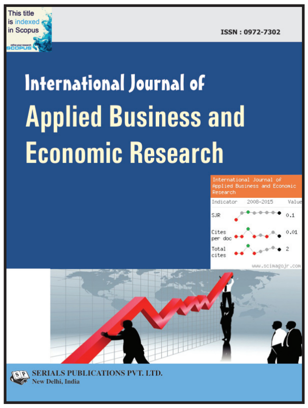

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Causal Nexus between Electricity Consumption and GDP in India

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ABSTRACT

This paper aimed at providing some answers relating to the long term association between per capita real GDP and per capita Electricity consumption using annual data covering the period 1971-2006 by using the co-integration and error correction models. Study reveals that there exists co-integration between the GDP per capita and per capita Electricity consumption. Both the time series per capita GDP and Electricity consumption are non stationary in level form, but are individually integrated of order one. Granger causality tests provided enough evidence of longer term equilibrium relation between the two variables. Empirical results have shown that up to lag 3 there exists a uni-directional causality running from GDP to per capita electricity consumption. Further VAR technique is used for forecasting the Electricity consumption. The validity of forecast made by VAR is limited to short term forecast with very mild forecast error.

JEL Classification: E21, E27, O4.

Keywords: Electricity Consumption, Causality, Economic growth, Energy policy.

1. INTRODUCTION

Indian economy growing as one of the fastest economies in the world naturally has a high demand for energy in particular electricity, during the period 1981-2000 it has witnessed an impressive GDP growth rate of around 6% per year and with per capita GDP rising by about 8 percent per year in 2000-2008, the growth in energy demand is enormous and in particular regarding electricity. India's electricity consumption is at the sixth position globally with 606 units of per capita consumption per annum. Soon it will become 1000 units per annum by 2012. Such high demand accounts from large population growth, rapid industrialization and urbanization and increasing per capita income. Electricity has been used as basic energy input because of its clean and efficient nature, consumption of electricity in India currently at some 600TWh annually and is all set to double by next ten years. Electricity is considered to be one of the key inputs for accelerating economic growth. The present per capita electricity generation in India is about 600 kWh per year. Since 1990s, India's gross domestic product (GDP) has been growing quite fast and it is forecast that it will continue to do so in the coming several decades.

GDP growth has to be accompanied by growth in consumption of primary energy as well as electricity. In line with the progress of Indian industry, the percentage share of various energy sources used in industrial activity also varying. At present approximately 14% share of electricity, about 38% of oil & natural gas and about 27% of coal has been used in various industrial activities. After the liberalization of Indian industry, the manufacturing and service industries are performing well to achieve higher growth in GDP. Economic growth causes expansion in the industrial and commercial sectors, as the correlation between per capita GDP and electricity consumption is very high, therefore careful analysis of these variables will guide to good policy making in determining the efficient use of energy sources.

A. Brief Literature Review

A number of studies have been carried out in the past that proved the importance of energy usage for the rate of economic development. A study on consumption of electricity and wealth creation (Ferguson et. al., 1997) for the Group of Seven (G-7) revealed that there is a strong correlation between electricity usage and wealth creation, but no relationship between total energy use and wealth. In continuation of the above study, Ferguson, Wilkinson and Hill (2000) expanded the scope of the study to almost all the countries of the world. The general conclusion of their study was that wealthy countries have a stronger correlation between electricity usage and wealth creation than between total energy use and wealth.

A study on "Electricity consumption and economic growth : a time series experience for 17 African countries" done by Wolde-Rufael et. al., has revealed that there was a long-run relationship between electricity consumption per capita and real GDP per capita for only 9 countries and Granger causality for only 12 countries. For 6 countries there was a positive uni-directional causality running from real GDP per capita to electricity consumption per capita; an opposite causality for 3 countries and bi-directional causality for the remaining 3 countries.

A study done by Pallab Mozumder and Achla Marathe for Bangladesh concluded that there is unidirectional causality from per capita GDP to per capita electricity consumption and the per capita electricity consumption does not cause per capita GDP.

A similar study on India was made by Sajal Ghosh titled "Electricity consumption and economic growth in India" examined the Granger causality between electricity consumption per capita and Gross Domestic Product (GDP) per capita using annual data covering the period 1950–51 to 1996–97. This study found 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.

Hypothesis & Research Questions

After a brief review of literature on the relationship between GDP and Electricity consumption we understood to believe that in most of the cases a uni-directional causality running from per capita GDP to per capita electricity consumption resulting in a dominated paradigm in this study. Therefore the hypothesis is assumed under this study is as follows.

H0: The relationship between per capita GDP and per capita Electricity consumption is uni-directional running from GDP to Electricity consumption.

The above hypothesis may be true or may not be true depending upon the empirical findings made for the period of study. However some research questions have to be addressed here.

Is the Increase in Electricity Consumption Leads to Higher Growth in GDP?

The answer to the above question is obviously the Causality factor that runs from each other. Thus, if there exist a uni-directional causality running from GDP to Electricity consumption which implies that economic activity causing electricity consumption.

Therefore in this case to cope with the expected demand in electricity consumption, electricity generation capacity must be increased otherwise we will impede GDP growth.

If there exist a bi directional causality between GDP and electricity consumption then policy makers has to see how well demand and supply of electricity can be managed at par with the economic activity so that a long run equilibrium relation between these variables used in energy policies to make sure that the use of available technology in converting other available energy sources in to electricity may go hand in hand in the future time.

Data and Methodology

This study covers the period 1971-2006; this period is the evidence for India's growth under the regimes of globalization and liberalization. The data variables are per capita electricity consumption (Billion KWH) and per capita real GDP (US $). This secondary data has been taken from the source of World Bank through the Gap minder documentation from World Wide Web. This time series data is analyzed by using the econometric techniques namely Engel-Granger two step procedure for co-integration and one step error correction mechanism to see the short run behavior of electricity consumption. The following Data Analysis section describes the results found through the application of gretl econometric software.

2. DATA ANALYSIS

Notations used

ELEC = Per Capita Electricity Consumption in Level form

GDP = Per Capita Real GDP in Level form

l_ELEC = Log Per Capita Electricity Consumption in Level form

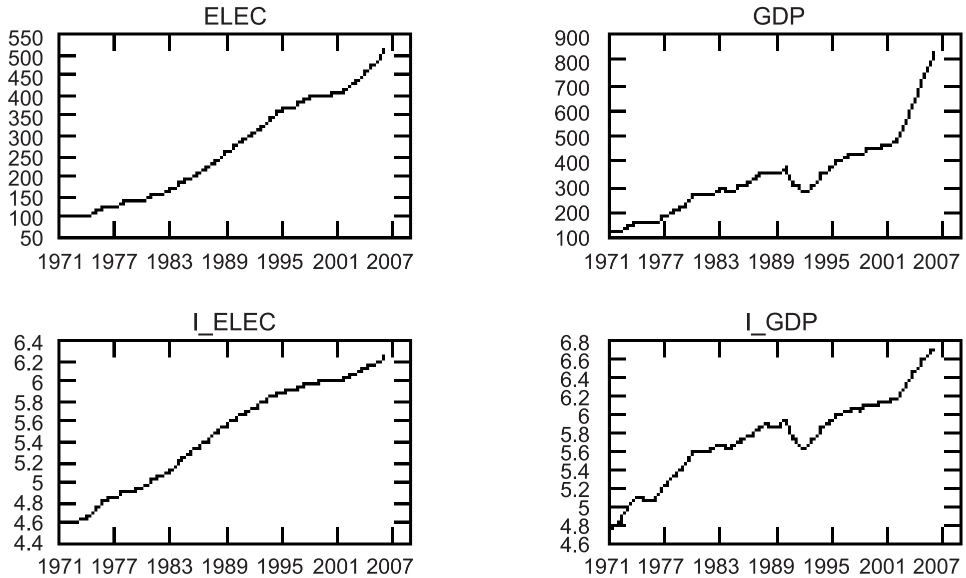
l_GDP = Log Per Capita Real GDP in Level form

d_l_ELEC = Log Per Capita Electricity Consumption in Difference form

d_l_GDP = Log Per Capita Real GDP in Difference form

uhat2 = OLS residual from co-integrating regression

Tests for Non Stationarity



The above time series graphs clearly shows an upward trend with some fluctuations, however after testing for non stationary using ACF and Correlogram tests we found that both the GDP and Electricity consumption are non stationary in both log form and without log form. We took logs for both variables to eliminate the scale effects and also the possible heteroskedasticity impact. The Q statistic developed by Box and Pierce has been used to check the non stationary, the *p*-value of statistic shows the evidence of non stationary of both the variables in level form, and the results are showed in Annexure-I.

Further the non stationary is supported by Augmented Dickey Fuller (ADF) test and KPSS statistics. The KPSS (Kwiatkowski, Phillips, Schmidt and Shin, 1992) is a unit root test in which the hypothesis is opposite to that in the ADF test: under the null, the series in question is stationary; the alternative is that the series I(1). If the calculated KPSS is greater than the critical value at the given level of significance then we reject the null hypothesis. The resulted *p*-values of ADF and critical values of KPSS statistics shows significant evidence of accepting the unit root hypothesis that confirms the non stationary, the results are provided in the following table.

Tests for Non Stationarity: ADF & KPSS

Sample size 36

Unit-root null hypothesis: $a = 1$

Variables	*Test*	*ADF Test– P-values*	*KPSS Statistic*				
			Calculated Values	*Critical Values*			
				10%	*5%*	*2.5%*	*1%*
In Log Level l_ ELEC	without constant	0.9999					
	with constant	0.7738	1.87297	0.347	0.463	0.574	0.739
	with constant and trend	0.9148					
l_GDP	without constant	0.9965					
	with constant	0.8647	1.6934	0.347	0.463	0.574	0.739
	with constant and trend	0.3544					

As we know that for foresting purpose the time series data should in stationary, therefore we take first difference of the level variables and check stationary of these variables through ADF and KSPSS statistics, results as showed in ***Annexure-I*** confirm the stationary in first differences.

Test for Co-integration

The next step is to see whether the two variables are co-integrated or not, that is whether per capita GDP and per capita Electricity consumption have long term or equilibrium relationship between them or not. For this we need to check the co-integration between these two variables. The time series graph of differenced variables shows an expected co-integration between two variables which is further confirmed by Engel and Granger causality test. Engel and Granger developed a co-integration test which uses the co-integrating OLS regression using level variables, where we can check the spurious regression results (R-Square value greater than Durbin Watson statistic) from which it test the stationary of the OLS residuals, if the residuals found to be white noise (stationary) then the variables are said to be co-integrated. The data variables found to be co-integrated as shown in the following illustration.

Model: OLS, using observations 1971-2006 (T = 36)

Dependent variable: l_ELEC

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	–0.519466	0.392998	–1.3218	0.19506	
l_GDP	1.04074	0.0682575	15.2472	<0.00001	***

Mean dependent var	5.452772	S.D. dependent var	0.529778
Sum squared resid	1.253354	S.E. of regression	0.191998
R-squared	0.872410	Adjusted R-squared	0.868657
F(1, 34)	232.4777	P-value(F)	9.12e-17
Log-likelihood	9.356731	Akaike criterion	–14.71346
Schwarz criterion	–11.54642	Hannan-Quinn	–13.60808
rho	0.891019	Durbin-Watson	0.234278

We took the model with constant as there was no trend effect and it is a difference stationary process. From the above OLS regression we found that R-Squared value is greater than the Durbin-Watson statistic value used as a thumb rule to identify spurious regression, but after testing for the stationary of OLS residuals through ADF test we found that residuals are white noise confirming the co-integration between per capita GDP and per capita Electricity, the results are given below.

Augmented Dickey-Fuller test for uhat2

including one lag of (1-L)uhat2

sample size 34

unit-root null hypothesis: $a = 1$

Test without constant

model: $(1 - L)y = (a - 1) \times y(-1) + \ldots + e$

1st-order autocorrelation coeff. for *e*: 0.008

estimated value of $(a - 1)$: −0.154304

test statistic: tau_nc(1) = −1.84682

asymptotic *p*-value 0.06175

Augmented Dickey-Fuller regression

OLS, using observations 1973-2006 (T = 34)

Dependent variable: d_uhat2

	coefficient	std. error	*t*-ratio	*p*-value
uhat2_1	−0.154304	0.0835513	−1.847	0.0317 **
d_uhat2_1	0.355460	0.167771	2.119	0.0420 **

The above *p*-value clearly indicates that the OLS residuals are stationary that confirms the co-integration. The OLS regression is l_ELEC = −0.519466 + 1.04074 × l_GDP, which is the static or long run per capita Electricity consumption function and the coefficient 1.04074 represents the long run or equilibrium marginal propensity to consumption (MPC) of Electricity. Economically a 10% increase in per capita GDP causes almost a 10% increase in per capita electricity consumption, this shows the significant impact of per capita GDP over per capita electricity consumption.

We just showed that per capita GDP and per capita Electricity are co-integrated; that is there is a long term or equilibrium relationship between the two. Of course in the short run there may be disequilibrium. Therefore one can treat the above OLS residual as the "Equilibrium Error" and we can use this error term to tie the short run behavior of per capita Electricity consumption to its long run value. This error correction mechanism (ECM) first used by Sargan and later developed by Engel and Granger corrects for disequilibrium. The following illustration gives the details of error correction check for short run behavior of the system. The following section gives a theoretical glimpse of ECM.

Error Correction Model

In addition to learning about a potential long-run relationship between two series, the concept of co-integration enriches the kinds of dynamic models. If Y_t and X_t are I(1) process and are not co-integrated, we might estimate a dynamic model in first differences. If Y and X are co-integrated, then the obtained estimated error term must be stationary, i.e., I(0). Now if we include the lagged estimated error term as

$$\Delta Y_t = \beta_0 + \sum_{j=1}^{k} \beta_j \Delta X_{1t-j} + \sum_{j=1}^{h} \alpha_j \Delta Y_{t-j} + \delta Z_{t-1} + \varepsilon_t$$

Where $Z_t = \hat{e}_t = Y_t - \hat{\beta}_0 - \sum_{j=1}^{k} \hat{\beta}_j \Delta X_{1t-j} - \sum_{j=1}^{h} \hat{\alpha}_j \Delta Y_{t-j}$ is the one-period lagged value of the estimated error of the co-integrating regression obtained from OLS estimation, this term is called the **error correction term**.

The error correction model of the consumption function becomes:

$$\Delta C_t = \beta_0 + \sum_{j=1}^{k} \beta_j \Delta Y_{t-1} + \sum_{j=1}^{h} \alpha_j \Delta C_{t-j} + \delta Z_{t-1} + e_t$$

The error correction term, $Z_t = C_t - \sum_{i=0}^{a} \gamma_i Y_{t-i} - \sum_{i=1}^{b} \vartheta_i C_{t-i}$, is obtained from the OLS regression.

Engel Granger one step Error Correction Model: using observations 1971-2006 (T = 36)

Dependent variable: d_l_ELEC

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
Const	0.0524258	0.0049512	10.5885	<0.00001	***
d_l_GDP	–0.0932118	0.0528264	–1.7645	0.08719	*
uhat2_1	–0.0608125	0.021724	–2.7993	0.00861	***

Mean dependent var	0.046851	S.D. dependent var	0.026926
Sum squared resid	0.017909	S.E. of regression	0.023657
R-squared	0.273495	Adjusted R-squared	0.228088
F(2, 32)	6.023246	P-value(F)	0.006023
Log-likelihood	82.94905	Akaike criterion	–159.8981
Schwarz criterion	–155.2321	Hannan-Quinn	–158.2874
Rho	0.259118	Durbin-Watson	1.464232

Therefore the error correction model becomes

$$\text{d\_l\_ELEC} = 0.013362 - 0.0932118 \times \text{d\_l\_GDP} - 0.0608125 \times \text{uhat2\_1} + \text{error}$$

The absolute value of $\delta = 0.0608125$ decides how quickly the equilibrium is restored. Statistically, the equilibrium error term (δ) is zero suggesting that Electricity consumption adjusts to changes in economic activity (GDP) in the same period, further more the short run changes in per capita GDP have a small negative impact on short run changes in electricity consumption and one can interpret the value 0.0932118 as the short run marginal propensity to consumption (MPC) of Electricity and the long run or equilibrium marginal propensity to consumption of Electricity is given by the coefficient 1.04074.

Selection of Lag Length: After confirming the co-integration relationship the next step is to determine the lag length by using the respective information criteria, AIC = Akaike criterion, BIC = Schwartz Bayesian criterion and HQC = Hannan-Quinn criterion. Above three criterions had given the lag length as 4, the results are showed in Annexure 1.

Vector Auto Regression (VAR) Model

The vector autoregressive (VAR) is commonly used for forecasting systems of interrelated time series and for analyzing the dynamic impact of random disturbances on the system of variables. The VAR approach sidesteps the need for structural modeling by treating every variable as endogenous in the system as a function of the lagged values of all endogenous variables in the system.

The term autoregressive is due to the appearance of the lagged values of the dependent variable on the right-hand side and the term vector is due to the fact that a vector of two (or more) variables is included in the system model. Since there are only lagged values of the endogenous variables appearing on the right-hand side of the equations, simultaneity is not an issue and OLS yields consistent estimates. Moreover, even though the innovations may be contemporaneously correlated, OLS is efficient and equivalent to GLS since all equations have identical regressors.

$$\mathrm{ELEC}_t = \mathrm{C}_1 + \sum_{i=1}^{k} a_{1i}\mathrm{ELEC}_{t-i} + \sum_{i=1}^{k} b_{1i}\mathrm{GDP}_{t-1} + e_{1t}$$

$$\mathrm{GDPM1}_t = \mathrm{C}_2 + \sum_{i=1}^{k} a_{2i}\mathrm{ELEC}_{t-i} + \sum_{i=1}^{k} b_{2i}\mathrm{GDP}_{t-1} + e_{2t}$$

Where e_{1t} and e_{2t} are stochastic error terms called as "Impulses or Innovations".

After selecting the suitable lag length, Vector Auto Regression (VAR) model is used to determine the direction of causality running in between the variables. The VAR calculation results are showed in the Annexure-I indicating the directional causality running between GDP and Electricity consumption at various lags. Up to lag 3 there exists a uni directional causality running from per capita GDP to per capita Electricity Consumption at 5% level of significance. (Exhibit-3.0 Annexure- I).

Finally the VAR model calculations (at lag3) are used for forecasting the per capita Electricity consumption, though we have used only per capita GDP the results have showed that forecast for the future years are accurate with very mild forecast error as specified in the Exhibit-4.0 of Annexure-I.

Limitations of the Study

- In this study unrestricted VAR is used to determine the causality and short-term forecast for per capita Electricity Consumption, therefore in considering the parametric restrictions user should be careful in giving the economic interpretations of the study.
- This empirical study is constrained to a small sample, hence any subsequent economic interpretations and corresponding policy implications must be treated with caution due to potential small sample, omitted variables and specification bias in considering the other macroeconomic variables.

Findings & Further Scope of Research:

In this study we used Engel-Granger two step procedures for co-integration, one step procedure for error correction mechanism, the same results can be obtained by using Johansen's rank method, where we find the rank as one indicating one co-integrating equation. Findings suggest that both the Engel-Granger and Johansen's methods proved to be good in case of two endogenous variable models.

This study will be further explored by adding more macroeconomic variables as endogenous variables in studying the per capita Electricity Consumption using multi variable VAR models and similar type of studies can be meaningful in studying the per capita energy consumption including alternative energy by using other macroeconomic factors.

3. CONCLUSION

In this empirical study the period of study covers the emergence of globalization and impact of liberalization on Indian economy, therefore the earlier results which ruled out the existence of long run relationship between GDP and Electricity Consumption need to be revisited to see the possible casual linkage as economy grows under the regimes of reforms.

From this empirical study we conclude and reiterate that the hypothesis the relationship between per capita GDP and per capita Electricity consumption is uni-directional running from GDP to Electricity consumption is true for India implies that increasing economic activity causing more electricity consumption, to cope with the expected demand in electricity consumption, electricity generation capacity must be increased otherwise we will impede economic growth. Results conclude that there exist a long term equilibrium relationship between per capita GDP and per capita Electricity Consumption that gives rise to careful electricity policies and regulations in tune with the economic growth. The existence of co-integration between GDP and Electricity Consumption draws up the attention of policy makers to devise more effective energy policies specially in using the electricity for economic activities.

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Annexure-I

Notations used in Data Analysis:

ELEC = Per Capita Electricity Consumption in Level form

GDP = Per Capita Real GDP in Level form

l_ELEC = Log Per Capita Electricity Consumption in Level form

l_GDP = Log Per Capita Real GDP in Level form

d_l_ELEC = Log Per Capita Electricity Consumption in Difference form

d_l_GDP = Log Per Capita Real GDP in Difference form

Tests for Non Stationarity:

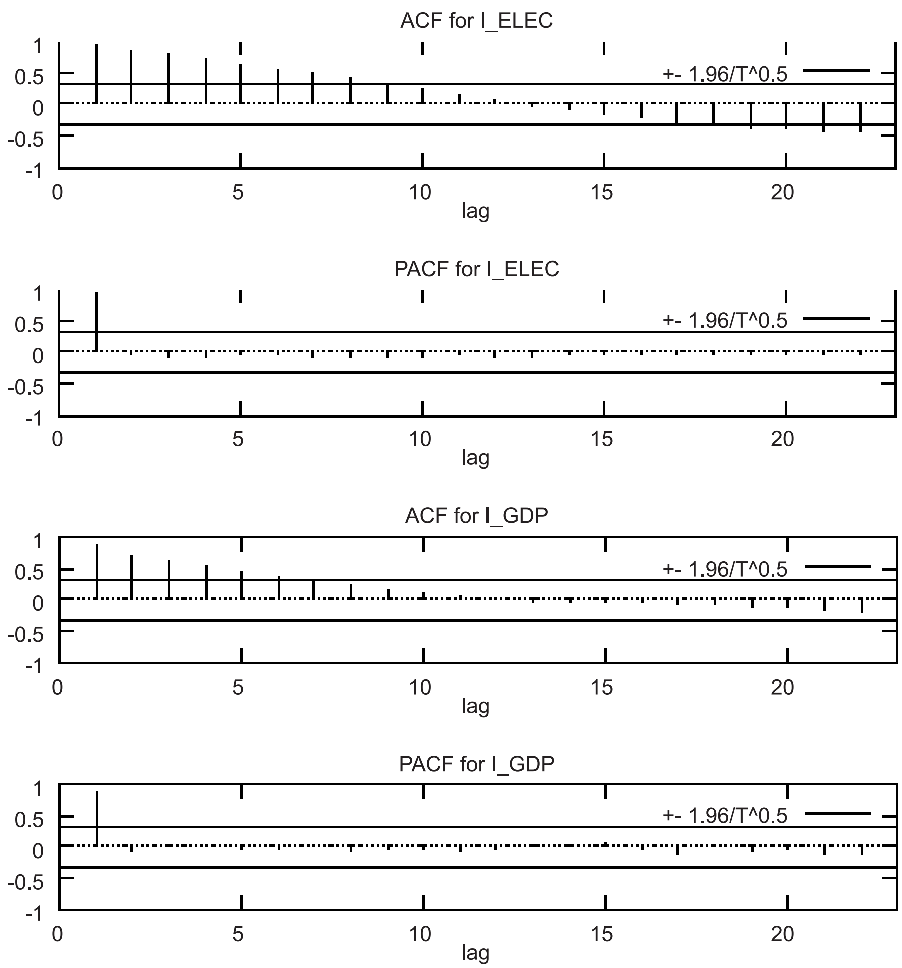

Exhibit 1.1

Summary Statistics, using the observations 1971-2006

Variable	*Mean*	*Median*	*Minimum*	*Maximum*
l_GDP	5.73847	5.74267	4.77305	6.71462
l_ELEC	5.45277	5.52722	4.59612	6.23589

Variable	*Std. Dev.*	*C.V.*	*Skewness*	*Ex. kurtosis*
l_GDP	0.475459	0.0828547	–0.173350	–0.353232
l_ELEC	0.529778	0.0971576	–0.196862	–1.40113

LAG	*ACF*	*PACF*	*Q-stat.*	*[p-value]*
1	0.9263***	0.9263***	33.5344	[0.000]
2	0.8522***	–0.0406	62.7553	[0.000]
3	0.7736***	–0.0719	87.5648	[0.000]
4	0.6940***	–0.0514	108.1551	[0.000]
5	0.6193***	–0.0115	125.0788	[0.000]
6	0.5475***	–0.0251	138.7452	[0.000]
7	0.4703***	–0.0867	149.1770	[0.000]
8	0.3937**	–0.0499	156.7488	[0.000]
9	0.3115*	–0.0922	161.6643	[0.000]
10	0.2279	–0.0711	164.3970	[0.000]
11	0.1480	–0.0415	165.5952	[0.000]
12	0.0661	–0.0840	165.8444	[0.000]
13	–0.0127	–0.0573	165.8540	[0.000]
14	–0.0840	–0.0266	166.2929	[0.000]
15	–0.1508	–0.0423	167.7749	[0.000]
16	–0.2116	–0.0377	170.8381	[0.000]
17	–0.2665	–0.0377	175.9504	[0.000]
18	–0.3132*	–0.0152	183.4034	[0.000]
19	–0.3518**	0.0177	193.3645	[0.000]
20	–0.3820**	–0.0122	205.8442	[0.000]
21	–0.4048**	–0.0147	220.7882	[0.000]
22	–0.4197**	–0.0129	238.0042	[0.000]

Exhibit 1.2: Autocorrelation function for l_ELEC

LAG	*ACF*	*PACF*	*Q-stat.*	*[p-value]*
1	0.8613***	0.8613***	28.9940	[0.000]
2	0.7213***	–0.0796	49.9248	[0.000]
3	0.6071***	0.0196	65.2054	[0.000]
4	0.5165***	0.0183	76.6101	[0.000]
5	0.4355***	–0.0183	84.9793	[0.000]
6	0.3563**	–0.0387	90.7684	[0.000]
7	0.2884*	–0.0043	94.6910	[0.000]
8	0.2199	–0.0518	97.0538	[0.000]
9	0.1598	–0.0163	98.3470	[0.000]
10	0.1092	–0.0125	98.9740	[0.000]
11	0.0549	–0.0598	99.1390	[0.000]
12	0.0095	–0.0108	99.1441	[0.000]
13	–0.0160	0.0311	99.1594	[0.000]

LAG	*ACF*	*PACF*	*Q-stat.*	*[p-value]*
14	–0.0306	0.0046	99.2177	[0.000]
15	–0.0244	0.0647	99.2565	[0.000]
16	–0.0274	–0.0370	99.3077	[0.000]
17	–0.0540	–0.0936	99.5178	[0.000]
18	–0.0758	–0.0001	99.9549	[0.000]
19	–0.1046	–0.0687	100.8349	[0.000]
20	–0.1248	–0.0126	102.1663	[0.000]
21	–0.1640	–0.1080	104.6189	[0.000]
22	–0.2174	–0.1069	109.2375	[0.000]

Exhibit 1.3: Autocorrelation function for l_GDP

Tests for Stationarity:

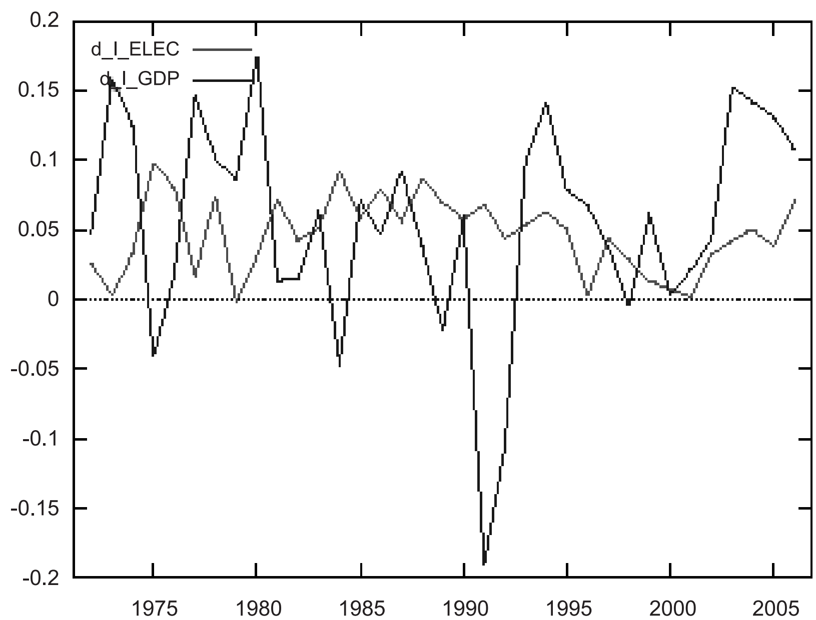

Exhibit 2.3

Tests for Stationary: ADF & KPSS

Sample size 34

For ADF Test: Unit-root null hypothesis: $a = 1$

Variables	*Test*	*ADF Test–P Values*	*KPSS Statistic (H0: Series is Stationary)*				
			Calculated Values	*Critical Values*			
				10%	*5%*	*2.5%*	*1%*
In difference	with constant	0.00229	0.239057	0.347	0.463	0.574	0.739
d_l_ELEC	with constant & trend	0.009781					
d_l_GDP	with constant	0.002889	0.138432	0.347	0.463	0.574	0.739
	with constant & trend	0.009609					

Exhibit 2.4

VAR system, maximum lag order 6

The asterisks below indicate the best (that is, minimized) values of the respective information criteria, AIC = Akaike criterion, BIC = Schwartz Bayesian criterion and HQC = Hannan-Quinn criterion.

lags	*loglik*	*p(LR)*	*AIC*	*BIC*	*HQC*
1	106.44193		–6.696129	–6.415889	–6.606478
2	109.67451	0.16700	–6.644967	–6.177902	–6.495549
3	117.89511	0.00248	–6.926340	–6.272448	–6.717155
4	127.62694	0.00064	–7.308463*	–6.467744*	–7.039510*
5	129.92063	0.33231	–7.194709	–6.167164	–6.865988
6	132.13258	0.35167	–7.075505	–5.861134	–6.687018

Selection of Lag Length:

VAR results showing direction of causality at different lags:

Null Hypothesis: Per capita GDP does not (Granger) cause per capita Electricity Consumption and vice versa

Direction of Causality	*Number of lags*	*F value [p value]*	*Decision*
l_ELEC → l_GDP	2	1.0536 [0.3617]	Accept
l_GDP → l_ELEC	2	2.7829 [0.0511]	Reject
l_ELEC → l_GDP	3	0.57729 [0.6351]	Accept
l_GDP → l_ELEC	3	2.881 [0.0218]	Reject
l_ELEC → l_GDP	4	2.1732 [0.1041]	Accept
l_GDP → l_ELEC	4	1.5139 [0.2311]	Accept

Exhibit 3.0

VAR Model to forecast the per capita Electricity Consumption:

VAR system, lag order 4

OLS estimates, observations 1975-2006 (T = 32)

$$\text{Log-likelihood} = 123.77525$$

$$\text{Determinant of covariance matrix} = 1.497509e - 006$$

$$\text{AIC} = -6.6110$$

$$\text{BIC} = -5.7865$$

$$\text{HQC} = -6.3377$$

Portmanteau test: LB(8) = 16.9832, *df* = 16 [0.3867]

Equation 1: l_ELEC

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.0301869	0.0816097	0.3699	0.71485	
l_ELEC_1	1.10593	0.224064	4.9358	0.00005	***
l_ELEC_2	–0.185624	0.335102	–0.5539	0.58497	
l_ELEC_3	0.0508368	0.312875	0.1625	0.87234	
l_ELEC_4	–0.0464826	0.190391	–0.2441	0.80929	
l_GDP_1	0.107381	0.068376	1.5704	0.12997	
l_GDP_2	–0.138696	0.118543	–1.1700	0.25398	
l_GDP_3	0.059253	0.11965	0.4952	0.62514	
l_GDP_4	0.0462041	0.0777782	0.5940	0.55828	

Mean dependent var	5.556132	S.D. dependent var	0.466436
Sum squared resid	0.014321	S.E. of regression	0.024953
R-squared	0.997877	Adjusted R-squared	0.997138
F(8, 23)	1351.093	P-value (F)	7.39e-29
rho	0.055556	Durbin-Watson	1.696339

F-tests of zero restrictions:

All lags of l_ELEC F(4, 23) = 228.13 [0.0000]

All lags of l_GDP F(4, 23) = 1.5139 [0.2311]

All vars, lag 4 F(2, 23) = 0.29774 [0.7453]

Equation 2: l_GDP

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.143056	0.236898	0.6039	0.55184	
l_ELEC_1	0.136244	0.650417	0.2095	0.83592	
l_ELEC_2	0.861339	0.972738	0.8855	0.38506	
l_ELEC_3	–2.34228	0.908218	–2.5790	0.01678	**
l_ELEC_4	1.4155	0.55267	2.5612	0.01746	**
l_GDP_1	1.39647	0.198483	7.0357	<0.00001	***
l_GDP_2	–0.574342	0.34411	–1.6691	0.10866	
l_GDP_3	–0.0078064	0.347323	–0.0225	0.98226	
l_GDP_4	0.10308	0.225776	0.4566	0.65227	

Mean dependent var	5.840840	S.D. dependent var	0.394519
Sum squared resid	0.120674	S.E. of regression	0.072434
R-squared	0.974990	Adjusted R-squared	0.966291
F(8, 23)	112.0784	P-value (F)	1.44e-16
rho	0.025730	Durbin-Watson	1.843075

F-tests of zero restrictions:

All lags of l_ELEC F(4, 23) = 2.1732 [0.1041]

All lags of l_GDP F(4, 23) = 34.264 [0.0000]

All vars, lag 4 F(2, 23) = 3.4072 [0.0506]

For the system as a whole

Null hypothesis: the longest lag is 3

Alternative hypothesis: the longest lag is 4

Likelihood ratio test: Chi-square(4) = 9.29114 [0.0542]

For 95% confidence intervals, $t(23, 0.025) = 2.069$

Obs	*Variable*	*prediction*	*std. error*	*95% interval*
2007	l_ELEC	6.29238	0.0211550	(6.24862, 6.33615)
2008	l_ELEC	6.34327	0.0305747	(6.28002, 6.40652)
2009	l_ELEC	6.40358	0.0370759	(6.32689, 6.48028)
2010	l_ELEC	6.46107	0.0432718	(6.37156, 6.55058)

The forecasted values in original level form are 540.43, 568.65, 604.00 and 639.74 respectively.

Exhibit 4.0