A CAUSAL RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND ECONOMIC GROWTH IN NEPAL

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In the present paper, an attempt is made to examine the causal relationship between the per capita consumption of coal, electricity, oil and total commercial energy and the per capita real gross domestic product (GDP), using a co-integration and vector error correction model. The increase in real GDP, among other things, indicates a higher demand for a large quantity of commercial energy such as coal, oil and electricity. This implies that low infrastructure development limits the usage of commercial energy, which may also hold back economic growth. Empirical findings reveal that there is a unidirectional causality running from coal, oil and commercial energy consumption to per capita real GDP, whereas a unidirectional causality running from per capita real GDP to per capita electricity consumption is found. It is suggested that the input of per capita energy consumption stimulates enhanced economic growth in Nepal.

I. INTRODUCTION

The causal relationship between energy consumption and economic growth is a well-studied subject in economic literature. In recent years, there has been a renewed interest in examining the relationship between these variables, given the impact that energy consumption has on climate change. The higher economic growth rates pursued by developing countries are achievable only in association with the consumption of a larger quantity of commercial energy, which is a key factor of production, along with capital, labour and raw materials. Moreover, the social development that represents the demand side of energy depends on the pattern of commercial energy consumption in an economy. Accordingly, a consumer decides to consume a set of energy products that maximizes his or her utility. From this perspective, energy is seen to play a vital role in the economic and

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social development of the nation. There is still debate on whether energy consumption is a stimulating factor for, or a result of, economic growth. However, when more commercial energy, particularly oil and coal, is used to achieve projected economic growth rates, carbon dioxide (CO_2) emissions rise accordingly. The increased share of CO_2 in the atmosphere, a product of the rampant use of fossil fuels, has negative impacts on natural systems and is a main factor contributing to climate change. In this context, the consumption of coal and oil should be replaced with renewable alternatives, such as wind, solar and hydropower, that do not emit CO_2.

II. A BRIEF SURVEY OF THE LITERATURE

A number of studies have investigated the causal relationship between energy consumption and economic growth. For example, Kraft and Kraft (1978) used the methodology of Sims (1972) to assess causality between energy consumption and economic growth over the period 1947-1974. Their work explicitly proved that the causality was running from gross national product (GNP) to energy consumption in the economy of the United States of America. Aqeel and Butt (2001) studied the causal relationship between energy consumption and economic growth in Pakistan. To investigate the causal relationship among the stated variables (economic growth, electricity, etc.), they preferred to use the co-integration and Granger tests. They found unidirectional causality running from economic growth to petroleum consumption, and causality running from economic growth to gas consumption. In contrast, they found unidirectional causality running from electricity consumption to economic growth.

Cheng and Lai (1997) found causality running from gross domestic product (GDP) to energy consumption in the case of Taiwan Province of China. They used a co-integration and error correction model to investigate the causality among chosen variables. Mozumder and Marathe (2007) applied a vector error correction model to explore the dynamic Granger causality. They found that per capita GDP Granger causes per capita energy consumption in Bangladesh.

Masih and Masih (1996) considered six Asian economies to examine the temporal causality between energy consumption and income; they applied a vector error correction. Those findings show that energy consumption was causing income in India, income was causing energy consumption in Indonesia, and that a bidirectional causality existed in Pakistan. They used an ordinary vector autoregressive model for the remaining three countries (Malaysia, Philippines and Singapore). In those cases, their investigation failed to reveal any causality between energy consumption and income. Soytas and Sari (2003), in their examination of causality, had mixed results. They found bidirectional causality in Argentina, and causality that ran from GDP to energy consumption in Italy and the Republic of Korea. In contrast, they found that the causality ran from energy consumption to GDP in France, Germany, Japan and Turkey.

Yang (2000), using updated data from 1954-1997 for Taiwan Province of China, investigated the causal relationship between GDP and the aggregate categories of energy consumption, including coal, natural gas and electricity. He found bidirectional causality between total energy consumption and GDP. Pachauri (1977) found that there was a strong correlation between economic development and energy consumption in India. Stern (2000), in a study of the United States economy, found in a multivariate dynamic analysis that energy not only Granger causes GDP, it is also significant in explaining GDP. He also found co-integration in a relationship between the factors (GDP, capital, labour and energy). Ghali and El-Sakka (2004) conducted a study on the causality between energy consumption and economic growth in Canada. They found that the short-run dynamics of variables indicate that Granger's causality between output growth and energy use was bidirectional.

Dhungel (2005) used co-integration to determine electricity demand in Nepal. The estimated income elasticity and price elasticity of electricity showed that there is a proportional change in the demand for electricity associated with changes in income and price. Abosedra and Baghestani (1989) argued that the direct Granger test should be used, and concluded that for all sample periods tested (1947-1972, 1947-1974, 1947-1979 and 1947-1987), there was a unidirectional causality between GNP and economic growth in the United States economy. Fatai, Oxley and Scrimgeour (2001) used both Granger and Toda-Yamamoto methodology to assess causality between energy consumption and economic growth over the period 1960-1999. Their work explicitly proved that causality was running from energy consumption to GDP in India, Indonesia, the Philippines and Thailand, and Granger causality was running from GDP to energy consumption in Australia and New Zealand. Cheng (1999) estimated Granger causality between energy consumption and economic growth for the period 1952-1995 by using co-integration and error correction models. He found that the Granger causality was running from GNP to energy consumption in India.

III. DATA AND ECONOMETRIC METHODOLOGY

Data and variables

Time series data on total commercial energy consumption and real GDP over the period 1980-2004 is used to investigate the causal relationship between energy consumption and economic growth. The necessary data were collected from various sources in Nepal. For example, the data for electricity consumption were collected from annual reports of the Nepal Electricity Authority (Nepal various years). Coal consumption data were collected from the Water and Energy Commission Secretariat (Nepal 1997, 2006). The data for petroleum consumption were collected from the Water and Energy Commission Secretariat and the Nepal Oil Corporation. Data on total commercial energy consumption and GDP were collected from several issues of the Economic Survey published by the Ministry of Finance (Nepal various years).

The main purpose of this article is to estimate the relationship between commercial energy consumption and economic growth in general, and attempts are made to assess the causality between total commercial energy consumption (TCEC) and real GDP. Furthermore, TCEC is decomposed into three main parts: coal, electricity and oil, facilitating the assessment of the relationships between the consumption of individual commercial energy types and real GDP.

Econometric methodology

The time series data present a number of methodological problems. It is convenient to estimate relationships through the regression method only if the series are stationary. In the context of a time series, “stationary” refers to a condition wherein the series have constant mean and constant variance. Most of the time series data reflect trend, cycle and/or seasonality. These deterministic patterns must be removed to make the series stationary. Time series that are not stationary and whose properties have not been subjected to an examination could produce invalid inferences. The coefficient determination (R^2) measures the variability in dependent variable explained by the independent variable. High value of R^2 will likely give rise to spurious regression (Granger and Newbold 1974). To examine the Granger causality between TCEC and real GDP, as well as between each of the three decomposed elements (coal, electricity and oil consumption) and real GDP, the following methodology has been adopted.

Co-integration test

Co-integration analysis and error correction models have become the standard techniques for the study of electricity demand. Engle and Granger (1987) applied both techniques to forecast electricity demand. Since 1987, subsequent developments related to this approach have relied on the use of new techniques to identify co-integrating relationships. Johansen's method is the latest improvement on the theory of co-integration as applied in long-run analysis of time series data.

The concept of co-integration has become popular in recent years. It states that if a long-run relationship exists between two variables, then the deviations from the long-run equilibrium path should be bounded. If this is the case, the variables are said to be co-integrated. For variables to be co-integrated, two conditions must be satisfied: the series for the individual variables must have the same statistical properties, and the variables must be integrated in the same order. If a series is stationary after differencing once, it is said to be integrated of order one or I(1).

When using time series data, the test of unit root is very important for determining stationarity. Stationarity tests which determine the unit root in a series are proposed by Dickey and Fuller (1981). The standard approach to test for non-stationarity of each observed time series (Y observed over T time periods (Y_t)) is to estimate an augmented Dickey Fuller (ADF) test regression, as shown below.

We consider a simple autoregressive (AR)(1) process:

$$Y_t = \rho\, Y_{t-1} + x_t\, \delta + \varepsilon_t, \qquad (1)$$

where x_t represent optional regressors that may consist only of a constant, or a constant and trend; ρ and δ are parameters to be estimated; and the ε_t are assumed to be white noise. If $| \rho | \geq 1$, y is a non-stationary series and the variance increases with time and approaches infinity. If $| \rho | \geq 1$, y is a (trend-) stationary series. Thus, the hypothesis of (trend-)stationarity can be evaluated by testing whether the absolute value of ρ is strictly less than one.

The ADF test is carried out by estimating equation (1) after subtracting y_{t-1} from both sides of the equation:

$$\Delta Y_t = \alpha\, Y_{t-1} + x_t\, \delta + \varepsilon_t, \qquad (2)$$

where $\alpha = \rho - 1$. The null and alternative hypotheses may be written as:

H_0: $\alpha = 0$ and H_1: $\alpha < 0$

The simple Dickey Fuller unit root test described above is valid only if the series is an AR(1) process. If the test does not provide enough basis to reject the null hypothesis, then the series are said to be level stationary. This would imply that they satisfy the condition to construct a co-integration system.

If the series are integrated of the same order, a static regression in the levels of the variables is run and tested to see if linear combinations of the variables are themselves integrated of the same order as the individual variables. If the variables are co-integrated, then there should exist a linear combination of these variables which is integrated of order one less than the individual variables. In the co-integrating regression

$$Y_t = b_0 + b_1X_t + u_t, \tag{3}$$

if $Y \rightarrow I(n)$ and $X \rightarrow I(n)$, then Y and X are said to be co-integrated if $u_t \rightarrow I(n-1)$. In equation (3), b_1 measures the long-run relationship between Y and X, and u is the divergence from the equilibrium path. If there is a long-run relationship between Y and X, then the divergence from it should be bounded. Engle and Granger (1987) argue that if co-integration holds, then the error correction model is a valid representation of the adjustment process.

Granger causality test

The Granger (1969) approach to the question of whether X causes Y is to determine how much of the current Y can be explained by past values of Y, and then to see whether adding lagged values of X can improve the explanation. Y is said to be Granger-caused by X if X helps in the prediction of Y, or if the coefficients on the lagged Xs are statistically significant. Note that two-way causation is frequently the case: X Granger causes Y and Y Granger causes X.

It is important to note that the statement “X Granger causes Y” does not imply that Y is the effect or the result of X. Granger causality measures precedence and information content but does not of itself indicate causality in the more common use of the term.

It is better to use more rather than fewer lags in the test regressions, since the Granger approach is couched in terms of the relevance of all past information. It is necessary to pick a lag length, l, that corresponds to reasonable beliefs about the longest time over which one variable could help predict the other.

If two series are co-integrated, then a Granger causality test must be applied to determine the direction of causality between the variables under consideration.

The following equations are used to determine the causality:

$$\Delta Y_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta X_{t-i} + \mu \qquad (4)$$

$$\Delta X_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \sum_{i=1}^{k} \psi_i \Delta Y_{t-i} + \mu \qquad (5)$$

where Y_t and X_t are defined as Y and X observed over t time periods; Δ is the difference operator; k represents the number of lags; α, β, ψ and γ are parameters to be estimated; and μ represents the serially uncorrelated error terms. The test is based on the following hypotheses:

H_0: $\gamma_i = \psi_i = 0$ for all i's

H_1: $\gamma_i \neq 0$ and $\psi_i \neq 0$ for at least some i's.

At this point, it is necessary to examine the criteria for causality. The hypothesis would be tested by using t-statistics. If the values of the γ_i coefficient are statistically significant but those of the ψ_i are not, then X causes Y ($X \rightarrow Y$). On the contrary, if the values of the ψ_i coefficients are statistically significant but those of the γ_i coefficients are not, then Y causes X ($Y \rightarrow X$). If both γ_i and ψ_i are significant then there exists bidirectional causality between X and Y ($X \rightarrow Y$).

IV. EMPIRICAL FINDINGS

Unit root test

The ADF test was used in most of the studies of the present paper to examine the unit root in the set of five series comprising the relationships between coal consumption, electricity consumption, oil consumption and TCEC and real GDP. In the level form the ADF test supports the hypothesis that all five series under consideration are non-stationary. However, in the first difference all become stationary. The ADF test for the data of first difference indicates that the five series under consideration are all of order I(1). However, the GDP variable is second difference stationary, or I(2). The ADF coefficients in the level and first difference are reported in table 1.

Co-integration test

The empirical findings of Johansen co-integration tests (table 2) reveal that both the Eigen and Trace tests indicate the existence of a consistently co-integrating vector or long-run equilibrium relation among variables during the sample period of 1980-2004. When the values of the test were estimated, linear

Table 1. Empirical results of a unit root test

Variable	Augmented Dickey Fuller statistics			
	Level	Probability	First difference	Probability
lnCC	-2.0544057	0.5412	-6.9540081*	0.0001
lnEC	-1.436815	0.8228	-7.783153*	0.0000
lnOC	-0.938054	0.9344	-5.298443*	0.0015
lnTCEC	-2.894120	0.1815	-6.212976*	0.0002
lnGDP	0.966159	0.9997	-9.696064*	0.0000

Source: Nepal various years a; Nepal various years b; Nepal 1997, 2006.

Abbreviations: ln, natural logarithm; CC, per capita coal consumption; EC, per capita electricity consumption; OC, per capita oil consumption; TCEC, per capita total commercial energy consumption; GDP, per capita gross domestic product (millions of Nepalese rupees)

* The Mackinnon values for the rejection of a hypothesis of a unit root test at 1, 5 and 10 per cent are -3.75, -2.99 and -2.64, respectively.

deterministic trend was assumed. The lag interval in first differences is three. The trace test indicates that there are three and two co-integrating equations at the 5 and 1 per cent levels, respectively. Moreover, the maximum Eigen value test indicates three co-integrating equations at both the 5 and 1 per cent levels.

More specifically, table 2 shows that at the 5 per cent level of significance the likelihood ratios (trace statistics) for the null hypothesis having no (r = 0), one (r = 1) or two (r = 2) co-integrations (171.77, 81.23 and 35.65) are higher than the critical values (76.07, 54.46 and 34.91). The likelihood ratios of having three and four co-integrating relationships (6.80 and 0.23) are less than the critical values (20.04 and 6.65).

Table 2. Unrestricted co-integration rank test

Null hypothesis (H_0)	Alternative hypothesis (H_1)	Maximum Eigen value statistics	Trace statistics	95 per cent critical value (Eigen)	95 per cent critical value (Trace)
r = 0	r = 1	90.53	171.77	38.77	76.07
r = 1	r = 2	46.32	81.23	32.24	54.46
r = 2	r = 3	28.11	35.65	25.52	34.91
r = 3	r = 4	6.56	6.80	18.63	20.04
r = 4	r = 5	0.23	0.23	6.65	6.65

Source: Nepal various years a; Nepal various years b; Nepal 1997, 2006.

Note: The letter “r” represents the number of co-integrating equations.

At the 5 per cent level of significance, the maximum Eigen value statistics for the null hypothesis having no, one and two co-integrations (90.53, 46.32 and 28.11, respectively) are higher than the critical values (38.77, 32.24 and 25.52). The maximum Eigen value statistics of having three and four co-integrating relationships (6.56 and 0.23, respectively) are less than the critical values (18.63 and 6.65). Hence, according to likelihood ratio and maximum Eigen value statistics tests, per capita coal consumption and GDP, electricity consumption and GDP, oil consumption and GDP and TCEC and GDP series are co-integrated. Thus, a long-run equilibrium relationship between these series is co-integrated.

Granger causality test

The results of Granger causality between per capita coal consumption, electricity consumption, oil consumption and TCEC and per capita real GDP, as well as the computed F values and their respective probabilities for the data of those series during the period 1980-2004 with specific lag period, as calculated through equations (4) and (5), are presented in table 3. To assess whether the null hypothesis is to be accepted or rejected, a significance level of 5 per cent is chosen. The lag lengths were chosen by using Akaike's information criterion.

The Granger causality is found to run from per capita coal consumption to per capita real GDP. The null hypothesis of "per capita coal consumption does not

Table 3. Empirical results of a causality test

Independent variable	*Lag*	*Equation 4[a]*		*Equation 5[b]*	
		F-statistics	*Probability*	*F-statistics*	*Probability*
lnCC	2	4.35504	0.00867	–	–
lnGDP		–	–	1.29862	0.29728
lnEC	4	1.39332	0.29740	–	–
lnGDP		–	–	5.20554	0.00148
lnOC	3	9.54973	0.00090	–	–
lnGDP		–	–	2.03772	0.16175
lnTCEC	6	5.81605	0.00504	–	–
lnGDP		–	–	2.15842	0.18547

Source: Nepal various years a; Nepal various years b; Nepal 1997, 2006.

[a] $\Delta Y_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta X_{t-i} + \mu$

[b] $\Delta X_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \sum_{i=1}^{k} \psi_i \Delta Y_{t-i} + \mu$

Abbreviations: ln, natural logarithm; CC, per capita coal consumption; EC, per capita electricity consumption; OC, per capita oil consumption; TCEC, per capita total commercial energy consumption; GDP, per capita gross domestic product (millions of Nepalese rupees)

Granger cause per capita real GDP" is rejected at the 5 per cent level of significance in equation (4), where the value of γ is 4.35504 with probability 0.00867. The null hypothesis "per capita real GDP does not Granger cause per capita coal consumption" is accepted in equation (5), where the value of ψ is 1.29862 with probability 0.29728. This indicates that per capita real GDP does not Granger cause per capita coal consumption, as the value of the test statistic is not significant even at the 10 per cent level of significance in equation (5). Both results were calculated using two lag periods.

In terms of electricity, the Granger causality is found to run from per capita real GDP to per capita electricity consumption. The null hypothesis of "per capita real GDP does not Granger cause per capita electricity consumption" is rejected at the five per cent level of significance in equation (5), where the value of ψ is 5.20554 with probability 0.00148. The null hypothesis "per capita electricity consumption does not Granger cause per capita real GDP" is accepted in equation (4), where the value of γ is 1.39332 with probability 0.29740. This indicates that per capita electricity consumption does not Granger cause per capita real GDP, as the value of the test statistic is not significant even at the 10 per cent level of significance in equation (4). Both results were calculated using four lag periods.

Turning to oil, the Granger causality is found to run from oil consumption to real GDP. The null hypothesis of "per capita oil consumption does not Granger cause per capita real GDP" is rejected at the 5 per cent level of significance in equation (4), where the value of γ is 9.54973 with probability 0.00090. The null hypothesis "per capita real GDP does not Granger cause per capita oil consumption" is accepted in equation (5), where the value of ψ is 2.03772 with probability 0.16175. This indicates that per capita real GDP does not Granger cause per capita oil consumption, as the value of the test statistic is not significant even at the 10 per cent level of significance in equation (5). Both results were calculated using three lag periods.

Most important is the assessment of the causality between per capita TCEC, which is the sum total of per capita coal, oil and electricity consumption and per capita real GDP. The empirical results show that the Granger causality is found to run from per capita TCEC to per capita real GDP. The null hypothesis of "per capita TCEC does not Granger cause per capita real GDP" is rejected at the 5 per cent level of significance in equation (4), where the value of γ is 5.81605 with probability 0.00504. The null hypothesis "per capita real GDP does not Granger cause per capita TCEC" is accepted in equation (5) where the value of ψ is 2.15842 with probability 0.18547. This indicates that per capita real GDP does not Granger cause per capita TCEC, as the value of the test statistics is not significant even at the 10 per cent level of significance in equation (5). Both results were calculated using six lag periods.

V. SUMMARY, POLICY IMPLICATIONS AND CONCLUSIONS

The economic development of Nepal is extremely low—less than 4 per cent during the period under consideration. The actual economic growth rate is much lower than the target rates set by the Government through its fiscal policies. If the targets are to be translated into action, the country must develop its capacity to adequately manage the supply of commercial energy.

Empirical findings reveal that there is a unidirectional causality running from coal, oil and commercial energy consumption to per capita real GDP, whereas a unidirectional causality running from per capita real GDP to per capita electricity consumption is found. This suggests that per capita energy consumption is the stimulating input for enhancing economic growth in Nepal. In view of these observations, it is suggested that the Government of Nepal make a rigorous effort to encourage investment in energy generation.

Nepal possesses 42,000 MW of economic hydroelectricity potential, but fewer than 600 MW have been tapped so far. A policy of increasing investment in electricity generation should be implemented to replace the use of coal and oil in the process of enhancing economic growth in Nepal. Also needed is a policy to supplement energy such as coal and oil through energy exchange programmes with neighbouring countries. In a previous paper (Dhungel 2003), the author estimated electricity income and price elasticity from the time series data (1980-1999) and found that the income elasticity of electricity was 3.51. That estimate shows that, for the long run, Nepal does not have to arrange demand management, which in turn suggests that Nepal should accelerate investment in the generation of hydroelectricity in order to improve supply management. Likewise, the present study suggests that Nepal will need to put more effort into increasing electricity supply investment as part of a national strategy towards advanced development in the long run.

Moreover, the present study supports the argument that an increase in real income ceteris paribus leads to increases in energy consumption. As their real income increases, people tend to spend a higher proportion of their income on goods or services that consume large amounts of energy, such as private cars and motorcycles, tractors and water pumps on farms and in households, plasma televisions and high-speed Internet connections; all this contributes to an increase in industrial establishments that are energy intensive.

Thus, for developing countries like Nepal, economic growth requires energy infrastructure—particularly for electricity. A high economic growth rate will increase the consumption of commercial energy. Development of immense water-resource projects to generate electricity is one infrastructure option. However, it requires a huge investment, and the infrastructure would take a significant amount of time to construct. Thus, small and microprojects and biogas (from animal dung) are better options for providing electric energy to the people of rural areas. These options, if developed adequately, would be helpful in reducing greenhouse gas emissions by reducing the use of fossil fuel and biomass.

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