ELSEVIER

Energy Policy 30 (2002) 125–129

ENERGY POLICY

www.elsevier.com/locate/enpol

Electricity consumption and economic growth in India

Sajal Ghosh*

Indira Gandhi Institute of Development Research (IGIDR), Mumbai, India

Received 2 September 2000

Abstract

This paper tries to examine the Granger causality between electricity consumption per capita and Gross Domestic Product (GDP) per capita for India using annual data covering the period 1950–51 to 1996–97. Phillips–Perron tests reveal that both the series, after logarithmic transformation, are non-stationary and individually integrated of order one. This study finds the absence of long-run equilibrium relationship among the variables but there exists unidirectional Granger causality running from economic growth to electricity consumption without any feedback effect. So, electricity conservation policies can be initiated without deteriorating economic side effects.

Keywords: Causality; Electricity; GDP; India; Cointegration and vector autoregression

1. Introduction

Energy is the basic building block of economic development. Electricity is the most flexible form of energy that constitutes one of the vital infra-structural inputs in socio-economic development.

Causal relationship between energy consumption and economic growth has been the prime focus of economists and policy analysts since 1970's (Kraft and Kraft, 1978; Beenstock and Willcocks, 1981; Samouilidis and Mitropopulous, 1984; Yu and Choi, 1985; Erol and Yu, 1987; Cheng and Lai, 1997; Yang, 2000, Stern, 2000, Adjaye, 2000).

The purpose of this paper is to investigate empirically the existence and direction of causal relationship between electricity consumption and economic growth in India. Such knowledge can play a crucial role from the policy formulation point of view. If, for example, there exists unidirectional Granger causality running from income to electricity consumption, it may be implied that electricity conservation policies may be implemented without deteriorating economic growth. On the other hand, if unidirectional causality runs from electricity consumption to income, reducing electricity consumption could lead to a fall in income.

The paper is organized in the following manner: a brief and intuitive account of econometric methodology and description of the data is provided in Section 2 before discussing the empirical results in Section 3. Conclusions of the study are produced in Section 4.

2. Econometric methodology and data description

Engle and Granger (1987) showed that if the two series X and Y (say) are individually $I(1)$ (i.e. integrated of order one) and cointegrated then there would be a causal relationship at least in one direction. The presence of cointegration among the variables rules out the possibility of "spurious" correlation. However, although cointegration indicates the presence or absence of Granger causality, it does not indicate in which direction causality runs between the variables. This direction of Granger's causality can be detected through the Vector Error Correction model of long-run cointegrating vectors. Furthermore, Granger's Representation Theorem demonstrates how to model a cointegrated $I(1)$ series in a vector autoregression (VAR) format. VAR can be constructed either in terms of the level of the data or in terms of their first differences, i.e. $I(0)$ variables, with the addition of an error correction term to capture the short-run dynamics.

*Corresponding author. Energy Division, CII, Gate No. 31, North Block, J.N. Stadium, New Delhi 110 003, India. Tel.: +91-11-4366-225; fax: +91-11-436-6271.

E-mail address: sajal.ghosh@ciionline.org (S. Ghosh).

PII: S0301-4215(01)00078-7

If the series are $I(1)$ but not cointegrated, causality test may give misleading results unless the data are transformed to induce stationarity.

Following Oxley and Greasley (1998), a three-stage procedure is used to test the direction of causality. The first step tests for the order of integration of the natural logarithm of the variables using Augmented Dickey-Fuller (ADF) and/or nonparametric $Z(t_\alpha)$ statistics (Phillips and Perron, 1988). Conditional on the outcome of the tests, the second stage involves in investigating bivariate cointegration using VAR approach of Johansen (1988, 1991) and Johansen and Juselius (1990).

The third stage (or second if bivariate cointegration is rejected), involves constructing standard Granger-type causality tests, augmented where appropriate with a lagged error correction term.

The three-stage procedure for testing causality leads to three alternative approaches. If the series X and Y are individually $I(1)$ and cointegrated then Granger causality tests may use $I(1)$ data because of the super-consistency properties of estimation.

$$X_t = \alpha + \sum_{i=1}^{m} \beta_i X_{t-i} + \sum_{j=1}^{n} \gamma_j Y_{t-j} + u_t, \tag{1}$$

$$Y_t = a + \sum_{i=1}^{q} b_i Y_{t-i} + \sum_{j=1}^{r} c_j X_{t-j} + v_t, \tag{2}$$

where u_t and v_t are zero-mean, serially uncorrelated, random disturbances.

Secondly, Granger causality tests with cointegrated variables may utilize the $I(0)$ data with an error correction term i.e.

$$\Delta X_t = \alpha + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \sum_{j=1}^{n} \gamma_j \Delta Y_{t-j} + \delta ECM_{t-1} + u_t \tag{3}$$

$$\Delta Y_t = a + \sum_{i=1}^{q} b_i \Delta Y_{t-i} + \sum_{j=1}^{r} c_j \Delta X_{t-j} + dECM_{t-1} + v_t \tag{4}$$

Thirdly, if the data are $I(1)$ but not cointegrated, valid Granger type tests require transformation to make them $I(0)$. So, in this case the equations become

$$\Delta X_t = \alpha + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \sum_{j=1}^{n} \gamma_j \Delta Y_{t-j} + u_t, \tag{5}$$

$$\Delta Y_t = a + \sum_{i=1}^{q} b_i \Delta Y_{t-i} + \sum_{j=1}^{r} c_j \Delta X_{t-j} + v_t. \tag{6}$$

The optimum lag length m, n, q and r are determined on the basis of Akaike's (AIC) and/or Schwarz Bayesian (SBC) and/or log-likelihood ratio test (LR) Criterion.

Now, for Eqs. (1) and (2), Y Granger causes (GC) X if,

H_0: $\gamma_1 = \gamma_2 = \ldots = \gamma_n = 0$ is rejected

against

H_A: =at least one $\gamma_j \neq 0, j = 1 \ldots n$

and X GC Y if, H_0: $c_1 = c_2 = \ldots = c_n = 0$ is rejected

against

H_A: =at least one $c_j \neq 0, j = 1 \ldots r$.

For Eqs. (3) and (4), ΔY GC ΔX if,

H_0: $\gamma_1 = \gamma_2 = \ldots = \gamma_n = 0$ is rejected

against

H_A: =at least one $\gamma_j \neq 0, j = 1 \ldots n$, or $\delta \neq 0$

and ΔX GC ΔY if, H_0: $c_1 = c_2 = \ldots = c_n = 0$ is rejected

against

H_A: =at least one $c_j \neq 0, j = 1 \ldots r$, or $d \neq 0$

For Eqs. (5) and (6), ΔY GC ΔX if, H_0: $\gamma_1 = \gamma_2 = \ldots = \gamma_n = 0$ is rejected

against

H_A: =at least one $\gamma_j \neq 0, j = 1 \ldots n$,

and ΔX GC ΔY if, H_0: $c_1 = c_2 = \ldots = c_n = 0$ is rejected

against

H_A: =at least one $c_j \neq 0, j = 1 \ldots r$,

The tests are conducted on the annual data for India covering the period 1950–51 to 1996–97. Data on Gross Domestic Product (GDP) in Rupees at 1980–81 price, which is a proxy to economic growth, has been collected from "National Accounts Statistics of India" published by Economic and Political Weekly Foundation, India. Electricity consumption (in KWh) has been taken from "Public Electricity Supply, All India Statistics" published by Central Electricity Authority, India. A graphical representation of the per capita GDP and per capita electricity consumption, after dividing both the series by respective year's populations (available in National Accounts Statistics of India) is given in Fig. 1. ***Lgdp*** and ***Lel*** represent per capita GDP and per capita electricity consumption respectively after logarithmic transformation. The computer packages used for statistical analysis are Shazam (Version 8) and Microfit (Version 4).

3. Empirical results

In the first stage the order of integration of the data is investigated. Table 1 presents the results of unit root tests on the natural logarithms of the levels and the first differences of the two time series viz. per capita GDP and per capita electricity consumption. On the basis of the Phillips–Perron statistics, the null hypothesis of a unit root cannot be rejected. Stationarity is obtained by running the similar test on the first difference of the variables. This indicates that both the series are $I(1)$ in nature.