{t-1} \\ \ln P_{t-1} \end{bmatrix} + \beta_2 \begin{bmatrix} \ln Y_{t-2} \\ \ln E_{t-2} \\ \ln K_{t-2} \\ \ln G_{t-2} \\ \ln P_{t-2} \end{bmatrix} + \beta_3 \begin{bmatrix} \ln Y_{t-3} \\ \ln E_{t-3} \\ \ln K_{t-3} \\ \ln G_{t-3} \\ \ln P_{t-3} \end{bmatrix} + \beta_4 \begin{bmatrix} \ln Y_{t-4} \\ \ln E_{t-4} \\ \ln K_{t-4} \\ \ln G_{t-4} \\ \ln P_{t-4} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\ln Yt} \\ \varepsilon_{\ln Et} \\ \varepsilon_{\ln Kt} \\ \varepsilon_{\ln Gt} \\ \varepsilon_{\ln Pt} \end{bmatrix}$$

(iv) Using diagnostic tests to checking the robustness of the augmented VAR (*p* + *d*).

(v) A modified Wald test (MWALD) is conducted for restrictions on the parameters of the VAR (p) where p is the optimum lag length, instead of on all parameters in the augmented VAR ($p + d$) model, and the MWALD statistic follows an asymptotic Chi-square distribution with p degrees of freedom.

4. Data

The economic growth model framework adopted in this study drives the choice of data variables. The neoclassical model of economic growth just considered two factor production functions with capital and labour as determinants of output while adding exogenously determined 'technology' to the production function (Solow, 1956; Swan, 1956). The basic growth model did not include any natural resources, which abundantly exists in finite stock or flows in many developing economies like Nepal. The modern perception of economic growth is that the interrelationships between environmental degradation, capital accumulation and other growth variables are centrally important in growth theory (Xepapadeas, 2005). However, there are only a limited stock of studies that have investigated the causal linkages between economic growth, energy consumption and emissions, which also include measures of labour and capital as additional variables.

We utilize the annual data on real GDP (Y) and gross fixed capital formation (K) (both in constant 2010, local currency NPR[3]), energy consumption (E) (kt of standard coal equivalent), CO_2 emissions (G) (kt), and total population (P). All data covering the period 1975–2013 are used in natural logarithm, and are obtained from the *World Development Indicators (WDI)* database. Capital stock data are not available. Thus, changes in investment of fixed capital which may be a closely reliable proxy variable for capital stock, assuming a constant depreciation rate is used. Earlier studies such as Soytas & Sari

[3] 1 USD = 100 NPR (average approximation).

(2003) and Zhang & Cheng (2009) among others also use gross fixed capital formation as a reliable proxy for capital stock. Labor force, urban population and total population are often-used variables in the income-energy consumption-emissions nexus literature (Soytas et al., 2007; Zhang and Cheng, 2009, Song et al., 2008). However, no previous study has used total population as a variable in investigating the interaction between output, energy use, and pollutant emissions in Nepal. The relationships between population growth and economic growth are central to the classical theory of economic growth developed more than 200 years ago by Malthus (1798), Ricardo (1817) and others (Anker and Farooq, 1978). However, views have varied and remains debatable if population growth impedes of facilitates economic growth. In this study, we try to explore the nexus investigation by using total population without making any distinction between rural or urban and employed or unemployed population[4]. We also chose Carbon dioxide (CO_2) as it is the primary greenhouse gas emitted through human activities.

Earlier studies have also used per capita estimates in their analysis. However, using per capita estimates scales the variable down as highlighted in earlier studies in a single country case study (Soytas et al., 2007) and (Zhang & Cheng, 2009). Hence, we use the total and not per capita data in this paper. Friedl and Getzner (2003) have also suggested the use of '*total*' rather than per capita emissions since they argue that international climate agreements like the Kyoto Protocol and Paris Agreements calls for a reduction in the percentage of total emissions.

We construct an index for each series using 2000 as the base year in order to illustrate the change trend of each series in the same scale. The diagram presented in Fig. 1 suggests that the series of Y (income), E (energy consumption), G (carbon emissions), and K (gross fixed capital formation) tend to move very closely together over the period. It is worth noting that the emissions and energy consumption series seem to change in trend, so there may be an interaction between them. The emission series seems to grow more quickly from the late 2007, and the income and energy consumption series seem to grow slowly from the beginning. However, energy consumption series decreases from the

[4] Some previous studies have also used the size of labour force as a proxy for 'labour'. However, the data is not available for longer periods in the Nepalese context.

period of 2010. Graphical analysis shows that there may be structural breaks, so it is necessary to take into account a structural break tests when employing the unit root tests. The energy consumption during 1975-1998 increased slightly with slower pace, while the GDP also increased in same pace. This phenomenon is due to Nepal's energy policies which were discussed in an earlier study by Bastola and Sapkota (2015) and (Parajuli et al., 2014). Thus, the findings from this study resulting by analyzing these data series has important implications for Nepal because the government has emphasized the need to increase the supply of renewable energy including the hydropower and reduce heavy dependence on traditional sources and petroleum imports in the national policy plan.

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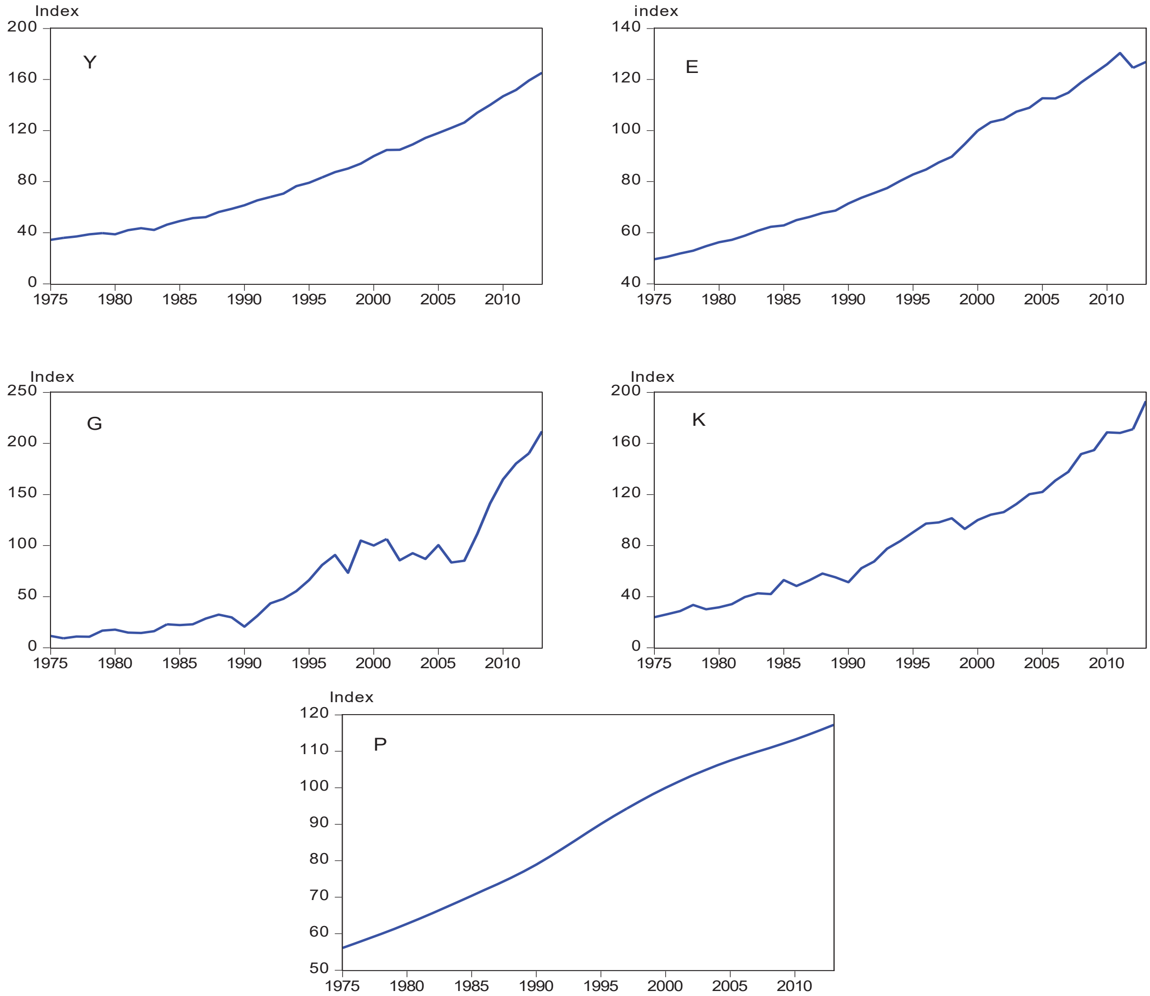

Figure 1. Trends of variables (before taking logarithm, 2000=100).

5. Empirical Analysis

This section reports the results from unit root tests (with and without structural breaks) and causality tests. The causality test is undertaken after selecting the optimal lag order of the VAR and followed by a series of diagnostic tests to check the robustness of VAR.

5.1. Unit root tests

Unit root tests are required to obtain the maximal integration order (*d*) of variables prior to undertaking the Toda-Yamamoto causality tests. We use three different unit root tests, namely augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS). The results of the unit root tests are reported in Table-1[5]. Based on the results, the integration orders of all variables without accounting for structural breaks in the time series do not appear to be exceeding 2, so we initially identify the maximal order of integration '*d*' as 2.

Table 1
Unit root test results

		ADF	*PP*	*KPSS*
Levels				
Intercept	*Y*	-0.266464(0)	0.468073	0.760008 [a]
	K	-0.965901(0)	-1.064989	0.760018 [a]
	E	-0.930843(0)	-0.923798	0.756615 [a]
	G	-0.454625(0)	0.259449	0.750746 [a]
	P	-2.001782(4)	-2.815623	0.753232 [a]
Intercept and trend	*Y*	-2.798762(0)	-2.757389	0.099528
	K	-3.196073(0)	-3.149765	0.153527[b]
	E	-1.132978(0)	-1.132978	0.107160
	G	-2.818913(0)	-2.826702	0.500000 [a]
	P	-0.690558(4)	1.202177	0.183391[b]
First differences				
Intercept	*Y*	-7.681257[a](0)	-7.950825 [a]	0.143318
	K	-7.749137 [a](0)	-7.916317 [a]	0.110445
	E	-5.684748 [a](0)	-5.68259 [a]	0.183843
	G	-6.867507 [a](0)	-10.04348 [a]	0.103990

[5] The Augmented Dickey and Fuller (ADF, 1979), the Phillips and Perron (PP, 1988), and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992) tests were performed to test whether the data are differenced stationary or trend stationary, as well as to determine the number of unit roots at their levels. If, designed on the basis of the null hypothesis that a series is I(1) has a low power of rejecting the null. Hence, KPSS is sometimes used to complement the widely used ADF and PP tests in order to have robust results.

	P	-1.441541(3)	-0.459799	0.529448 [b]
Intercept and trend	*Y*	-7.681257 [a](0)	-7.941543 [a]	0.123729c
	K	-7.712865 [a] (0)	-7.890772 [a]	0.055897
	E	-5.755997 [a] (0)	-5.753677 [a]	0.142402[c]
	G	-6.767988 [a] (0)	-11.15187 [a]	0.500000 [a]
	P	-2.465935(3)	-1.742062	0.158264[b]
Second differences				
Intercept	*P*	-4.245412 [a] (1)	-4.616835 [a]	0.201906
Intercept and trend	*P*	-4.608865 [a] (1)	-6.117186 [a]	0.110180

Note: Superscripts a, b, and c represent significance at 1%, 5%, and 10% respectively. The number in parentheses indicates the lag length, which are determined via Schwarz Information Criteria. All unit root tests (except the KPSS) employed in our study have a null hypothesis that the series has a unit root against the alternative of stationary. The null of KPSS, on contrary, states that the variable is stationary.

However, many macroeconomic time series with structural break exhibit stationary fluctuation around a deterministic trend function if allowance is made for a possible change in intercept and slope (Perron, 1989). As such, the standard unit root tests can fail to test the stationary of series in the presence of structural break. Zivot and Andrews (1992) (hereafter ZA) developed a unit root testing procedure that allows for estimating structural break in the trend function under the alternative hypothesis. Hence, we test the order of integration of a series employing ZA unit root test to account for the structural breaks, and the test results are summarized in Table 2.

ZA tests indicate that all the series (except the population '*P*' series) are integrated of order 1 (i.e. I (1)) at 5% critical level. The results show that the population series is integrated of order 2. The structural break in the income series during 2002 is due to the promulgation of the current Nepal Rastra Bank (NRB) Act 2002, which led to the introduction of a new monetary policy. The Act empowered autonomy in monetary and foreign exchange policy as well as monitoring and regulating banks and financial institutions across the nation. The deepening of the Maoist civil war in 1998 and the resulting economic and political uncertainty might have affected the capital formation variables. The structural break in the population series in 1997 can be attributed to mass war killings as well as the breakout of the disease '*encephalitis*' in the nation.

Table 2

Zivot-Andrews structural break unit root test.

Series	Break	break	Break

	Level $t(\hat{\lambda}_{\inf})$		First difference $t(\hat{\lambda}_{\inf})$		Second difference $t(\hat{\lambda}_{\inf})$	
Y	-3.0721(C)	2002	-5.8631(C)***	1982	-	-
K	-4.0923(C)	1998	-5.6458 (C)***	1995	-	-
E	-3.4569(C)	1999	-7.1574[a](C)***	1999	-	-
G	-4.1815(C)	2001	-7.1275(C)***	2006	-	-
P	-3.4508(C)	1997	-4.085(C)	1995	-8.7761(C)***	1995

*Notes: The letters in parenthesis indicates the model A, B and C of Zivot and Andrews (1992), respectively. Model A, B, and C allow for a change in the level, slope of trend, and combines both of the series respectively. Break denotes the time of the structure change. ***, **, * indicate significance at the level of 1%, 5% and 10% level of significance of t-stat. A, B, C represents intercept, trend and both breaks respectively. The Z-A critical statistics at 1% level of significance for intercept, trend and both are -5.34, -4.80 and -5.57 respectively.*

5.2. The Long-run causality tests

Table 1 confirms that not all series used in our analysis are integrated of the same order, so the TY procedure to test for Granger causality appears to be the most appropriate method. However, the optimum lag length of VAR model has to be decided first to conduct the TY procedure. We conducted 4 different lag length criteria to decide the optimal lag length, namely sequential modified Likelihood ratio test statistic (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan–Quinn information criterion (HQ). The results of lag length selection of the VAR are presented in table 3.

Table 3
Selection criteria of VAR lag order.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	195.368	NA	1.30E-11	-10.878	-10.656	-10.801
1	428.391	386.153	9.08E-17	-22.765	-21.432	-22.305
2##	494.339	90.442	9.60E-18	-25.105	-24.789*	-24.261
3	576.013	88.675*	4.86e-19*	-28.344	-22.661	-27.116*
4	602.649	21.309	7.80E-19	-28.437*	-23.771	-26.826

**indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at the 5% level), FPE: Final prediction error, AIC: Akaike information cri- terion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.*

AIC suggests a lag length of 4 while LR, FPE, HQ, suggest a lag length of 3. SC indicates an optimum lag length of 2 for the VAR. However, performing VAR diagnostic test results indicate that neither the augment VAR (*6*) (*p* + *d* = *6*) nor VAR (*5*) (*p* + *d* = *5*) is well behaved while checking for its stability. Therefore, we infer and estimate the augmented VAR (*4*) (*p* + *d* = *4*) with $V_t = (\ln Y_t, \ln K_t, \ln E_t, \ln G_t, \ln P_t)$ and apply a series of diagnostic tests to check the robustness of VAR (*4*). The result of diagnostic test are summarized in Table 4.

Table 4
Diagnostic test results.

Equation	Adj.R	J-B test	B-G test	ARCH LM	White test	Ramsey RESET
Y	0.994644	1.185838	1.238579	1.238579[1]	12.17536	0.252032
K	0.98553	0.321203	0.984110	1.126815[1]	9.524126	0.604988
E	0.993594	0.972983	0.376634	1.751981[1]	23.70406	0.269018
G	0.957657	0.663252	0.445558	0.084886[1]	9.655757	1.025199
P	0.990599	0.276133	8.188333	4.457551[2]	13.11753	17.14425[a]

J-B test null is normally. B-G test null is no serial correlation up to the selected lag. ARCH LM null is no ARCH up to the selected lag. Lag lengths are selected by SC and showed in parentheses. White test null is no heteroscedasticity. Ramsey RESET test null is no specification errors with one fitted term using LR. Superscript a represents significance at the 1%.

The adjusted R^2 values are rather high and slightly lower than that of unadjusted R^2. Hence, the explanatory power of these equations cannot be attributed to using too many explanatory variables relative to the sample size. The J–B test results show that all residuals assume normality. Lagrange multiplier tests indicate that there is no autoregressive conditional heteroscedasticity (ARCH LM), and White tests shows there is no heteroscedasticity for all equations. The results of Breusch-Godfrey test show there is no serial correlation for all equations in 5% significance level for any of the equations. However, Ramsey RESET test results indicate that parameter seems to be unstable for the *P* series while the CUSUM and CUSUM of square tests could not verify a stability violation. The VAR (*4*) is stable with all AR roots within the unit circle. We proceed with the Granger causality tests satisfied with the diagnostics of VAR (*4*). The test results are presented in Table 5.

Table 5
Granger causality test results[6].

Dependent Variables	Y	K	E	G	P
Y		6.0376[c]	2.6944	11.6720[a]	0.5901
K	4.6247		0.0733	0.8813	0.1809
E	7.0353[b]	0.9234		7.8783[b]	1.3323
G	4.7810	3.8721	1.8859		2.6276
P	0.2713	11.5328[a]	9.6244[b]	2.3691	

Superscript a, b and c represent significance at the 1%, 5% and 10% respectively. Significance implies that the column variable Granger causes the row variable.

The results reveal that there is a unidirectional Granger causality running from real GDP to energy consumption at the 5% significance level in Nepal. That is, an increase in GDP will bring about an increase in energy use, but not vice versa. Hence, the government of Nepal should be conservative and energy should be efficiently utilized because energy consumption does not contribute much to the growth of the economy. This result supports Zhang and Cheng (2009) but differs from that of Soytas and Sari (2006) and Yuan et al. (2008).

The most interesting outcome of our causality test is that there is a unidirectional causality running from carbon dioxide emissions (CO_2) to economic growth without feedback, which indicates that higher CO_2 emissions promote economic growth. The implication of our finding is that it is not possible to reduce emissions without sacrificing economic growth as reduction in CO_2 emissions can cause output to decline. Our result is consistent with the empirical evidence found by Ang (2008) for Malaysia and Soytas and Sari (2009) for Turkey and Menyah and Wolde-Rufael (2010) for South Africa, and Ghosh (2010) for India but not consistent with Soytas et al. (2007) for the United States and Zhang and Cheng (2009) for China.

[6] We would also have alternatively conducted and compared the results from an ARDL bounds testing approach to cointegration if our series were integrated of different orders (strictly (I(1)) or (I(0)) as in earlier studies. However, this is not the case with our data since our population series is strictly (I(2)).

We found income and population to be statistically significant in gross fixed capital formation equation, while income and carbon emissions appear to be insignificant. In the energy consumption equation, only population was found to be significant, while no significant variables are present in the population equation. Overall, our results do not indicate a strong link environmental and economic growth after accounting for the influences of investment in capital stock, population and energy use.

5.3. Generalized impulse response and short-run causality

The TY process established the long run Granger causality relationship among the series. However, test results do not consider how variables in general, respond to innovations in other variables. We utilize generalized impulse response based on Koop et al. (1996) and Pesaran and Shin (1998), which overcomes the orthogonality problem in traditional out-of-sample Granger causality tests, in order to examine how a shock to one variable affects another variable and how long the effect lasts in short-run. The generalized impulse response results are plotted out in Figure 2.

The figure shows that carbon emissions and energy consumption do not respond at all to changes in population in the short-run. However, energy consumption affects population with minimal significance for up to two years. Shocks to capital formation and income have positive and significant initial impacts on emissions and energy consumption. The initial impact of emissions shocks to energy consumption is higher in impact and also appears to last slightly longer than those of capital formation and income. Another important finding is that a shock in energy use has higher initial impacts on carbon emission than the others, but the impacts last rather shorter than those of gross fixed capital and GDP. Therefore, our impulse response analysis imparts some support for the long-run Granger causality test results.

We find that impacts of policy shocks on income and emissions are increasing constantly over the horizons, which indicates that the impacts are insignificant. It also implies that the population has seemingly no effect on the economic growth and carbon emissions, but it seems significant to generate initial impacts on energy consumption. This suggests that population size has positive effect on the energy consumption in Nepal.

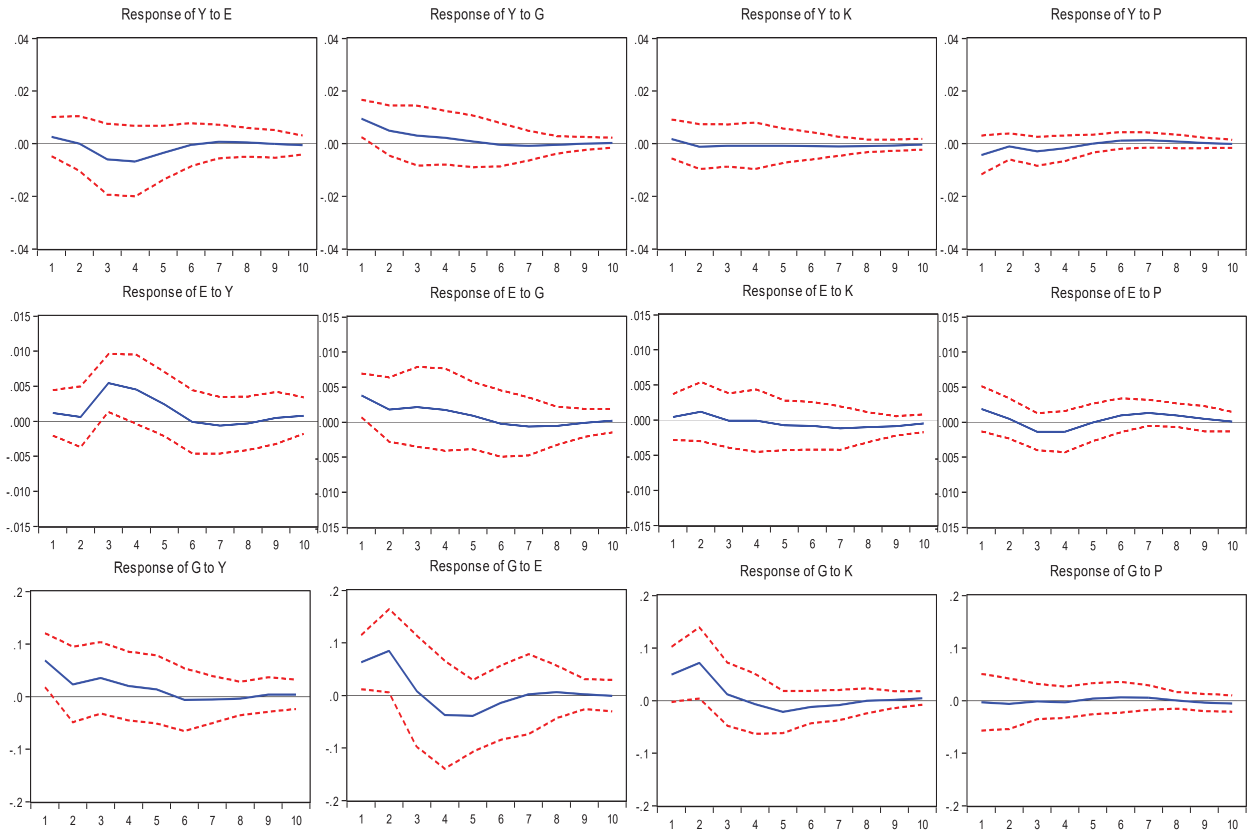

Figure 2. Generalize impulse response of Y, E, K, and G to other variables.

6. Conclusions and policy implications

Developing economies characterized as mountain economies are facing a crucial challenge to meet their growing energy needs while reducing the adverse impacts on the environment as global providers of ecosystem goods and services. These economies are confronted with the urgent need of balancing their economic growth priority with minimal adverse associated environmental impacts coupled with sustainable energy usage. Hence, an in-depth understanding on the income-emissions-energy consumption nexus is necessary and serves as a starting point towards finding appropriate policy solutions in meeting the national energy, environmental and economic objectives in these economies.

This paper examined the long run and short-run causal relationship between economic growth, pollutant emissions, energy consumption, population and capital in Nepal, a mountainous economy in South Asia, for the period 1975–2013 by applying the augmented VAR modelling. The Toda and Yamamoto (1995) long run Granger causality tests were applied to test for long-run Granger causality while impulse response functions were estimated to understand the short-run impacts. The empirical findings, from our causality tests indicate that there was a unidirectional Granger causality running from carbon emissions to economic growth; from economic growth to energy consumption and from CO_2 to energy consumption, all without feedbacks. The evidence suggest that increase in income is not a solution to reducing the levels of CO_2 emissions. If Nepal is to reduce its emission levels, it has to reduce not only her energy consumption per unit of output but also need to sacrifice the economic growth. However, the results from impulse responses provided evidence that shocks in all variables, except total population, have significant initial impact on anyone of them. Therefore, enhancing energy efficiency is an effective way to save energy. Nepal has huge potential sources of renewable energy that can simultaneously address both the energy needs as well as the environmental concerns due to CO_2 emissions. The study indicates that Nepal has not fully utilized these alternative energy resources.

The evidence also suggests that degradation of the environment precedes economic growth. In Nepal, an increases in pollution level leads to economic expansion. It is not surprising given that much energy inputs have been consumed in the production (which have resulted in more pollution) to promote heavy industry. The results have important implication for policy makers, as our empirical findings are lucid and robust across different measurements and estimators. A unidirectional causality running from GDP to energy use in the long-run implies that Nepal is not an energy dependent economy and the causality running from pollution emission to energy consumption, policies that boost CO_2 are likely to motivate economic growth, however, these are more likely to degrade the environment. Economic growth is the outcome of growth in inputs and increases in the productivity of the inputs. Therefore, rapid industrialization requires higher and/or more efficient consumption of energy products. Given that over-consumption of resources can have negative impacts on the environment, developing energy conservation strategies seem to be the most appropriate policy for Nepal. However, we suggest that the results should be interpreted with care, as these findings are not a guarantee against the choice of an incorrect policy option by a mountain economy like Nepal. The costs of adopting false policy options can be too high for developing economies.

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