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Long-Run Relationship between Use of Electricity in Industries and Industrial Development in India: A Co-Integration Analysis

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I. Introduction

Energy has been played vital role in production process as an important factor. Previous studies have proved that there is a 'long-run stable relationship' between energy and economic development (Premakumara, 2012). In the present paper an effort has made to extend this argument to industrial energy consumption and industrial development; specifically, electricity consumption and industrial development. Accordingly, in the present work, an effort has made to examine the 'long-run relationship' between electricity consumption by industrial sector and industrial development. Use of long-run time series data always has threat of non-stationarity. Address the issue of stationarity is one of the objectives of this paper. After checked the data for stationarity, they have used to identify the co-integrating vectors for electricity use and industrial development. Based on the co-integration short-term disturbances in the long-run relationships have been analyzed.

II. Review of Literature

Positive relationship between energy and economic developmenthas been found from many previous studies (Masih A. M., 1996)(Asafu-Adjaye, 2000). Energy plays a significant role in determining industrial production (Premakumara, 2012)Electricity is one of the factors of production in industrial production process (Premakumara, 2012). There is a 'long-run relationship' between energy and economic development (Sascha & Andreas, 2015) (Sreenivas, 2014). There is also the long-run relationship between energy and industrial development (Kokichi Ito & Komiyama, 2005). However, long-run relationship between electricity use in industries and industrial development has not examined by the previous studies. Given the background, the present study has tried to estimate the 'long-run relationship' between electricity use in industries and industrial development by using 'Johansen co-integration' analysis.

III. Methodology

The 'long-run' time series data 1972 to 2015 have used for the analysis. The analysis used co-integration econometric and vector error correction methods. 'Johansen model' has used for co-integration analysis. Stationarity of data have checked with 'Phillips-Perron' test. CAGR and graphs have also used trend analysis. Results have estimated with the help of E-views and Gretl soft-wares. Parameters used in the analysis are;

- **Parameter represents Industrial Development**
  - INDINCOME: Industrial Incomeat Constant Prices, Amount in Billion,and Base Year: 2004-05.
- **Parameters represent Energy Use in Industries**
  - ELECTGEN: Gross Generation of Electricity in GWHs.
  - ELECTAVAIL: Availability (net Electricity available for supply) in GWHs.
  - TOTELECTCON: Total Consumption of Electricity in GWHs.
  - INDELECTCON: Industrial consumption of Electricity in GWHs.

Stationarity:

In this section an attempt has made to check the stationarity of time series data used in the analysis. 'Phillips-Perron' test has used for 'stationarity' of data. The following section presents results of Phillips-Perron test.

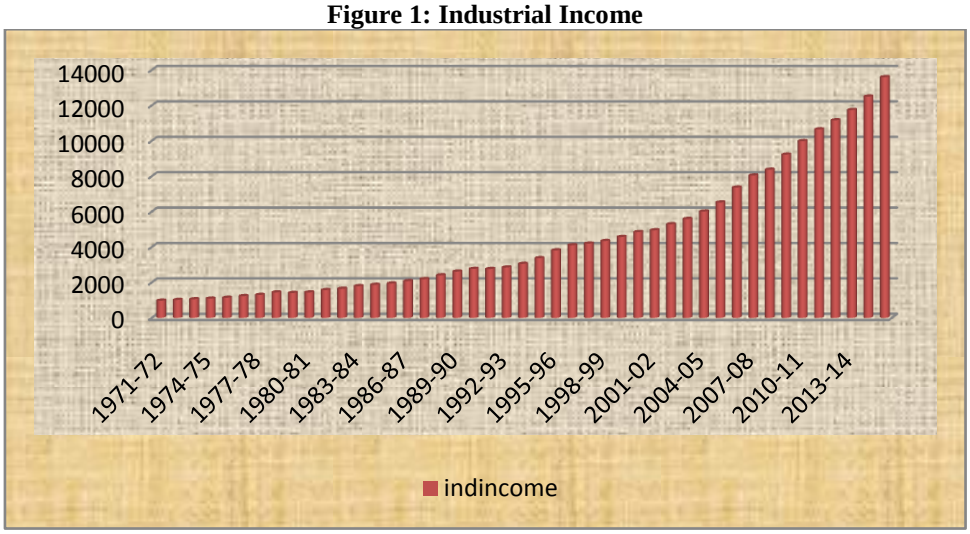
Table 1: Phillips-Perron Unit Root Test

Sl No	Variable	Adj. Statistic	P-value	Level	Model
1.	**INDINCOME**	**-5.594847**	**0.0000**	*I ~ (1)*	$\Delta y_t = y_{t-1} + e_t$
2.	**ELECTAVAIL**	**-4.913160**	**0.000**	*I ~ (1)*	$\Delta y_t = \alpha + y_{t-1} + T + e_t$
3.	**ELECTGEN**	**-5.950824**	**0.0001**	*I ~ (1)*	$\Delta y_t = \alpha + y_{t-1} + T + e_t$
4.	**TOTELECTCON**	**-6.831506**	**0.0000**	*I ~ (2)*	$\Delta y_t = y_{t-1} + e_t$
5.	**INDELECTCON**	**-2.009007**	**0.0438**	*I ~ (1)*	$\Delta y_t = y_{t-1} + e_t$

Source: Data are culled from RBI Website during 2017. Values are computed by researcher.
Note: *I ~ (1) means integrated order of one.*
I ~ (2) means integrated order of two

Trend Analysis:
The data used in this analysis have presented in the form of graphs in order to capture the trends and direction of data variations.

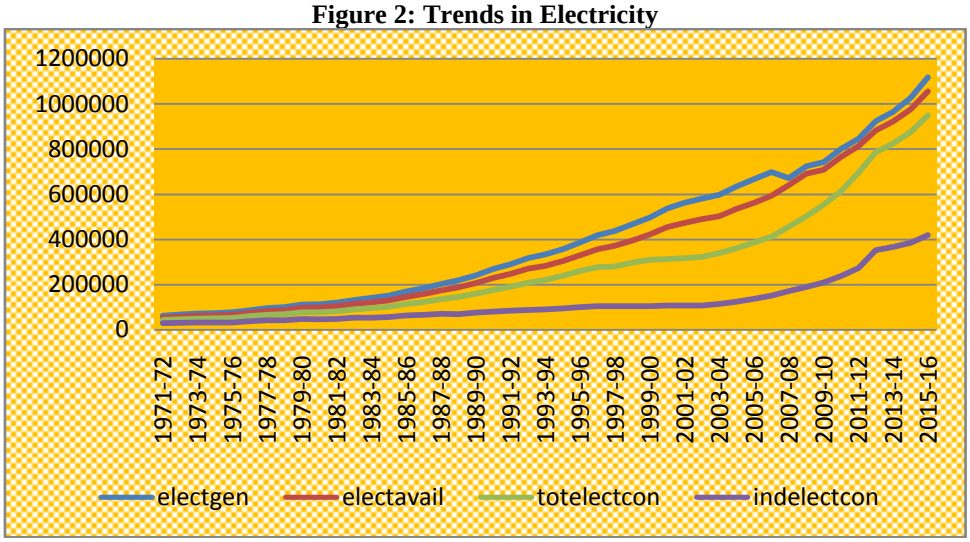
Figure 1: Industrial Income



Source: Data are culled from RBI Website during 2017. Values are computed by researcher.

Industrial income in India for the period from 1972-2015 has presented in the above graph. It has been found from the graph that there has been increasing trends in industrial income. The average growth of the industrial income will be analyzed with the help of CAGR.

Figure 2: Trends in Electricity



Source: Data are culled from RBI Website during 2017. Values are computed by researcher.

Electricity generation, availability, total consumption and industrial consumption in India for the period from 1972-2015 have presented in the above graph. It has been found from the graph that all the parameters have shown increasing trends in India. The average growth of the industrial income will be analyzed with the help of CAGR.

Growth Analysis:
The following section presents the growth of selected variables used in the present analysis. Growth has estimated in terms of compound annual growth rate, computed with log linear exponential functions.

Table 2: Growth of Industrial Income and Electricity

Sl.No.	Variable	CAGR	Std Error	t-Value	p-Value
1.	INDINCOME	7.1	0.00338119	21.24	0.0000
2.	ELECTAVAIL	6.8	0.000863921	79.75	0.0000
3.	ELECTGEN	6.7	0.00121303	55.38	0.0000
4.	TOTELECTCON	6.8	0.000948137	71.98	0.0000
5.	INDELECTCON	5.3	0.00179298	29.80	0.0000

Source: Data are culled from RBI Website during 2017. Values are computed by researcher.

The CAGR of electricity generation, availability, total consumption of electricity and industrial income in India are computed in the above table. It has found from the CAGR that growths of electricity generation, availability, total consumption of electricity and industrial income in India were significant at one percent level. Accordingly, the CAGR of industrial income is greater than growth rates of electricity generation, availability, total consumption of electricity in India.

Co-Integration Analysis:

'Long-run relationship' of industrial income in India with selected variables of electricity use in economy and industries has estimated. The co-integration analysis has made for the 'non-stationary' time series data. 'Johansen co-integration' test has used to find 'long-run stable relationships'. Vector Error Correction (VEC) models used to find 'short-run relationship'. Therefore, 'long-run relationship' of industrial income with electricity generation in India, electricity availability in India, total electricity consumption in India and electricity consumption by industries in India has estimated and analyzed.

Relationship of Industrial Income with Electricity Generation:

Industrial income and electricity generation in India have been used for the analysis.

Table 3: Co-Integration Test for Industrial Income and Electricity Generation

Trend assumption: Quadratic deterministic trend				
Industrial Income and Electricity Generation				
Unrestricted Co-integration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigen-value	Statistic	Table-value	P-value
None	0.304	19.559	18.397	0.034
At most one	0.087	3.943	3.841	0.047

Source: Values have computed by using base data with the help of E-views

The Johansen test has used to estimate the 'long-run relationship' between industrial income and electricity generation in India. It has been found from the co-integration test that the trace has identified two co-integrating equations. Means, both the parameters used in this analysis have been co-integrating with each other. Accordingly, there has been long-run stable relationship between industrial income and electricity generation in India. Therefore, industrial income and electricity generation go hand in hand. Hence, industrial income and electricity generation are inter-dependent. Matter of fact, electricity generation without industrial income and industrial income without electricity generation cannot be imagined and realized in India.

Table 4: VEC for Industrial Income and Electricity Generation

Error Correction:	D(INDINCOME)	D(ELECTGEN)
CointEq1	0.081215	5.786902
Standard errors in ( )	(0.01713)	(2.08824)
t-statistics in [ ]	[4.74224]	[2.77119]
D(INDINCOME(-1))	0.430912	-26.04131
Standard errors in ( )	(0.15843)	(19.3186)
t-statistics in [ ]	[2.71983]	[-1.34799]
D(INDINCOME(-2))	-0.492339	-4.827268
Standard errors in ( )	(0.16576)	(20.2125)
t-statistics in [ ]	[-2.97011]	[-0.23883]

Source: Values have computed by using base data with the help of E-views

The Vector Error Correction identifies the variable which responsible to restore the relationship between industrial income and electricity generation. It has found from the VEC that both the parameters correct the short-term disturbances in the long-run relationship. However, electricity generation takes one time period to restore the relationship and industrial income takes two periods to restore the relationship.

Relationship of Industrial Income with Electricity Availability:
Industrial income and electricity availability in India are used for the analysis.

Table 5: Co-Integration Test for Industrial Income and Electricity Availability

Trend assumption: Quadratic deterministic trend				
Industrial Income and Electricity Availability				
Unrestricted Co-integration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigen-value	Statistic	Table-values	P-value
None	0.358090	23.71836	18.39771	0.0082
At most one	0.102625	4.656120	3.841466	0.0309

Source: Values have computed by using base data with the help of E-views

'Johansen' test has used to estimate the 'long-run relationship' between industrial income and electricity availability in India. It has been found from the co-integration test that the trace has identified two co-integrating equations. Means, both the parameters used in this analysis have been co-integrating with each other. Accordingly, there has been long-run stable relationship between industrial income and electricity availability in India. Therefore, industrial income and electricity availability go hand in hand. Hence, industrial income and electricity availability are inter-dependent. Matter of fact, electricity availability without industrial income and industrial income without electricity availability cannot be imagined and realized in India.

Table 6: VEC for Industrial Income and Electricity Availability

Error Correction:	D(INDINCOME)	D(ELECTAVAIL)
CointEq1	0.082955	3.525791
Standard errors in ( )	(0.02537)	(1.43388)
t-statistics in [ ]	[3.27029]	[2.45891]
D(INDINCOME(-1))	0.262158	30.56597
Standard errors in ( )	(0.19556)	(11.0542)
t-statistics in [ ]	[1.34058]	[2.76509]
D(INDINCOME(-2))	-0.228600	-3.886595
Standard errors in ( )	(0.21693)	(12.2623)
t-statistics in [ ]	[-1.05381]	[-0.31695]

Source: Values have computed by using base data with the help of E-views

The Vector Error Correction identifies the variable which responsible to restore the relationship between industrial income and electricity availability. It has found from the VEC that both the parameters correct the short-term disturbances in the long-run relationship. Matter of fact both electricity availability and industrial income takes two periods to restore the relationship.

Relationship of Industrial Income with Total Electricity Consumption:
Industrial income and total electricity consumption in India have been used for the analysis.

Table 7: Co-Integration Test for Industrial Income and Total Electricity Consumption

Trend assumption: Linear deterministic trend				
Industrial Income and Total Electricity Consumption				
Unrestricted Co-integration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Table-value	P-value
None	0.328104	19.21608	15.49471	0.0131
At most one	0.048041	2.117049	3.841466	0.1457

Source: Values have computed by using base data with the help of E-views

The Johansen test has used to estimate the 'long-run relationship' between industrial income and total electricity consumption in India. It has been found from the co-integration test that the trace has identified one co-integrating equation. Means, one of the parameters used in this analysis has been co-integrating with other. Accordingly, there has been 'long-run stable relationship' between industrial income and total electricity consumption in India.

Table 8: VEC for Industrial Income and Total Electricity Consumption

Error Correction:	D(INDINCOME)	D(TOTELECTCON)
CointEq1	0.156851	3.734612
Standard errors in ( )	(0.03652)	(2.57981)
t-statistics in [ ]	[4.29546]	[1.44763]
D(INDINCOME(-1))	0.201593	23.59644
Standard errors in ( )	(0.18910)	(13.3597)
t-statistics in [ ]	[1.06608]	[1.76625]
D(INDINCOME(-2))	-0.345038	5.605297
Standard errors in ( )	(0.19690)	(13.9108)
t-statistics in [ ]	[-1.75236]	[0.40295]

Source: Values have computed by using base data with the help of E-views

The Vector Error Correction identifies the variable which responsible to restore the 'relationship' between industrial income and total electricity consumption. It has found from the VEC that one of the parameters correct the short-term disturbances in the long-run relationship. Matter of fact industrial income is the correcting parameter and it takes two periods to restore the relationship.

Relationship of Industrial Income with Industrial Electricity Consumption:
Industrial income and industrial electricity consumption in India have been used for the analysis.

Table 9: Co-Integration Test for Industrial Income and Industrial Electricity Consumption

Trend assumption: Linear deterministic trend				
Industrial Income and Industrial Electricity Consumption				
Unrestricted Co-integration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigen-value	Statistic	Table-value	P-value
None	0.376169	20.42926	15.49471	0.0083
At most one	0.003219	0.138632	3.841466	0.7096

Source: Values have computed by using base data with the help of E-views

The Johansen test has used to estimate the 'long-run relationship' between industrial income and industrial electricity consumption in India. It has been found from the co-integration test that the trace has identified one co-integrating equation. Means, one of the parameters used in this analysis has been co-integrating with other. Accordingly, there has been 'long-run stable relationship' between industrial income and industrial electricity consumption in India.

Table 10: VEC for Industrial Income and Industrial Electricity Consumption

Error Correction:	D(INDINCOME)	D(INDELECTCON)
CointEq1	0.080207	0.925790
Standard Errors in ( )	(0.01843)	(1.38199)
t-value [ ]	[4.35215]	[0.66989]
D(INDINCOME(-1))	0.280733	19.63266
Standard Errors in ( )	(0.17856)	(13.3900)
t-value [ ]	[1.57219]	[1.46621]
D(INDINCOME(-2))	-0.246634	11.95316
Standard Errors in ( )	(0.18521)	(13.8889)
t-value [ ]	[-1.33162]	[0.86063]
D(INDELECTCON(-1))	-0.002044	0.083865
Standard Errors in ( )	(0.00222)	(0.16626)
t-value [ ]	[-0.92206]	[0.50441]

Source: Values have computed by using base data with the help of E-views

The Vector Error Correction identifies the variable which responsible to restore the 'relationship' between industrial income and industrial electricity consumption. It has found from the VEC that one of the parameters correct the short-term disturbances in the long-run relationship. Matter of fact, industrial electricity is the correcting parameter and it takes one period to restore the relationship. Therefore, electricity plays predominant role in determinant of industrial income in India. Intuitively, efficiency of industry has been determined by electricity efficiency in India.

IV. Conclusion

In the present paper estimated the 'long-run stable relationship' between industrial income and electricity. Accordingly, industrial income has 'long-run stable relationship' with electricity generation, availability and total consumption in India. Specifically, industrial electricity consumption has 'long-run stable relationship' with industrial income. 'Short-term disturbances' in 'long-run relationships' have been corrected in one or two time periods. Specifically, industrial electricity consumption has acted as a correcting parameter of long-run relationship with industrial income. Therefore, electricity plays predominant role in determinant of industrial income in India. Hence, there is need to integrate the electricity policy with industrial policy for better outcomes of both industrial sector as well as economy. Accordingly, there is a need to estimate the different energy requirements of different industrial sectors and energy supply has to be made available to all industries to realize the expected production. Matter of fact, only reliable, adequate, uninterrupted desired energy supply can ensure the desired level of industrial output in India. Therefore, energy is the pre-requisite for industrial development.

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