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RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ELECTRICITY CONSUMPTION IN INDIA: A RE-INVESTIGATION

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ABSTRACT

This paper attempts to re-examine the relationship between economic growth and electricity consumption in India for the period 1971-72 – 2016-17 for the country as a whole and for the agricultural and industrial sectors separately. Using gross value added (GVA) and per capita net national product (NNP) as indicators of economic growth techniques like cointegration, error correction model and Granger causality tests are applied for the study. The results indicate that there is a long run positive relationship between economic growth and electricity consumption when GVA is the indicator of growth. However, the short run coefficients are not statistically significant. Per capita NNP does not have any long run relationship with per capita electricity consumption but there is a unidirectional Granger-cause from log per capita NNP to log per capita electricity consumption when lag length is three. There is unidirectional Granger-causality from log GVA to log electricity consumption in the agricultural sector also. For the industrial sector, however, neither variable Granger causes the other. The cross section analysis for thirty two states and union territories of India reveals that per capita net state domestic product (NSDP) positively and significantly affects per capita electricity consumption of states in each of the years from 2012-13 to 2016-17. But the responsiveness of electricity consumption with respect to NSDP declines over the years.

Contribution/ Originality: This study contributes to the existing literature by examining the relationship between electricity consumption and economic growth of India separately for the agricultural and the industrial sectors of the country while the previous studies focused on the relationship at the aggregate level. Further, it is analyzed for the states also.

1. INTRODUCTION

The issue of relationship between energy consumption and economic growth has been a major concern among the academicians and policy makers throughout the world and over a long period of time. It is noted that primarily energy was not considered as a principal factor of production. Later on, it is argued that improved technique of production using energy may be employed to increase production as well as productivity at various sectors. Energy consumption can increase present and future income of people as that may be engaged in various income-generating activities. So, energy consumption can affect GDP of a country. The World Economic Forum also commented that "The energy industry fuels the economy and steady availability of reasonably priced energy is a crucial to economic growth" (World Economic Forum, 2012). On the other hand, larger GDP needs larger amount of energy. Thus, GDP of a country also can affect energy consumption. Therefore, there is a debate on the issue whether larger energy consumption leads to more GDP growth or larger GDP growth is the reason behind increased energy consumption. Some of the studies reveal that energy use leads to economic growth significantly when capital and labour inputs also increase; again, increase in capital and labour without any increase in energy use also cannot generate much economic growth. Thus, another literature is developed which examines whether energy is a substitute or complement to capital. The results differ in the short run and long run and also for cross section and time series analysis.

There is also concern about the adverse effects of using various types of energy from environmental point of view. The quality of energy is another important aspect. According to the view of resources model of economic growth use of poor quality energy leads to more CO_2 emission and that hampers the path of economic growth.

The direction of causation in the relationship between energy consumption and economic growth is very important in this respect. Because, if energy consumption causes GDP the economy is energy dependent and the economy should attempt to generate energy for improving economic growth (Gupta & Sahu, 2009). In that case lowering energy consumption for protecting environment would have negative impact on economic growth, i.e. energy conservation policies would not be justified from economic point of view. So, broadly the different ideas relating to the issue of relationship between energy consumption and economic growth are the following:

First, the growth hypothesis emphasizes on the important role played by energy consumption on economic growth; second, the conservation hypothesis believes that energy consumption does not affect real GDP; third, the neutrality hypothesis supports the idea that energy consumption and CO_2 emissions do not have a significant impact on economic growth; fourth, according to the feedback hypothesis energy consumption, CO_2 emission and GDP growth are interdependent.

Some studies include different types of renewable and non-renewable energy. Electricity being one form of energy used in the production process the relationship between electricity consumption and economic growth is also examined.

The present paper attempts to reconsider the issue of relationship between electricity consumption and economic growth in the context of the Indian economy. First, we consider it at the country level considering the period 1971-72 – 2016-17. Gross value added and per capita net national product are used as indicators of economic growth. Second, at the industry level the relationship is analyzed separately for the agricultural sector and industrial sector during the same period. Third, at the state level a cross section analysis is done for each of five years from 2012-13 to 2016-17.

The rest of the paper is organized as follows: Section 2 provides a brief survey of the literature on the issue. Data and methodology are given in Section 3. The examinations of the relationship between electricity consumption and economic growth at the country level, industry level and state level are presented in Sections 4, 5 and 6 respectively. Some concluding remarks are made in Section 7.

2. A BRIEF SURVEY OF THE LITERATURE

The issue of the relationship between energy consumption and economic growth formally begins with Kraft and Kraft (1978) where the existence of a relationship between gross energy consumption and GNP of the US was examined using data for the period 1947 – 74. The study is important because the results would have significant implications for the policy of energy conservation. However, the study comes up with the findings that there is definitely a relationship between these two variables, but the direction of causation moves from GNP to energy consumption and not from energy consumption to GNP, which implies that energy conservation would not affect economic growth adversely. Since then a huge number of studies are made on this issue. Bhatia (1987) presented a review the various aspects relating to energy demand analysis for developing countries and suggests that the relationship is to be examined for various sectors of the economy like agriculture, industry, transport, household etc., because energy-intensity differs across sectors. Behara (2015) summarised the various issues relating to the relationship between energy consumption and economic growth developed in the literature. It is observed that while the earlier studies focused on the relationship considering aggregate energy consumption, he examined how economic growth and various forms of energy consumption, viz., electricity, lignite, natural gas and petroleum are related for the period 1970 -2011 in case of Indian economy. The Granger causality test results suggest that economic growth causes natural gas and lignite energy consumption to increase; none of the energy forms has impact on GDP growth rate. The variance decomposition analysis, on the other hand, indicates a two-way causation between economic growth and lignite consumption, and between economic growth and electricity consumption, whereas, a unidirectional influence from economic growth to natural gas consumption.

Chary and Bohara (2010) showed that energy consumption in Bangladesh, India and Pakistan are co-integrated and the relationship was bidirectional for the period 1965 – 2005.

Sinha (2015) incorporated an additional explanatory variable viz., energy efficiency measured by reduction in energy waste. The findings show a direction of causation from economic growth to energy waste.

While most of the works are related to energy consumption some authors examine the relationship between electricity consumption and economic growth as electricity is the main source of power, and in modern age, per capita electricity consumption is considered as one of the measuring stick of economic development of a country. (Dhungel, 2017). Khanna and Rao (2009) surveyed the literature on the relationship between electricity consumption and economic growth and provided the theoretical foundation of the econometric model that is used by the authors to examine the relationship.

Some studies focus on the relationship between electricity consumption and economic growth for a single country. A few of those studies are Amusa and Leshoro (2013) for Botswana, Atif and Siddiqi (2010) for Pakistan, Khobai, Abel, and Le Roux (2016) for South Africa, Shahbaz, Sbia, Hamdi, and Ozturk (2014) for United Arab Emirates, Ogundipe and Apata (2013) and Chindo, Abdulrahim, Waziri, Huong, and Ahmad (2015) for Nigeria, Zaman (2015) for Pakistan, Zhao, Zhao, Han, He, and Guo (2016) for North China, Tang and Tan (2012) for Portugal. The analysis has been done for specific groups of countries also. Some of such contributions are Joyeux and Ripple (2011) for 30 OECD and 26 non-OECD countries by, Shakeel, Iqbal, and Majeed (2014) for South Asian countries, Khanna and Rao (2009) for developing countries, Campo and Sarmiento (2013) for 10 Latin American countries, Hamdi et al. for BIICS countries, and Dhungel (2017) for South Asian economies. Certain industry level studies are also there which examine the relationship between electricity consumption and output in different sectors. For example, Mushtaq (2008) examined the relationship for the agricultural sector of Pakistan and Lu (2017) examines for seventeen Taiwanese industries. Khandker, Samad, Ali, and Barnes (2014) studied the relationship at the micro level using household data for India to examine the impact of rural electrification on reduction of poverty.

The study of Bruns, Gross, and Stern (2014) comprises a full sample of 72 individual empirical studies having 574 growth causes energy statistics and 564 energy causes growth statistics and a meta-analysis is conducted. The results reveal that when energy price is a controlled variable then there is a genuine effect from output to energy use, whereas it seems valid from energy to output when employment is controlled.

The results of the studies do not indicate any common trend. Essentially, the findings can be classified into four groups, viz. unidirectional causality running from energy use to economic growth, unidirectional causality running from economic growth to energy use, bi-directional relationship between energy consumption and economic growth and no causal relationship between them.[1]

Since our study is related to electricity consumption and economic growth in India, we shall focus now on the works done on this area.

[1] A classification of the studies on the basis of these findings is provided by Tiwari (2012).

Ghosh (2002) examined the relation between electricity consumption and GDP per capita for the Indian economy. The study indicates existence of relationships between the variables for the period 1950-51 – 1996-97 where direction of causation moves from GDP to electricity consumption. Mukherjee (2008a) focused on inter-state disparities in electricity consumption in India. The disparities are caused by scale effect (measured by total production), structural effect (measured by structural composition) and intensity effect (measured by per unit electricity use with respect to gross state domestic product). For 18 major states of India the relative contributions in the total change in electricity consumption of these effects are estimated for the two periods early 1990s and late 1990s. Mukherjee (2008b) suggested a composite index for estimating efficiency in the use of electricity by incorporating various determining factors rather than using the ratio of total electricity consumption to gross state domestic product of a state. It has been applied for 18 major states of India and they are ranked according to this composite measure to compare the change in efficiency levels of the states from early 1990s to late 1990s.

Gupta and Sahu (2009) applied Granger causality test for the Indian economy for the period 1960 – 2006 and the results indicate that electricity consumption causes economic growth. Mallick (2009) examined the direction of causation in India considering different forms of energy consumption for the period 1970-71 – 2004-05. The major findings are that growth in GDP leads to more demand for natural gas, electricity and overall energy consumption, but only coal energy consumption affects GDP growth. Tiwari (2012) studied the validity of the growth hypothesis, conservation hypothesis, neutrality hypothesis and feedback hypothesis for the Indian economy during the period 1970 – 2005. The results indicate partial acceptance of the growth hypothesis while rejection of the other hypotheses.

Mahalik and Mallick (2014) extended the existing literature by incorporating the role of financial development as another determinant of energy consumption in case of Indian economy for the period 1971 - 2009. Kumar (2014) focused on balanced regional growth among the Indian states using convergence analysis for the period from 1990-91 to 2011-12. The study reveals that income disparities are increasing over time, whereas disparities in electricity consumption have decreased but remain stagnant.

The studies on the relationship between electricity consumption and economic growth of India focused mainly on the relationship at the aggregate level. In the present study we analyze the relationship separately for the agricultural and industrial sectors of the country. Further, it is considered for the states and union territories also.

3. DATA AND METHODOLOGY

We study the relationship between the following pairs of variables:

(a) Total gross value added (GVA) and total electricity consumption.
(b) Per capita net national product (NNP) and per capita electricity consumption.
(c) GVA by Agriculture and electricity consumption in agriculture.
(d) GVA by Industry and electricity consumption in industry.
(e) Per capita net state domestic product (NSDP) and per capita electricity consumption of states.

Table 1 shows the sources of data for each variable.

The model considered for time series analysis can be expressed as

$$\log Y_t = \alpha + \beta \log E_t + u_t$$

where Y is an indicator of economic growth and E is electricity consumption level.

For each pair of variables under study we follow the following methodology (Enders, 2018). In sections IV and V time series regression analysis is done. First, logarithm of each variable is taken and then unit root test is conducted to determine the order of integration of each variable using augmented Dickey-Fuller (ADF) test and Philips-Perron (PP) Test where optimum lag length is determined by Hannan-Quinn information criterion (HQIC), Schwartz Bayesian information criterion (SBIC) and Akaike information criterion (AIC). When both variables are found to be stationary at first difference Johansen methodology is used to examine whether the variables are co-integrated i.e., to check whether there exists a long run relationship between the variables.

Table-1. Variables and sources of data

Variable	Unit	Period	Source of data
GVA at factor cost (2004-05 prices)	Rs. Crore	1971-72 – 2017-18	Economic Survey Statistical Appendix 2018-19
GVA by agricultural sector	Rs. Crore	1971-72 – 2017-18	Economic Survey Statistical Appendix 2018-19
GVA by industrial sector	Rs. Crore	1971-72 – 2017-18	Economic Survey Statistical Appendix 2018-19
Per capita NNP	Rs.	1971-72 – 2014-15	Economic Survey Statistical Appendix 2018-19
Total electricity consumption	GWH	1971-72 – 2017-18	Energy Statistics 2007, 2011, 2018, 2019 www.mospi.gov.in
Electricity consumption by Agricultural sector	GWH	1971-72 – 2017-18	Energy Statistics 2007, 2011, 2018, 2019 www.mospi.gov.in
Electricity consumption by Industrial sector	GWH	1971-72 – 2017-18	Energy Statistics 2007, 2011, 2018, 2019 www.mospi.gov.in
Per capita electricity consumption	KWH	1971-72 – 2014-15[2]	http://data.worldbank.org
Per capita NSDP	Rs.	2012-13 – 2016-17	data.gov.in
Per capita Electricity consumption by states	KWH	2012-13 – 2016-17	data.gov.in

For the cases where the variables are found to be co-integrated an error correction model is estimated to analyse the short run relationship between them. The error correction model can be expressed as:

$$DlogY_t = a_0 + a_1 DlogY_{t-1} + a_2 DlogE_{t-1} + a_3 ECT_{t-1}$$

$$DlogE_t = b_0 + b_1 DlogY_{t-1} + b_2 DlogE_{t-1} + b_3 ECT_{t-1}$$

where ECT_{t-1} is the lagged error correction term, and a_3 and b_3 are the adjustment parameters.

For the cases where the variables are not found to be co-integrated a vector autoregressive model in first difference is used and Granger causality test is done. For cross section analysis done in section VI ordinary least squares technique is used and heteroscedasticity is checked using Breusch-Pagan test. Software stata is used to conduct the study.

4. THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ELECTRICITY CONSUMPTION AT THE COUNTRY LEVEL

As GVA and per capita NNP are used as indicators of economic growth we study the relationship between the following pairs of variables:

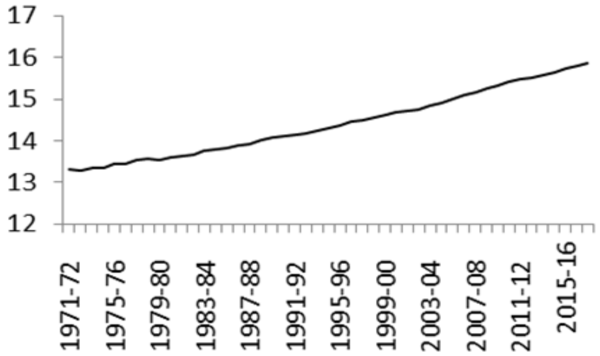
(a) Logarithm of GVA (Total) [lgva_t] and logarithm of total electricity consumption [lelcon_t].

(b) Logarithm of per capita NNP [lnnp_pc] and logarithm of per capita electricity consumption [lelcon_pc].

(a) Relationship between lgva_t and lelcon_t.

Figures 1(a) – 1(d) indicate that both the variables are non-stationary at level and stationary at first difference.

[2] We follow the guideline that 'if a country's fiscal year ends before June 30, world bank data are shown for the first year of the fiscal period' [https://datahelpdesk.worldbank.org].



Figures 1(a). Level of loggva_t

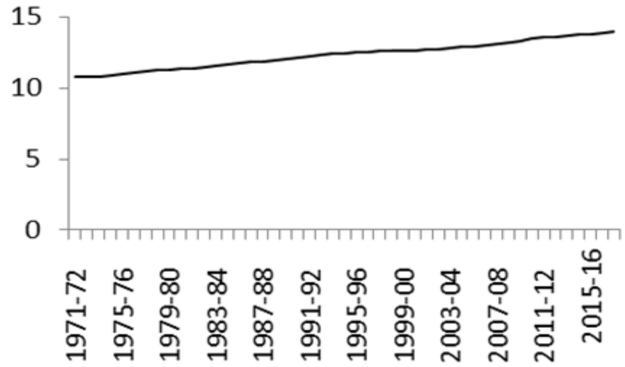
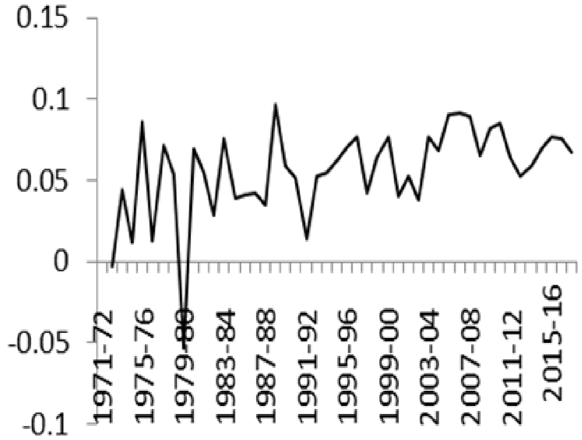


Figure1(b). Level of lelcon_t



Figures 1(c). First difference of lgva_t

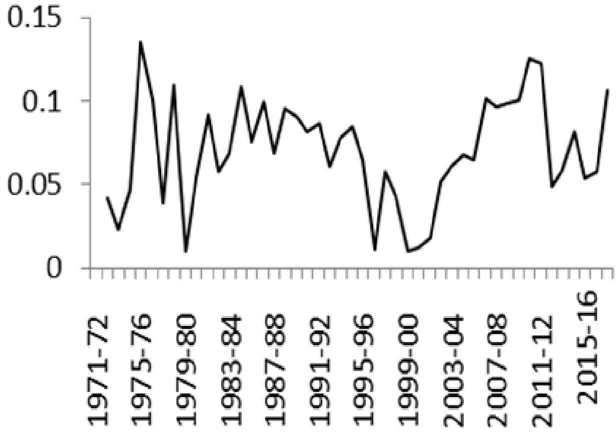


Figure 1(d): First difference of lelcon_t

Unit root tests are conducted for each variable to determine the order of integration using ADF and PP tests. From Table 2 it is found that the variables lgva_t and lelcon_t both are I(1) in a model with trend and constant.

Table-2. Unit Root Test Results for lgva_t and lelcon_t.

Model: Intercept and Trend	**Variable**	**ADF test statistic (5% critical value)**	**PP test statistic (5% critical value)**
Level			
	lgva_t	-1.240 (-3.524)	-1.732 (-3.516)
	lelcon_t	-2.032 (-3.524)	-1.546 (-3.516)
First Difference			
	lgva_t	-8.465 (-3.520)	-8.465 (-3.520)
	lelcon_t	-3.527 (-3.524)	-4.424 (-3.520)

Table 3 shows that for the VAR model the optimum lag length is 1 according to SBIC, 2 according to HQIC and 4 according to AIC.

Table-3. Selection-order criteria for VAR in lgva_t and lelcon_t.

Lag	**AIC**	**HQIC**	**SBIC**
0	.89286	.923068	.974776
1	-8.64997	-8.55935	-8.40422*
2	-8.75467	-8.60363*	-8.34509
3	-8.72709	-8.51563	-8.15367
4	-8.78498*	-8.51311	-8.04774

For lag length 2 the results of co-integration test are presented in Table 4. The results show that the null hypothesis of no co-integration (r=0) between the variables is rejected at 5 per cent level and we fail to reject the null hypothesis of r = 1. Thus, the two variables are co-integrated, i.e., there may be a long run relationship between the two variables.

Table-4. Results of Johansen tests for co-integration between lgva_t and lelcon_t Trend: Constant.

Maximum Rank	Trace Statistic	5% Critical Value
0	18.3750	15.41
1	2.0296*	3.76
2		

Estimating the ECM we analyze the long run and short run relationship between the variables where the figures within parentheses are p-values.

Long run relationship:

$ECT_{t-1} = lgva\_t_{t-1} - 1.49 lelcon\_t_{t-1} + 1.52$

(0.0)

Short run relationships:

$Dlgva\_t_t = -0.02ECT_{t-1} - 0.17Dlgva\_t_{t-1} - 0.07Dlelcon\_t_{t-1} + 0.02$

(0.01) (0.275) (0.561) (0.346)

$Dlelcon\_t_t = 0.007ECT_{t-1} + 0.28Dlgva\_t_{t-1} + 0.28Dlelcon\_t_{t-1} + 0.05$

(0.412) (0.141) (0.060) (0.012)

The estimated coefficient of lelcon_t (−1.49) is statistically significant as p value (0.00) is less than any preassigned level of significance and in the long run lelcon_t positively affects lgva_t. The estimated adjustment parameters (− 0.02 and 0.007) have correct signs. Further, the estimated adjustment parameter for lgva_t is statistically significant also. This implies that previous year's error or any deviation from long run equilibrium is corrected for within the current year at a speed of adjustment of 2 per cent. In the short run, lelcon_t negatively impacts lgva_t which is unexpected; however, the estimated coefficient is statistically insignificant. In the short sun lgva_t has positive impact on lelcon_t which is expected, although the estimated coefficient is insignificant.

Further, the diagnostic tests reveal that no autocorrelation in residuals is detected and the model satisfies stability conditions.

(b) Relationship between lnnp_pc and lelcon_pc

The ADF and PP unit root test results, presented in Table 5 show that both lnnp_pc and lelcon_pc are I(1).

Table-5. Unit Root Test Results for lnnp_pc and lelcon_pc.

Model: Intercept and Trend	Variable	ADF test statistic (5% critical value)	PP test statistic (5% critical value)
Level			
	lnnp_pc	-.924 (-3.520)	-1.436 (-3.516)
	lelcon_pc	-1.603 (-3.532)	-1.507 (-3.528)
First Difference			
	lnnp_pc	-8.465 (-3.520)	-8.465 (-3.520)
	lelcon_pc	-4.999 (-3.532)	-4.999 (-3.532)

Table-6. Selection-order criteria for VAR in lnnp_pc and lelcon_pc.

Lag	AIC	HQIC	SBIC
0	.265659	.296191	.350103
1	-8.74982*	-8.65822*	-8.49648*
2	-8.69631	-8.54365	-8.27409
3	-8.71211	-8.49838	-8.121
4	-8.66033	-8.38554	-7.90033

Table 6 shows that according to all criteria the optimum lag length is 1. Now we examine whether the two variables are co-integrated.

Table-7. Results of Johansen tests for co-integration between lnnp_pc and lelcon_pc.

Trend: Constant

Maximum rank	Trace statistic	5% critical value
0	14.3429*	15.41
1	0.1968	3.76
2		

In Table 7 since we find that the trace statistic is less than the 5 per cent critical value we fail to reject the null hypothesis of 'no co-integration between the variables' and conclude that there may not be any long run relationship between the variables.[3] Since, lnnp_pc and lelcon_pc are both I(1) and they are not co-integrated we consider VAR in first differences of the variables followed by Granger-causality test. The results are presented in Table 8.

Table-8. Granger causality wald tests results for dlnnp_pc and dlelcon_pc with lag 1[a].

Null Hypothesis (H_0)	Chi2	df	p-value	Decision
Dlelcon_pc does not Granger cause Dlnnp_pc	.13541	1	0.713	H_0 is not rejected
Dlnnp_pc does not Granger cause Dlelc_onpc	.65413	1	0.419	H_0 is not rejected

Note: a: optimum lag length is one according to SBIC and HQIC, and three according to AIC.

In Table 8 since, the p-value 0.713 is more than any pre-assigned level of significance we fail to reject the null hypothesis that 'lelcon_pc does not Granger-cause lnnp_pc' and conclude that lelcon_pc may not Granger-cause lnnp_pc. Similarly, it is observed that lelcon_pc may not Granger-cause lnnp_pc.

As according to AIC the optimum lag length for VAR in first difference is 3 we conduct Granger-causality test using VAR in first difference with lag 3 also. The results are presented in.

Table-9. Granger causality Wald tests Results for lnnp_pc and lelcon_pc with lag length 3.

Null Hypothesis (H_0)	Chi2	df	p-value	Decision
Dlelcon_pc does not Granger cause Dlnnp_pc	3.222	3	0.359	H_0 is not rejected
Dlnnp_pc does not Granger cause Dlelc_onpc	8.9042	3	0.031	H_0 is rejected

Table 9 which reveal that lnnp_pc Granger-causes lelcon_pc. Hence, we may conclude that there is a unidirectional causation running from lnnp_pc to lelcon_pc when the lag length is 3.[4]

Further, the diagnostic tests reveal that no autocorrelation in residuals is detected and the model satisfies stability conditions.

5. THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ELECTRICITY CONSUMPTION IN THE AGRICULTURAL AND INDUSTRIAL SECTORS

Bhatia (1987) rightly pointed out that energy intensities differ across various sectors of an economy which is evident from Figure 2. So, as suggested by him we examine the relationship separately for agriculture and industry. We thus consider the relationship between.

[3] This is the result in a model with trend (constant). It is checked that the variables are not co-integrated for alternative specifications also.

[4] Ghosh (2002) examined the relation between electricity consumption and GDP per capita for the Indian economy for the period 1950-51 – 1996-97 and found that direction of causation moves from GDP to electricity consumption.

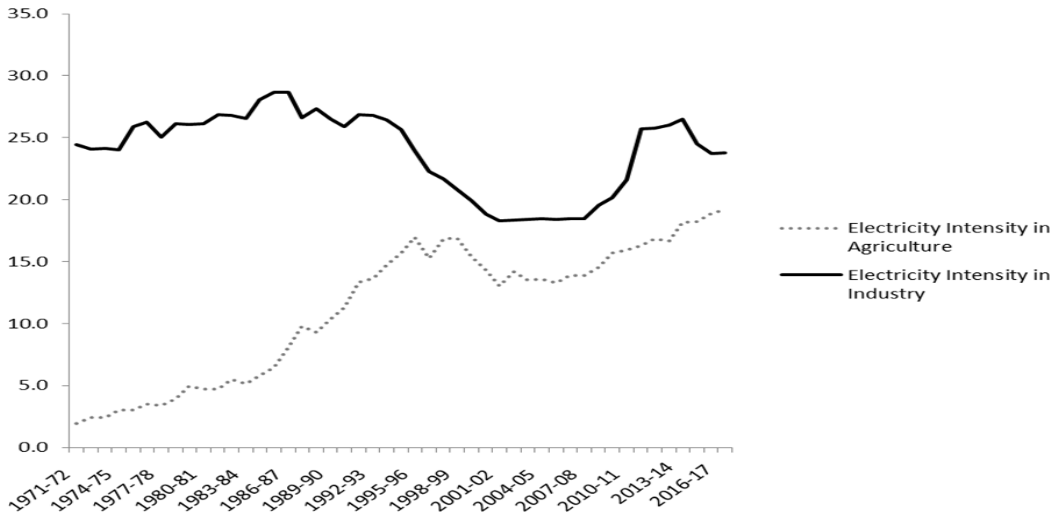


Figure-2. Electricity intencities (GHW/Rs. 2004-05 crore) in agriculture and industry.

(a) Logarithm of GVA by Agriculture [lgva_a] and logarithm of electricity consumption by agriculture [lelcon_a].

(b) Logarithm of GVA by Industry [lgva_i] and logarithm of electricity consumption in industry [lelcon_i].

(a) Relationship between lgva_a and lelcon_a.

Table 10 reveals that the variables are I(1) according to the ADF test whereas according to PP test.

Table-10. Unit Root Test Results for lgva_a and lelcon_a.

	Variable	ADF test statistic (5% critical value)	PP test statistic (5% critical value)
Level			
	lgva_a	-3.317 (-3.524)	-6.400 (-3.516)
	lelcon_a	-1.875 (-3.524)	-1.450 (-3.516)
First Difference			
	lgva_a	-5.312 (-3.528)	
	lelcon_a	-2.502 (-1.683)[d]	-4.809 (-3.520)

Note: **d:** with drift.

lgva_a is I(0) and lelcon_a is I(1).

When the two variables are integrated of different order they cannot be co-integrated. For the case when they are both I(1) Johansen co-integration test results are shown in Table 11.

Table-11. Results of Johansen tests for co-integration between lgva_a and lelcon_a Trend: Constant

Maximum rank	Trace statistic	5% critical value
0	6.4049*	15.41
1	0.2214	3.76
2		

The result indicates that lgva_a and lelcon_a are not co-integrated.

The results of Granger-causality test on VAR in first difference of the variables presented in Table 12.

Table-12. Granger causality Wald tests Results for Dlgva_a and Dlelcon_a.

Null hypothesis (H_0)	Chi2	df	p-value	Decision
Dlelcon_a does not Granger cause Dlgva_a	.07735	1	0.781	H_0 is not rejected
Dlgva_a does not Granger cause Dlelcon_a	4.3607	1	0.037	H_0 is rejected

Indicate a unidirectional Granger-cause running from lgva_a to l_elcon_a.

Further, the diagnostic test results show that there is no autocorrelation and the VAR model is stable.

(b) Relationship between lgva_i and lelcon_i

Table-13. Unit Root Test Results for lgva_i and lelcon_i.

Model: Intercept and Trend	Variable	ADF test statistic (5% critical value)	PP test statistic (5% critical value)
Level			
	lgva_i	-2.007 (-3.520)	-1.894 (-3.516)
	lelcon_i	-1.013 (-3.520)	-0.820 (-3.516)
First Difference			
	lgva_i	-5.310 (-3.520)	-5.310 (-3.520)
	lelcon_i	-3.510 (-3.524)	-5.101 (-3.520)

Table 13 shows that both lgva_i and lelcon_i are I(1) according to ADF and PP tests. Table 14 shows that lgva_i and lelcon_i are not cointegrated.

Table-14. Johansen tests Results for cointegration between lgva_i and lelcon_i Trend: Constant.

Maximum rank	Trace statistic	5% critical value
0	6.4962*	15.41
1	1.0488	3.76
2		

The Granger-causality test results presented in Table 15 indicate that neither variable Granger-causes the other.

Table-15. Granger causality Wald tests for lgva_i and lelcon_i.

Null hypothesis (H_0)	Chi2	df	p-value	Decision
Dlelcon_i does not Granger-cause Dlgva_i	.16955	1	0.681	H_0 is not rejected
Dlgva_i does not Granger-cause Dlelcon_i	.01916	1	0.890	H_0 is not rejected

6. THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ELECTRICITY CONSUMPTION FOR INDIAN STATES AND UNION TERRITORIES

In this section we examine the relationship between economic growth and electricity consumption at the state level. We conduct cross section analysis for 32 States and Union Territories of India in each of 5 periods from 2012-13 to 2016-17.[5] Per capita net state domestic product is used as the indicator of economic growth of a state. First we look at the descriptive statistics presented in Table 16. It is found that in this five year period both mean and SD have increased for nsdp_pc as well as for elcon_pcs; but while coefficient of variation for nsdp_pc has increased, that for elcon_pcs has remained same. That is, while disparity in NSDP increases disparity in electricity consumption does not change. This observation was made by Kumar (2014) during 1990-91-2011-12.

Table-16. Some Descriptive Statistics on per capita net state domestic product (nsdp_pc) and per capita electricity consumption of states (elcon_pcs).

Year	Mean nsdp_pc (Rs.)	SD nsdp_pc (Rs.)	CV nsdp_pc (%)	Mean elcon_pcs (KWH)	SD elcon_pcs (KWH)	CV elcon_pcs (%)
2012-13	84616.28	47180.37	55.76	1007.84	547.81	54.35
2013-14	87898.84	46527.13	52.93	1002.59	567.21	56.57
2014-15	93460.78	52143.72	55.79	1025.31	563.78	54.99
2015-16	100101.2	58778.03	58.72	1115.94	641.78	57.51
2016-17	107497.4	63731.46	59.29	1150.06	627.89	54.60

[5] Data were not available for D. and N. Haveli, Daman & Diu, Lakshadeep and Telangana.

We now consider regression of lelcon_pcs on lnsdp_pc where lelcon_pcs and lnsdp_pc are the logarithms of per capita electricity consumption of a state and per capita net state domestic product respectively.

$$\text{Model: lelcon\_pcs} = \alpha + \beta \text{ lnsdp\_pc} + v,$$

where v is the error term.

The summary regression results are presented in Table 17.

Table-17. Results of Regression of lelcon_pc on lnsdp_pc.

Year	$\hat{\alpha}$	$\hat{\beta}$	se $\hat{\beta}$	t $\hat{\beta}$	p-value H_0:β=0	R^2	$\bar{R}^2$	p-value for H_0: constant error variance
2012-13	-3.40	0.90	0.16	5.49	0.000	0.50	0.48	0.12
2013-14	-2.88	0.85	0.18	4.64	0.000	0.41	0.40	0.43
2014-15	-1.18	0.70	0.18	3.83	0.001	0.33	0.31	0.44
2015-16	-0.80	0.67	0.17	3.81	0.001	0.33	0.30	0.67
2016-17	-0.63	0.66	0.17	3.90	0.001	0.34	0.31	0.58

The regression results can be interpreted in the following way. For cross section analysis we suspect presence of heteroscedasticity. But the p-values (shown in the last column of Table) are more than any pre-assigned level of significance. Therefore, we fail to reject the null hypothesis of constant error variance and may conclude that heteroscedasticity is not detected. Then, an ordinary least squares technique is applicable. We find that the regression coefficient is positive that is having anticipated sign and it is statistically significant in each year as the p-values (shown in the sixth column) are less than any pre-assigned level of significance. So, we may conclude that the per capita NSDP positively affects the per capita electricity consumption of states. However, the estimated elasticity of states' per capita electricity consumption with respect to per capita net state domestic product (given by the value of estimated coefficient) falls from 90 per cent to 66 per cent. Overall, only 30 – 48 per cent of variation in lelcon_pcs is explained by the model, that is, the model is not a good fit for any of the years.

7. CONCLUDING REMARKS

This paper attempts to re-examine the relationship between economic growth and electricity consumption in India for the period 1971-72 – 2016-17 for the country as a whole and for the agricultural and industrial sectors separately. Further, the relationship is also examined at the state level.

The results indicate that when gross value added is used as the indicator of economic growth there is a long run positive relationship between economic growth and electricity consumption of the country. The estimated adjustment coefficients have correct signs and any short run deviation of logarithm of GVA from the long run equilibrium is corrected at a speed of 2 per cent. However, the other short run coefficients are not statistically significant. When per capita net national product is used as the indicator of economic growth there is no long run relationship between per capita NNP and per capita electricity consumption and there is a unidirectional Granger-cause running from log per capita NNP to log per capita electricity consumption when lag length is 3. For the agricultural sector also there is no long run relationship between GVA and electricity consumption and there is unidirectional Granger-cause from log GVA in agriculture to log electricity consumption in agriculture. For the industrial sector there is no long run relationship between GVA and electricity consumption and neither variable Granger causes the other.

At the state level also per capita NSDP has a positive and significant impact on per capita electricity consumption of states. But the responsiveness of electricity consumption with respect to NSDP declines over the years.

In general, our study indicates a unidirectional causation from economic growth to electricity consumption in India during the study period. Thus, we may come to the remark that the energy conservation policies in terms of electricity would not have adverse effects on the economic growth the country.

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REFERENCES

Amusa, K., & Leshoro, T. L. A. (2013). The relationship between electricity consumption and economic growth in Botswana. *Corporate Ownership and Control*, *10*(4), 400 – 408.Available at: https://doi.org/10.22495/cocv10i4c4art3.

Atif, S. M., & Siddiqi, M. W. (2010). The electricity consumption and economic growth nexus in Pakistan: A new evidence.

Behara, J. (2015). Energy consumption and economic growth in India: Areconciliation of disaggregate analysis. *Journal of Energy Technologies and Policy*, *5*(6), 15 – 27.

Bhatia, R. (1987). Energy demand analysis in developing countries: A review. *The Energy Journal Special LDC*, *8*(1), 1 – 33.Available at: https://doi.org/10.5547/issn0195-6574-ej-vol8-nosi-2.

Bruns, S., Gross, C., & Stern, D. (2014). Is there really granger causality between energy use and output? *Energy Journal*, *35*(4), 101-133.Available at: https://doi.org/10.5547/01956574.35.4.5.

Campo, J., & Sarmiento, V. (2013). The relationship between energy consumption and GDP: Evidence from a panel of 10 Latin American countries. *Latin american Journal of Economics*, *50*(2), 233-255.Available at: https://doi.org/10.7764/laje.50.2.233.

Chary, S. R., & Bohara, A. K. (2010). Energy consumption in Bangladesh, India, and Pakistan: Cointegration analysis. *The Journal of Developing Areas*, *44*(1), 41-50.Available at: https://doi.org/10.1353/jda.0.0089.

Chindo, S., Abdulrahim, A., Waziri, S. I., Huong, W. M., & Ahmad, A. A. (2015). Energy consumption, CO 2 emissions and GDP in Nigeria. *Geo Journal*, *80*(3), 315-322.Available at: https://doi.org/10.1007/s10708-014-9558-6.

Dhungel, K. R. (2017). Linkages between electricity consumption and economic growth: Evidences from South Asian economies. *Hydro Nepal: Journal of Water, Energy and Environment*, *20*, 18-22.Available at: https://doi.org/10.3126/hn.v20i0.16484.

Enders, W. (2018). *Applied econometric time series*. New Delhi: Wiley India Pvt. Ltd.

Ghosh, S. (2002). Electricity consumption and economic growth in India. *Energy Policy*, *30*(2), 125-129.Available at: https://doi.org/10.1016/s0301-4215(01)00078-7.

Gupta, G., & Sahu, N. C. (2009). Causality between electricity consumption and economic growth: Empirical evidence from India. *MPRA Paper No. 22942*.

Joyeux, R., & Ripple, R. D. (2011). Energy consumption and real income: A panel co-integration multi-country study. *The Energy Journal*, *32*(2), 107-141.Available at: https://doi.org/10.5547/issn0195-6574-ej-vol32-no2-5.

Khandker, S. R., Samad, H. A., Ali, R., & Barnes, D. F. (2014). Who benefits most from rural electrification? evidence in India. *The Energy Journal*, *35*(2), 75-96.Available at: https://doi.org/10.5547/01956574.35.2.4.

Khanna, M., & Rao, N. D. (2009). Supply and demand of electricity in the developing world. *Annual Review of Resource Economics*, *1*(1), 567-596.Available at: https://doi.org/10.1146/annurev.resource.050708.144230.

Khobai, H., Abel, S., & Le Roux, P. (2016). Co-integration between electricity supply and economic growth in South Africa. *International Journal of Energy Economics and Policy*, *6*(3), 637-645.

Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *The Journal of Energy and Development*, 401-403.

Kumar, S. (2014). Convergence in electricity consumption in India: A state level analysis. *Indian Economic Review*, *49*(2), 173-191.

Lu, W.-C. (2017). Electricity consumption and economic growth: Evidence from 17 taiwanese industries. *Sustainability*, *9*(50), 1 – 15.

Mahalik, M. K., & Mallick, H. (2014). Energy consumption, economic growth and financial development: Exploring the empirical linkages for India. *The Journal of Developing Areas, 48*(4), 139-159.Available at: https://doi.org/10.1353/jda.2014.0063.

Mallick, H. (2009). Examining the linkage between energy consumption and economic growth in India. *The Journal of Developing Areas, 43*(1), 249-280.Available at: https://doi.org/10.1353/jda.0.0038.

Mukherjee, S. (2008a). Decomposition analysis of electricity consumption: A state-wise assessment. *Economic and Political Weekly, 43*(3), 57-64.

Mukherjee, S. (2008b). An alternative measure of efficiency in the use of electricity in India: A state wise assessment. *Indian Economic Review New Series, 43*(2), 229-251.

Mushtaq, K. (2008). *Energy use for economic growth: Co-integration and causality analysis from the agriculture sector of Pakistan*. Paper presented at the The Pakistan Development Review 46(4), Papers and Proceedings PARTS I and II Twenty-third Annual General Meeting and Conference of the Pakistan Society of Development Economists Islamabad, March 12-14, 2008 (Winter 2007): 1065-1073.

Ogundipe, A. A., & Apata, A. (2013). Electricity consumption and economic growth in Nigeria. *Journal of Business Management and Applied Economics, 2*(4), 1 – 14.

Shahbaz, M., Sbia, R., Hamdi, H., & Ozturk, I. (2014). Economic growth, electricity consumption, urbanization and environmental degradation relationship in United Arab Emirates. *Ecological Indicators, 45*, 622-631.Available at: https://doi.org/10.1016/j.ecolind.2014.05.022.

Shakeel, M., Iqbal, M. M., & Majeed, M. T. (2014). *Energy consumption, trade and GDP: A case study of South Asian countries*. Paper presented at the The Pakistan Development Review 53(4), Papers and Proceedings: PART II The 29th Annual General Meeting and Conference of the Pakistan Society of Development Economists Islamabad, December 19 - 21, 2013 (Winter 2014).

Sinha, A. (2015). Modeling energy efficiency and economic Growth: Evidences from India. *International Journal of Energy Economics and Policy, 5*(1), 96-104.

Tang, C., & Tan, E. (2012). Electricity consumption and economic growth in portugal: Evidence from a multivariate framework analysis. *Energy Journal, 33*(4), 23-48.Available at: https://doi.org/10.5547/01956574.33.4.2

Tiwari, A. K. (2012). On the dynamics of energy consumption, co- emissions and economic Growth: Evidence from India. *Indian Economic Review, 47*(1), 57-87.

World Economic Forum. (2012). Energy for economic growth, energy vision update. Retrieved from weforum.org. [Accessed 7.9.2019 1.05 PM]. 45.

Zaman, M. (2015). Examining relationship between electricity consumption and its major determinants in Pakistan. *International Journal of Energy Economics and Policy, 5*(4), 998 – 1009.

Zhao, H., Zhao, H., Han, X., He, Z., & Guo, S. (2016). Economic growth, electricity consumption, labor force and capital input: A more comprehensive analysis on North China using panel data. *Energies, 9*(11), 1-21.Available at: https://doi.org/10.3390/en9110891.

Websites:

data.gov.in Accessed 12.12.2019 12.40 PM

www.mospi.gov.in Accessed 12.12.19 11.20 AM

http://data.worldbank.org Accessed 17.12.19 2.30 PM