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. © 2002 Elsevier Science Ltd. All rights reserved.

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.

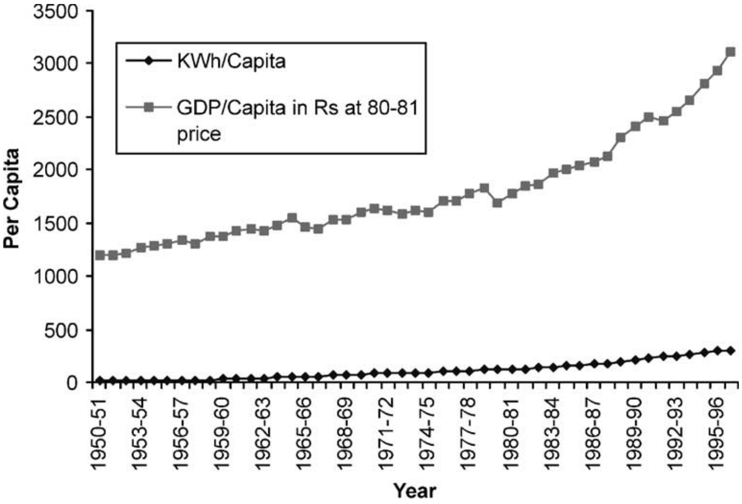

Fig. 1. Per capita GDP and per capita electricity consumption.

Table 1
Phillips–Perron unit root test

Variables	Constant, no trend	Constant, trend
Levels		
Lgdp	2.0379	−0.1288
Lel	−1.0304	−1.383
First difference		
$\Delta Lgdp$	−7.7306[a]	−8.3237[a]
ΔLel	−4.3299[a]	−5.3563[a]

[a] Represents rejection of null hypothesis at 10% level of significance. *Note*: 90 per cent critical values for PP statistic (without trend) = −2.57. 90 per cent critical values for PP statistic (with trend) = −3.13.

In the second stage, Johansen maximum likelihood procedure is used to detect cointegration. This provides a unified framework for estimation and testing of cointegrating relations in the context of a VAR error correction model. The cointegration rank, r, of the time series was tested using two test statistics. Denoting the number of cointegrating vectors by r_0, the maximum eigenvalue ($\lambda_{\max}$) test is calculated under the null hypothesis that $r_o = r$, against the alternative of $r_0 > r$. The trace test is calculated under the null hypothesis that $r_0 \leqslant r$, against $r_0 > r$.

The results of the Johansen maximum likelihood cointegration tests are presented in Table 2. Starting with the null hypothesis of no cointegration, among the variables i.e. $r = 0$, the maximal eigenvalue statistic is 10.3785, which is below the 90 per cent critical value of 16.2800. Hence the null hypothesis of $r = 0$ cannot be rejected at 10 per cent level of significance. Turning to the trace test as shown in Table 2, the null hypothesis of no cointegration is not rejected at 10 per cent level of significance. Hence, both eigenvalue ($\lambda_{\max}$) and trace test indicate that there is no cointegration relationship between ***Lgdp*** and ***Lel***.

Consequently the bivariate system $\boldsymbol{\Delta}$***Lgdp*** and $\boldsymbol{\Delta}$***Lel***, where 'Δ' is the first difference operator and hence define the growth of the respective variables, can be modeled as an unrestricted VAR.

On the basis of Schwarz Bayesian (SBC) and adjusted log-likelihood ratio (LR) test criteria, the optimal lag order of the VAR is chosen as 1. The absence of residual serial correlation of the individual equations has also confirmed the correct order of VAR selection.

Finally, Granger causality Test to the bivariate VAR has been examined. As shown in Table 3, the LR ratio

Table 2
Johansen–Juselius likelihood cointegration tests[a]

Null	Alternative	Statistic	90% critical value
Maximal eigenvalue test			
$r = 0$	$r = 1$	10.3785	16.2800
$r \leqslant 1$	$r = 2$	0.0094219	9.7500
Trace Test			
$r = 0$	$r \geqslant 1$	10.3879	21.2300
$r \leqslant 1$	$r = 2$	0.0094219	9.7500

[a] r is the number of cointegrating relations.

Table 3
Granger's causality tests

Null hypothesis	Chi-Sq (χ^2)	Dof[a]	P^b-value
Non-causality $\Delta Lgdp => \Delta Lel$	4.6360	1	0.031
Non-causality $\Delta Lel => \Delta Lgdp$	0.0097	1	0.921

[a] Degrees of freedom.
[b] Acceptance Probability.

statistic for the test of non-causality of the growth of electricity consumption per capita in the GDP growth per capita which is asymptotically distributed as a chi-square variate with one degree of freedom is clearly not statistically significant. While testing the non-causality of GDP growth per capita in electricity consumption growth per capita equation the observed LR statistic (follows chi-square distribution with one degree of freedom) 4.6360 is found to be statistically significant. This indicates the existence of causality running from GDP growth to electricity consumption with the absence of any feedback effect.

4. Conclusion

India is a populous country accounting nearly one-sixth of the world's population. The Indian economy has grown by about 4.5% per annum on a long-term basis in the second half of the twentieth century whereas the installed power generation capacity and generation has increased at the rate of 9% and 10% per annum compounded, respectively. The demand for electricity has been growing at a compound annual rate of growth (CARG) of nearly 8% (Das et al., 1999).

This paper has investigated the existence and direction of Granger causality between electricity consumption and economic growth in India using the annual data covering the period 1950–51 to 1996–97. Empirical results have established the existence of Granger causality running from economic growth to electricity consumption without any feedback effect. Thus, a growth in income is responsible for a high level of electricity consumption. This result can be interpreted as follows.

With the advancement of Indian economy, there has been inter-fuel substitution from conventional fuel like coal, firewood and oil to electricity in various sectors. Households, because of their higher disposable income, have become more and more dependent on the electric gadgets for recreation and comfort. Economic growth causes expansion in the industrial and commercial sectors where electricity has been used as basic energy input because of its clean and efficient nature. Electricity consumption in agricultural and transport sector has also accelerated to keep pace with country's economic growth. In the agricultural sector, pumps have been energized electrically for irrigation purpose since independence. As on 31st March 1997, the total number of pumpsets/tubewells energized were 11565342 (Public Electricity Supply, All India Statistics, 1996–97). Electricity consumption in transport sector (railway in particular) has been increased at an annual growth rate of 15% between the period 1970–1995. Under such circumstances, one could reasonably expect that economic growth enhances electricity consumption in India.

Indian electricity sector has been suffering from chronic supply shortage, high T&D losses of about 25–20 per cent against the world's average of 6–9 per cent mainly because of power theft, high auxiliary consumption and environmental problems associated with the coal based power plants. Due to irrational tariff structure, most of the State Electricity Boards (SEBs) in India have been suffering from poor operational and financial performances. Lower electricity tariffs in the agricultural and domestic sector, which have been cross-subsidized by industrial sector, encourage the consumers for wasteful use of electricity.

According to the projection made by Central Electricity Authority, India need another 100,000 MW install capacity in the next 10–12 years to bridge its future demand–supply gap. Government of India (GOI) has already started electricity sector reform aimed at corporatization of SEBs and rationalization of the tariff structure to make them independent profit centers. GOI is also planing to initiate a major energy conservation and efficiency improvement program as a part of the ongoing reform process because of high energy saving potentials in India. While energy conservation aims at reducing the need for energy without reducing the end use benefit, it provides a range of personal as well as social rewards also. First, conservation is cheaper than production. For example, 1 MW of power generation costs as much as 3–4 crores whereas same power can be saved with less investment. Second, electricity conservation avoids the environmental costs associated with the additional power generation.

In this situation, the existence of unidirectional causality running from economic growth to electricity consumption in India has serious policy implications for decision-makers as electricity conservation policies through rationalizing the tariff structure, efficiency improvement and demand side management, which aim at curtailment of wastage of electricity and there by reduce the electricity consumption without affecting the end-use benefits, can be initiated with no damaging impact on India's economic growth.

Acknowledgements

I am grateful to my wife Kakali for her help and encouragement.

References

Adjaye, A.J., 2000. The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Economics 22, 615–625.

Beenstock, M., Willcocks, P., 1981. Energy consumption and economic activity in industrialized countries: the dynamic aggregate time series relationship. Energy Economics 3 (4), 225–232.

Cheng, B.S., Lai, T.W., 1997. An investigation of co-integration and causality between energy consumption and economic activity in Taiwan. Energy Economics 19 (4), 435–444.

Das, A., Parikh, J., Parikh, K.S., 1999. Power the critical infrastructure. In: Parikh, K.S. (Ed.), India Development Report 1999–2000. Oxford University Press, New Delhi, pp. 113–124 ((Chapter 7)).

Engle, R.F., Granger, C.W.J., 1987. Co-integration and error-correction: representation, estimation and testing. Econometrica 55 (2), 251–276.

Erol, U., Yu, E.S.H., 1987. On the relationship between energy and income for industrialized countries. Journal of Energy and Employment 13 (1), 113–122.

Johansen, S., 1988. Statistical analysis of cointegration vectors. Journal of Economics Dynamics and control. 12 (2/3), 231–254.

Johansen, S., 1991. Estimation and hypothesis testing of cointegrating vectors in Gaussian vector autoregressive models. Econometrics 59 (6), 1551–1580.

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration with application to money demand. Oxford Bulletin of Economics and Statistics 52 (2), 169–210.

Kraft, J., Kraft, A., 1978. On the relationship between energy and GNP. Journal of Energy and Development 3 (2), 401–403.

Oxley, L., Greasley, D., 1998. Vector autoregression, cointegration and causality: testing for cause of the British industrial revolution. Applied Economics 30 (10), 1387–1397.

Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika 75, 335–346.

Samouilidis, J., Mitropopulous, C.S., 1984. Energy and economic growth in industrializing countries: the case of Greece. Energy Economics 6 (3), 191–206.

Stern, D.I., 2000. A multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy Economics 22 (2), 267–283.

Yang, H.Y., 2000. Coal consumption and economic growth in Taiwan. Energy Sources. 22 (2), 109–115.

Yu, E.S.H., Choi, J.Y., 1985. The casual relationship between energy and GNP: an international comparison. Journal of Energy and Development 10 (2), 249–272.