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Electricity Consumption and Economic Growth in Karnataka

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ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH IN KARNATAKA

Laxmi Rajkumari* and K Gayithri†

Abstract

The paper aims to study the trend and pattern of electricity consumption in Karnataka, to investigate the direction of causality between electricity consumption and economic growth, and to forecast the future electricity consumption in the state. The methodology used for causality test is Granger causality test, while forecasting is done through ARIMA modelling. The trend and pattern of electricity consumption in Karnataka reveals that the value and share of consumption by the 'Agriculture' category is higher than that by 'Industries' and 'Commercial' consumers. Since the former category is highly subsidised by the state government and partly cross-subsidised by the latter categories which pay higher-than-cost tariff, the current trend is not ideal for revenue realisation of the power utilities as well as for state finances. Empirical results further show there is unidirectional Granger causality from economic growth to electricity consumption in Karnataka. Hence, economic growth will induce higher electricity consumption in future. Lastly, the electricity consumption is predicted to be around 90645 GWh by 2020, which would require significant investment and supply planning, as there is still a power deficit of about 13.9% in 2012-13.

Key words: Electricity Consumption, Economic Growth, Karnataka, Granger Causality test, ARIMA forecasting

Introduction

Economic growth, industrialization, and urbanization are closely associated with levels and growth of electricity consumption, as the latter is essential for the production and consumption activities of an economy. Besides lighting and heating, electricity is required for running all kinds of machineries in households, manufacturing industries, IT industries, businesses as well as in agriculture. In 2012-13, the total electricity units sold by the utilities in India is about 708843.4 GWh and about 51439.5 GWh in Karnataka (7.3%) (CEA, 2014). Higher economic growth also leads to increase in number of households, higher growth of industry and service sector, and growing demand for infrastructural facilities like metro lines, sky rises, huge malls, street light, so on, which require electricity to function. Whether electricity consumption precedes economic growth, or, vice versa, has been a topic of considerable interest for many researchers.

Available literature comprises numerous studies that tried to find the direction of causality between the electricity consumption and economic growth, for different countries, for different time periods as well as with different methodologies, thereby drawing corresponding policy implications (Ghosh, 2002; Altinay and Karagol, 2005; Narayan and Smyth, 2005; Wolde-Rufael, 2006; Ho and Siu, 2007; Gupta and Sahu, 2009; Acaravci and Ozturk, 2010; Adom, 2011; Masuduzzaman, 2012; Abbas

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and Choudhury, 2013; Pempetzoglou, 2014). There is also a large amount of literature on relation between total energy consumption and economic growth (Glasure and Lee, 1997; Ghali and Sakka, 2004; Paul and Bhattacharya, 2004; Fatai *et al*, 2004; Zahid, 2008; Akinlo, 2008; Odhiambo, 2009).However, the empirical evidences have been mixed and conflicting, with same, or different methodologies, for same/different countries, for different time periods. The direction of causality between the two gives specific implications for policymaking. For example, according to literature, if the unidirectional causality runs from economic growth to energy consumption, then energy conservation policy could be undertaken with hardly any effect on economic growth (Ozturk I, 2010).

Few papers have studied the relation between electricity consumption and economic growth in India (Ghosh, 2002; Gupta and Sahu, 2009). However, there seems to be a lack of literature in this area for the state of Karnataka. With about 5.05% of India's population (2011 Census), Karnataka is one of the rapidly developing states, with its capital, Bangalore, renowned as a booming IT hub. In Karnataka, the number of households has increased by 28.4%, and the population has grown by 15.7% during 2001 - 2011. Alongside, the growth in all sectors of the economy has also been notable. The Gross State Domestic Product (GSDP) in real terms is expected to grow at 6.2% in 2015-16. Despite the fairly modest economic growth, power shortage is a towering problem in the state, with about 5.2% energy deficit and 6.8% peak deficit in 2015-16(CEA, 2015-16). To improve the situation in the electricity industry, significant power sector reforms took place in Karnataka. Karnataka Power Corporation Limited (KPCL) was responsible for major share of electricity generation since 1975, while transmission and distribution were handled by Karnataka Electricity Board (KEB). The private sector was invited to participate in generation since 1991, as the power utilities were facing severe resource constraints. The most important power sector reform in the state was the Karnataka Electricity Reforms Act (KERA), 1999, which unbundled the KEB and set up Karnataka Power Transmission Corporation (KPTCL), as a corporate entity to handle electricity transmission and distribution. An independent regulatory commission, Karnataka Electricity Regulatory Commission (KERC), was also formed in 1999. KPTCL was further unbundled to form 4 Electricity Supply Companies (ESCOMs) in 2002 and 1 more in 2004— a total of 5 ESCOMs (Bangalore Electricity Supply Company, Gulbarga Electricity Supply Company, Hubli Electricity Supply Company, Mangalore Electricity Supply Company, and Chamundeshwari Electricity Supply Company) — to handle electricity distribution separately, while KPTCL remained responsible for transmission alone. Further, the Electricity Act 2003 at the Central level consolidated the existing laws and laid down various policies to introduce competition and efficiency in the electricity industry. The power sector reforms and policies were intended to improve the situation in power sector from both supply and demand aspects.

The purpose of the study is to investigate the electricity demand side scenario in Karnataka under the existing reforms and policies, and predicting the future consumption. Given the focus of the power sector reforms, the current paper aims to analyse the trend and pattern of electricity consumption, and its relation to economic growth in Karnataka. The paper dissects the trend and pattern of electricity consumption in Karnataka, analyses the causality between the electricity consumption and economic growth in the state, and further, forecasts future consumption. The results are expected to offer policy suggestions in formulating appropriate investment decisions depending on the forecasted consumption for the state of Karnataka.

The paper is structured as follows: After the first section that gives a brief introduction of the Karnataka power sector reforms and policies, the importance of demand side scenario in the electricity and the intent of the paper, section two surveys the existing literature in this area. Section three provides the data and methodology used in the analysis. Section four discusses the empirical results obtained from the analysis, and the last section presents the conclusions and policy implications.

Literature Review

Numerous studies have examined the relationship between the economic growth and energy/ electricity consumption, applying varied causality tests. However, the empirical evidences have been mixed and conflicting. The direction of causality between the two can draw significant implications for policymaking. Literature reveals that the directions of the causal relationship between the energy/ electricity consumption and economic growth can be categorised into four types: 1) no causality: No causality between energy/ electricity consumption and economic growth, also called 'neutrality hypothesis', 2) unidirectional causality from economic growth to energy/ electricity consumption (conservation hypothesis) which suggests that the energy conservation policies may be implemented with little or no effect on economic growth, 3) unidirectional causality from energy/ electricity consumption to economic growth (growth hypothesis) which implies that restrictions on the use of energy/ electricity may adversely affect economic growth, and suggests that energy conservation plays an important role in economic growth , and 4) bidirectional causality (feedback hypothesis) where energy/ electricity consumption and economic growth are jointly determined and affected at the same time (Ozturk I, 2010). Hence, if the unidirectional causality runs from economic growth to energy consumption, then energy conservation policy could be undertaken with hardly any effect on economic growth.

Literature shows that the studies on the relation and causality between electricity consumption and economic growth follow bivariate or multivariate analysis. Different studies have used varying methodologies, different time period for same/ different countries. However, the results have been mixed and conflicting even for same countries, probably due to different time periods under study, or differing methodology. Using the same methodology, the results are also inconsistent for different countries/ regions. For instance, using the same methodology (Granger causality test), Ghosh (2002) observed unidirectional causality from economic growth (GDP per capita) to electricity consumption per capita for India for the period 1950-1996, while Gupta and Sahu (2009) observed unidirectional causality from electricity consumption to economic growth for the period 1960-2006.

In addition, the results also varied depending on the different countries and time period. For example, Paul and Bhattacharya (2004) found unidirectional causality from energy consumption to economic growth in India, using Granger causality test for the period 1950-1996. However, using the Granger causality method and Toda and Yamamoto's (1995) approach for New Zealand, unidirectional link from real GDP to aggregate final energy consumption was found for period 1960-1999 (Fatai *et al*, 2004).

Zahid (2008) found no Granger causality in either direction between GDP and energy consumption for India for 1971-2003, in the study of five South Asian countries —Pakistan, India, Sri Lanka, Bangladesh and Nepal, using Error Correction Model and Toda and Yamamoto approach. Abbas and Choudhury (2013) conducted the causality analysis at an aggregated and a disaggregated level with focus on agricultural sector, for India and Pakistan. Their result was bidirectional causality between agricultural electricity consumption and agricultural GDP in India during 1972-2008, while at aggregate level, unidirectional causality from economic growth to electricity consumption.

Fatai *et al* (2004) found unidirectional link from real GDP to aggregate final energy consumption and also to industrial and commercial energy consumption in New Zealand and Australia, using Granger causality, for the period 1960-1999. However, using the same methodology, they observed opposite causality for India and Indonesia, and a bi-directional link for Thailand and the Philippines. They confirmed the result using Toda and Yamamoto (1995) approach. Using the Toda and Yamamoto Granger Causality test, Adom (2011) also observed one-way causality from economic growth to electricity consumption in case of Ghana from 1971-2008. Glasure and Lee (1997) have observed bidirectional causality for energy consumption and income for South Korea and Singapore.

The mixed results on the causal relation between the energy consumption and economic growth are well illustrated in the study of 17 African countries for the period 1971-2000 by Wolde-Rufael (2006). Using Co-integration Test suggested by Perasan *et al* (2001), and the Toda and Yamamoto Granger Causality Test, he concluded positive unidirectional causality from real GDP per capita to electricity consumption for 6 countries, opposite causality for 3 countries, and bidirectional causality for other 3 countries. Another study on 11 Sub Saharan African countries for period 1980-2003 by Akinlo (2008) used ARDL bounds test and Vector Error Correction Model (VECM) to show bidirectional causality between energy consumption (commercial energy use in kilograms of oil equivalent per capita) and economic growth (GDP in 1985 prices) for 3 countries, unidirectional causality from economic growth to energy consumption in 2 countries, and neutrality in other 2 countries. Based on the different results, the paper suggested that each country needs to formulate appropriate energy conservation policies considering its peculiar characteristics.

As for the causality from electricity consumption to income, Altinay and Karagol (2005) found evidence from Turkey for the period 1950-2000 using the standard Granger Causality Test and the Dolado Lutkepohl Test using the VARs in levels.

Ho and Siu (2007) also showed long-run equilibrium relationship between electricity consumption and real GDP, and a one-way causal effect from electricity consumption to real GDP in Hong Kong for period 1966-2002, using VEC model. Masuduzzaman (2012) also found the same unidirectional causality for Bangladesh during the time period 1981-2011, using the same methodology, although with investment as an additional variable. The same result is also observed for China during 1978-2004, using Granger Causality Test (Yuan *et al*, 2007). Further, they found co-integration between the trend as well as cyclical components of the two series, after decomposing using the Hodrick-Prescott Filter, implying that the Granger Causality is probably related with the business cycle. The unidirectional causality from total energy consumption to economic growth was also observed for Tanzania during period 1971-2006, using Autoregressive Distributed Lag (ARDL) bounds testing approach (Odhiambo, 2009). He also found short run causality from electricity consumption to economic growth.

A multivariate approach undertaken by Ghali and Sakka (2004) showed short run bidirectional causality between output growth and energy use for Canada during 1961-1997, and concluded that energy can be considered as a limiting factor to output growth. Another multivariate Granger Causality Test on VEC model was undertaken by Narayan and Smyth (2005) for Australia for the period 1966-1999, which observed long run causality from employment and income to electricity consumption.

A slightly different result was found by Acaravci and Ozturk (2010), where they observed no long term equilibrium relationship between electricity consumption per capita and real GDP per capita for 15 European transition countries for period 1990-2006, using Pedroni panel co-integration method. Their conclusion that electricity consumption-related policies have no effect/relation on the level of real output in the long run for these countries seems rather suspect, although any explanation at this point is not clearly known.

Thus, the causal relation between the two variables in India is mixed and conflicting, with the use of different methods and varying time periods. However, such a causality study, which is significant to initiate informed policy decisions, seems to be missing for the state of Karnataka. In addition, given the fact that Karnataka government had initiated power sector reforms more than a decade ago, it is important to have a comprehensive understanding of the level, trend and pattern of power consumption in the state, to identify the size and nature of the necessary investment in the sector. The paper, therefore, aims to fill this gap in literature.

Forecasting

Forecasting future electricity demand could be helpful for planning and resource management in generation to avoid power shortage in future. Literature reveals many forecasting techniques for varying time periods, depending on aggregate or disaggregate data. Forecasting future electricity demand is essential for policymaking as well as for planning and management decisions in areas like capital investment in generation, transmission and distribution, operational decisions, purchasing decisions on fuel, tariff and revenue calculation, etc.

The pioneering works on energy demand forecasting, as observed by Bose (1989), are those done by National Council of Applied Economic Research (NCAER) in early 1960s relating total energy consumption to economic development, Dhar and Sastry (1967) using input output model, Energy Survey Committee (1965) using relation between energy consumption and income, Central Electricity Authority (CEA, 1975) using trend method, end-use method, and Scheer's formula, Fuel Policy Committee (1971) analysing the existing methods and using end-use method. Some simulation models were used by Pachauri (1975, 1977), and Parikh (1980). Bose also noted forecasting studies based on advanced countries, namely, Fisher and Kaysen (1962), on US data using multiple regression and covariance analysis.

Rhys (1983) listed the commonly used forecasting techniques, viz., the projection of past trends, econometric analysis of fundamental economic factors affecting energy demand, and those based on detailed research into nature of energy use. Fatai *et al* (2003) compared different forecasting approaches, using data from 1960-1999 for New Zealand, including Engel-Granger's Error Correction Model, Phillip and Hansen's Fully Modified Least Squares, and the Autoregressive Distributed Lag (ARDL) approach of Perasan *et al*, and found the ARDL approach to be better than others.

Erdogdu (2007) estimated the short run and long run price and income elasticities of electricity demand in Turkey for period 1984-2004, and forecast future demand using Autoregressive Integrated Moving Average (ARIMA) methodology. He observed that the current official projections highly over-estimated the electricity demand.

In a comparative study of energy demand models, Bhattacharya *et al* (2009) listed many forecasting techniques ranging from simple approaches that use simple indicators like growth rates, elasticities, specific consumption and energy intensities, to sophisticated approaches like econometric models grounded in economic theories, engineering-economy models (or end use method), or hybrid models combining both features. Input output model is also used for forecasting by Wei *et al* (2006), Liang *et al* (2007), and O'Doherty and Tol (2007). However, the data requirement for this analysis is very demanding.

Ghods and Kalantar (2011) also studied different methods of long-term electric load demand forecasting, including traditional econometric methods, neural networks, genetic algorithm, fuzzy rules, so on, and concluded that the power system should be known in detail and the most appropriate technique should be selected. Traditional methods like time series, regression models are used in most countries due to their reliable result, while neural networks can solve nonlinear problems. It depends on the type and availability of data, and also from area to area.

Forecasting the future energy requirement for India and the states is done by the Central Electricity Authority (CEA) in the Electric Power Survey (EPS) of India, using partial end-use method. This methodology uses vast range of data for each consumer categories and forecast for each category according to the type of available data. Such elaborate data is difficult for individual researchers to procure for individual states. The paper endeavours to predict the future electricity consumption in Karnataka through ARIMA modelling, which basically predicts the future consumption given the current trend of consumption.

Data Source and Methodology

Since electricity cannot be stored, 'electricity sales' to ultimate consumers is to be considered as the 'electricity consumption' by the different consumer categories—Domestic, Industry (low and medium voltage), Industry (high voltage), Commercial, Irrigation and Others. The proxy variable for electricity consumption used in the paper is, thus, the 'Total electricity sales' to end consumers in Karnataka by the utilities and non-utilities. This variable would be used for checking the general trend and pattern of electricity consumption in Karnataka as well as to find the causality relation with economic growth in the state. For economic growth, the proxy variable used is Gross State Domestic Product (GSDP) at factor cost of Karnataka. The purpose of the paper is to analyse the electricity consumption in the state at the macro level, and its relation with economic growth. Since there is wide variation in the types of consumer categories, we do not consider per capita GSDP and per capita consumption for the causality study.

The unit of measurement for electricity sales to consumers is Gigawatt-hour, GWh (or, Billion unit), and that for GSDP is Rupees lakh. The source of data for electricity sales to end consumers of Karnataka is General Review (All India Electricity Statistics) published by Central Electricity Authority (CEA), Ministry of Power, Government of India. The GSDP at factor cost for Karnataka is taken from Central Statistical Organisation (CSO), Ministry Of Statistics and Programme Implementation, Government of India.

The time period used for causality test and for forecasting is from 1980-81 to 2012-2013. The data on GSDP is available in parts at differential base years. Hence, the different series are spliced together so as to get comparable series at 2004-05 constant prices.

The methodology used for unit root test of the variables are Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test, while that for testing co-integration is through Engel and Granger co-integration test. The methodology used for causality test is the standard Granger Causality Test, and that for forecasting is through Autoregressive Integrated Moving Average (ARIMA) modelling.

The most common test of causality is Granger Causality Test. This test assumes that the information relevant to the prediction of the variables is contained solely in the time series data of the variables. Also, the variables should be stationary.

The Granger Causality Test involves the following pair of regressions:

$$Y_t = \Sigma\beta_j Y_{t-j} + u_{1t} \quad (1)$$

$$Y_t = \Sigma\lambda_i X_{t-i} + \Sigma\delta_j Y_{t-j} + u_{2t} \quad (2)$$

assuming the disturbances u_{1t} and u_{2t} are uncorrelated.

If variable X Granger causes variable Y, then changes in X should precede changes in Y. Therefore, if Y is regressed on other variables, including its own past values, and if we include past values of X, and it significantly improves the prediction of Y, then it is said that X(Granger) causes Y. First, the variable Y is regressed on its own past values and other variables (if any) without including lagged X values (Restricted regression) and obtain the restricted sum of squares RSS_R. Then we run the regression including the lagged X terms (unrestricted regression), and obtain the unrestricted sum of squares (RSS_{UR}). To test the hypothesis of $\Sigma\ \lambda_i=0$, the F-statistic is used:

$$F= [(RSS_R - RSS_{UR})/m]/\ [RSS_{UR}/(n-k)]$$

If the computed F value exceeds the critical value at the chosen level of significance, we reject the null hypothesis, which implies that X Granger causes Y.

As for the Autoregressive Integrated Moving Average (ARIMA), it is one of the techniques used for forecasting time series data. The ARIMA (p, d, q) model indicates that the time series has to be differentiated 'd' times to make it stationary, includes 'p' number of autoregressive terms, and 'q' number of moving average terms. Basically, in this model, a variable is predicted by its past values and moving average of the current and past error terms.

Empirical Results

A. Trend and Pattern of Electricity Consumption in Karnataka

The energy sales to end consumers (in million kilowatt-hour, or, Gigawatt-hour, GWh) are taken as the 'electricity consumption' by the consumers, since electricity cannot be stored for future consumption. The different categories of consumers to which the electricity is sold (as per the classification made by CEA) are as follows:

- Domestic
- Commercial
- Industry (Low and Medium voltage)
- Industry (High voltage)
- Public lighting
- Traction
- Agriculture
- Public water works and sewage pumping, and
- Miscellaneous

The smaller categories like Public Lighting, Traction, Public Water works and Sewage Pumping and Miscellaneous are clubbed together to form the category 'Others', which would be used in the remaining part of the paper. Hence, the main consumer categories considered in the paper are: 1. Domestic, 2. Commercial, 3. Industry (Low and medium voltage), 4. Industry (High voltage), 5. Agriculture and 6. Others.

The total electricity consumption in Karnataka has increased from 5163.94 GWh in 1980-81 to 51439.47 GWh in 2012-13 (CEA). The average values and the average annual growth rates (AAGR) of the consumption by different categories before and after 1999 are presented in Table 1, which gives a basic comparative picture of the consumption situation in Karnataka pre and post-reform period.

Table 1: Electricity Consumption by main consumer-categories

[Average Values (Billion units, BU) and Average Annual Growth Rate (AAGR) (%)]

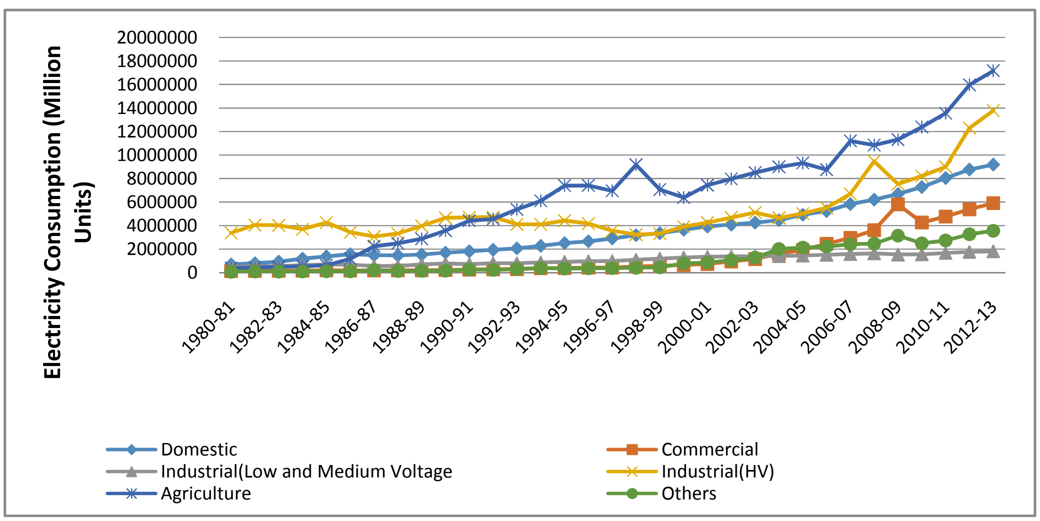
Time period	Total Electricity Consumption		Domestic		Commercial		Industry (Low and Medium Voltage)		Industry (High Voltage)		Agriculture	
	Average Value (BU)	AAGR (%)	Average Value (BU)	AAGR (%)	Average Value (BU)	AAGR (%)	Average Value (BU)	AAGR (%)	Average Value (BU)	AAGR (%)	Average Value (BU)	AAGR (%)
Pre-reform (1980-81 to 1998-99)	10896.6	6.8	1863.5	9.3	280.4	8.8	762.2	5.4	3906.5	0.6	3876.9	20.1
Post reform (1999-2000 to 2012-13)	30465	8.8	5897.5	7.5	3016.4	19.5	1523.1	3.1	7153.3	11.7	10701.6	7.0

Source: Computed by authors from Central Electricity Authority (CEA), Ministry of Power, Government of India

However, it requires further probe before making any concrete conclusions. The major power sector reform in Karnataka took place in the year 1999, when the Karnataka Electricity Reform Act (KERA) was enacted. It led to unbundling of the utilities to different entities with separate functions (KPTCL and ESCOMs for transmission and distribution respectively), along with formation of independent regulatory body (KERC). It was expected to improve the situation of the electricity industry in the state, thereby reducing the demand-supply gap. Hence, the reform year is taken as 1999.

The AAGR of 'Total Electricity consumption' increased from 6.8% from pre-reform period to 8.8% in the period after reform, which is a slight improvement. The AAGR of consumption by 'Commercial' and 'Industry (High Voltage)' consumers jumped after reform, as the growth rate of these categories before reform was quite slow. Electricity consumption by 'Agriculture' category witnessed quite lower AAGR in the second period. In Karnataka's power sector, an important landmark was the decision to de-meter irrigation pumpsets (IPS), along with the tariff revision process starting in 1981 giving electricity to IPS on a HP basis and ending in 1990 with 'free electricity'. In addition, the decision to cap supplies to high tension (HT) users shifted the emphasis of KEB to IPS energisation. KEB's nexus with large industries was adversely affected by the decision'. Since the agricultural electricity consumption was de-metered, its exact consumption amount is unknown. The utilities 'allocate' the Agricultural consumption and Transmission and Distribution losses (T&D loss) from a common pool. Thus, the de-metering made it possible for the 'theft' component to be disguised by KEB as Irrigation Pump Set (IPS) consumption (Reddy, Sumithra, 1997). This might be one of the reasons for sudden rise in growth rate of Agricultural consumption around mid-1980s (88.9% growth in 1985-86, compared to the years after 1999. The AAGR of the 'Agriculture' consumption probably declined after 1999 compared to the earlier years which saw a steep growth.

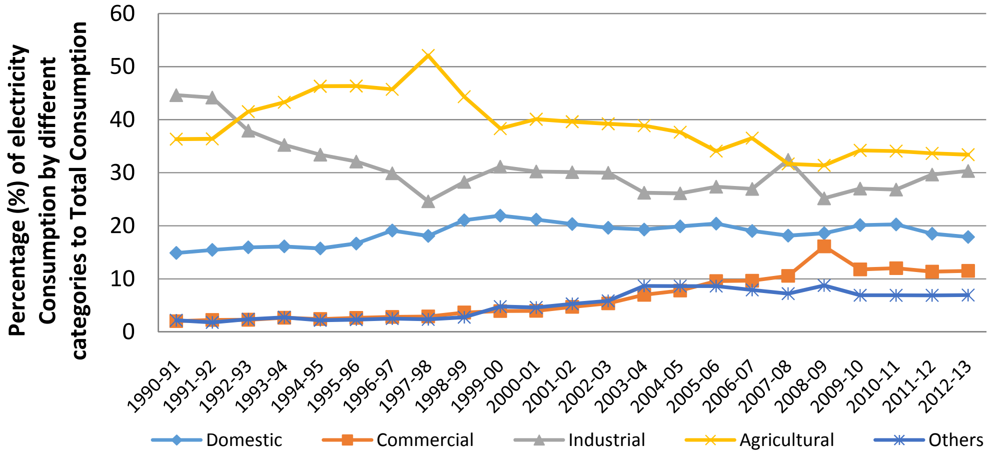
Figure 1: Electricity Consumption by major consumer categories in Karnataka (Million units)



Source: Computed by authors from Central Electricity Authority (CEA), Ministry of Power, Government of India, various years

The overall trend of electricity consumption by different categories (Figure 1) gives a clearer picture of the above figures. A rising trend is visible in almost all the categories in last four years. The absolute figures show that highest level of consumption is by 'Agriculture', followed by 'Industry (HV)' and 'Domestic' consumers. The 'Industry HV' shows higher AAGR in recent years, however, the absolute levels are still lower than that of 'Agriculture', which is of great concern for the utilities, since the industrial and commercial consumers cross-subsidize the 'Agriculture' category by paying higher tariffs. Moreover, the agricultural sector pays very meagre/ zero tariff for power supply, and the government, therefore, incurs a huge bill on account of power subsidy to irrigation pumpsets. Thus, higher consumption by 'Agriculture' compared to the more revenue yielding 'Industry' and 'Commercial' consumers is not financially viable for the utilities. The pattern of consumption in terms of percentage share of each categories to total consumption also shows higher share of 'Agriculture' than all other categories, although the share is falling slightly in the last 4 years (Figure 2). The next highest share is 'Industrial' consumers (aggregate of Low, Medium and High voltage), which is rising slowly in the last 5 years. This improvement is sound for the financial health of the utilities, as the Industries and Commercial consumers pays higher-than-cost tariff and cross-subsidize the Agriculture and Domestic consumers, who pay lower price for electricity.

Figure 2: Pattern of Electricity Consumption (%) in Karnataka



Source: Computed by authors from Central Electricity Authority (CEA), Ministry of Power, Government of India, various years

The overall trend and pattern of electricity consumption in Karnataka by different categories show that the 'Agriculture' consumption is still higher than that of other categories, although the AAGR and percentage share seem to be declining slowly. On the other hand, the Industrial consumption is rising over time, both in absolute terms and percentage share, which is a welcome sign for the utilities.

B. Causality between Electricity Consumption and Economic Growth in Karnataka

Electricity consumption is closely related to economic growth, due to its requirement in economic activities. Electricity input acts as an important growth engine. The Central Electricity Authority found that at a GDP growth of 9% per annum in India, the power sector must also grow at 7.2% per annum (CEA, 2008-9). Hence, the paper further investigates the direction of causality between electricity consumption and economic growth in Karnataka. The causality test is to observe if the past values of one variable helps in explaining another variable. This would reflect which variable — electricity consumption or economic growth —precedes the other in case of Karnataka. Literature has shown that empirical evidences produce mixed and conflicting results regarding the direction of causality even for same country, despite the use of same methodologies (Ghosh, 2002; Paul and Bhattacharya, 2004). These studies are relevant for India as a whole. However, the states in India would most probably behave differently, thereby indicating state-specific policy implications. Since the paper endeavours to study the electricity consumption in Karnataka, we would test for the causality between the electricity consumption and GSDP for Karnataka from period 1980-81 to 2012-13.

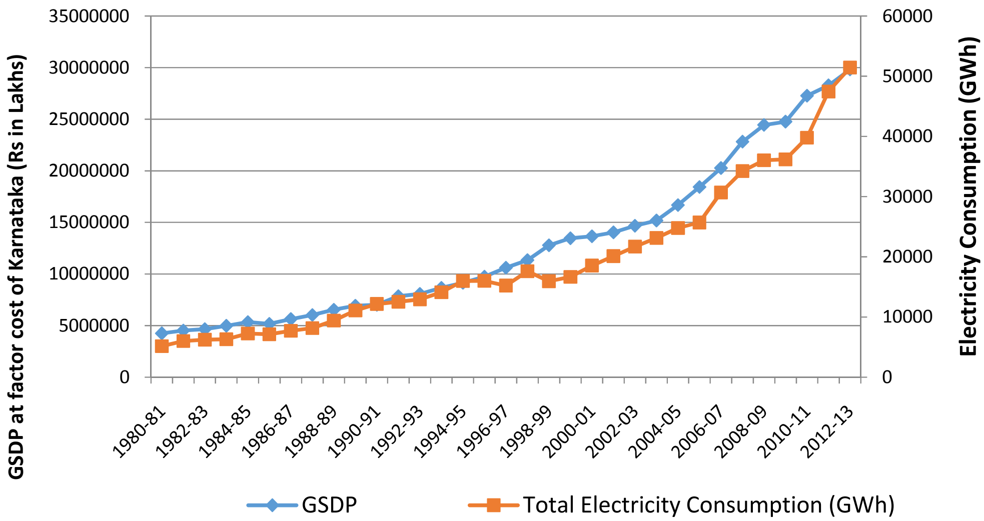
First, the basic summary statistics (Table 2) and the general trend (Figure 3) of the two variables are as follows:

Table 2: Summary Details of the Variables:

Statistics	Electricity Consumption (GWh)	GSDP Karnataka (₹ lakh)
Mean	19198.3	12816517.2
Median	15988.5	10604067.8
Maximum	51439.5	29824103.8
Minimum	5163.9	4242460.3
Sum	633545.1	422945066.4
Standard Deviation	12389.5	7733734.9
Number of observations	33	33

Source: Computed by the authors

Figure 3: Trend of GSDP and Electricity Consumption in Karnataka



Source: Compiled from Central Statistics Office and Central Electricity Authority ,Government of India, various years

To test for causality, the most commonly used Granger causality test is used. The steps involved in the causality test are as follows:

***1. Stationarity of the Variables*:** To conduct Granger causality test, firstly, we need to check for stationarity properties of the variables. Augmented Dickey Fuller (ADF) (1979) test adopts the following form:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \Sigma \alpha_i \, \Delta Y_{t-i} + u_t$$

where, β_1 is the drift term, β_2 is the trend effect, and the lagged differenced terms ΔY_{t-i} are added to overcome the problem of autocorrelation among the error terms.

We also check the Phillips-Perron Test for stationarity, which uses non-parametric statistical methods to take care of serial correlation in the error terms without adding lagged difference terms. It has the same asymptotic distribution as ADF test.

Table 3: Unit root test results of GSDP and Electricity Consumption

Variables	ADF Test		Phillips-Perron Test	
	Level	First difference	Level	First difference
GSDP	4.989046 (1.000)	-3.146503* (0.0333)	4.914599 (1.000)	-3.242913* (0.0268)
Electricity Consumption	4.422897 (1.000)	-3.251228* (0.0263)	12.72044 (1.000)	-3.185455* (0.0306)

Notes: The figures in the brackets denote the p-values corresponding to the t-statistics

* denotes significant at 5% level of significance

Source: Computed by the authors

Table 3 shows that both the variables GSDP and Electricity Consumption are integrated of Order I (1).

2. *Co-integration*: The second step is to check if the two variables are co-integrated. Co-integration can be understood as a systematic co-movement among two or more economic variables over a long time. According to Engle and Granger (1987), if two variables X and Y are non-stationary, and a particular combination of X and Y turns out to be stationary, i.e., their residuals, u, turn out to be stationary, then X and Y are said to be co-integrated. If X and Y are non-stationary and not co-integrated, the standard Granger causality test should be adopted (Yoo, 2005).

We run the regression of Electricity Consumption (ec) on GSDP (gsdp), and obtain the residuals. We also run regression of gsdp on ec. Checking the stationarity of the residuals through ADF test, it is found that the residuals turn out to be non-stationary at level, as shown in Table 4.

Table 4: Co-integration Test (Unit root test of residuals)

Variable	Level	1st Difference
	t-statistic (p-value)	t-statistic (p-value)
Residuals (gsdp on ec)	-1.957799 (0.3030)	-5.338551* (0.0001)
Residuals (ec on gsdp)	-1.813140 (0.3676)	-5.300864* (0.0001)

* denotes significantat 1% level of significance

Source: Calculated by Authors

The Engle and Granger co-integration test shows that the series 'gsdp' and 'ec' are not co-integrated.

Hence, the variables, *gsdp* and *ec* are I (1) and not co-integrated.

Thus, the standard Granger causality test can be applied. The variables are transformed to make them I (0), as follows:

$\Delta X_t = \alpha + \sum\beta_i \Delta X_{t-i} + \sum\gamma_j \Delta Y_{t-j} + u_t$

$\Delta Y_t = a + \sum b_i \Delta Y_{t-i} + \sum c_j \Delta X_{t-j} + v_t$

Running the Granger causality test, we find the result in Table 5.

Table 5: Result of Granger Causality Test between GSDP and EC

Null Hypothesis	F-statistic	Prob
D(GSDP) does not Granger Cause D(EC)	6.60763*	**0.0158**
D(EC) does not Granger Cause D(GSDP)	2.38073	0.1341

Note: * denotes significance at 5% level of significance

Source: Calculated by Authors

The null hypothesis that GSDP does not Granger cause electricity consumption is rejected at 5% level of significance (Table 5). This signifies that there is unidirectional causality from economic growth to electricity consumption in Karnataka for this period without feedback effect, according to the standard Granger causality test. This result is in conformity with some studies, including Ghosh (2002) for India (1950-1996), Abbas and Choudhary (2013) for India (1972-2008), Fatai *et al* (2004) for New Zealand and Australia, so on. This indicates that the economic growth in Karnataka induces the consumption of electricity in the state, and not the other way round. A possible explanation for not observing the reverse direction is that industries, which account for large share in state GSDP (28.3%), have resorted mostly to its own captive generation for the production process, which is not reflected in this data. In addition, the data under study is only for the grid supply of electricity. Also, since electricity consumption is an input for other factors of production, the absence of the latter may have led to this result of unidirectional causality from economic growth to electricity consumption and not vice-versa. The result points towards the policy implication that electricity conservation in Karnataka would not affect economic growth severely. However, it would be premature to infer this implication without further probe, due to the paucity of exhaustive data and presence of power deficit in the state. This aspect is out of the scope of the present paper, nonetheless, it offers a good background for further research.

C. Forecasting

A very important task for policymaking in electricity industry is to forecast future demand for electricity, in order to plan ahead in resource allocation and technical decisions, so that the demand could be met adequately. Hence, the paper tries to forecast future electricity consumption for Karnataka, since the data on demand as such is not available. This paper has used data from Central Electricity Authority (CEA) for the purpose of forecasting future consumption using Autoregressive Integrated Moving Average (ARIMA) modelling.

The ARIMA (p,d,q) model requires identification of parameters p (number of autoregressive terms), d (order of integration) and q (number of moving average terms). The total electricity consumption (EC) is integrated of order I(1), according to Augmented Dickey Fuller, ADF test and Phillips-Perron Test.

For ARIMA modelling, Autocorrelation Function (ACF) and Partial Autocorrelation Functions (PAF) of the variable concerned were checked, to have an idea of the order of the AR and MA. The PAF of the variable 'EC' at 1st difference shows significance till 9 lags. Since it could not give a clear order of the model, we run different ARIMA models in different orders. Checking for all possible number of orders, we found only two models to have significant coefficients, namely, AR (1) and ARMA (1, (1,2,3)). Out of the two, however, the model ARIMA (1, (1,2, 3)) has the lower values of Residual Sum of Squares (RSS) of 52873723 and lower AIC and SBC of 17.50989and 17.74118. The same procedure is followed to check if the model fitted better with the natural logarithm of 'EC'. However, the coefficients were not significant for any of the orders of the model in the logarithm form. Hence, the chosen model is ARIMA (1, (1,2,3))[1] of variable 'EC'. Following the concept behind ARIMA modelling, it

[1] The internal forecast error is tested for this model with the help of Z-test, and the result showed that there is no significant difference in the standard deviation of the forecasted values and the actual values at 1% level of significance. Hence, the forecast is made with this ARIMA model.

will 'let the data speak for itself', and give a broad estimate of the future consumption of electricity in the state.

With ARIMA (1, (1,2,3)) , the future electricity consumption of Karnataka is forecasted till year 2020 as shown in Table 6.

Table 6: Forecast of Electricity Consumption in Karnataka

Year	Forecasted values (in GWh)
2013-14	70048.43
2014-15	73386.34
2015-16	76764.83
2016-17	80181.86
2017-18	83635.51
2018-19	87123.94
2019-20	90645.42

Source: Computed by the authors

The total electricity consumption in Karnataka is expected to be in tune of about 90645 billion units by 2020, according to the above model. The data used for this calculation, as mentioned above, is the 'Total electricity sales', which does not reflect the load shedding, power cuts or deficit in the state. The actual electricity demand by consumers are, thus, higher than the quantity of electricity sold to them. Hence, the demand for electricity would most likely be higher than these consumption figures. In order to meet this level of consumption, without power cuts, or load shedding, much larger investment would be required for adequate and efficient supply of electricity in Karnataka. The total installed capacity in Karnataka is about 12000.19 MW, and the total electricity generation is about 46338.36 GWh in 2012-13. Still the power shortage in the same year is about 13.9%. Also, the share of public sector in total generation (58%) in 2012-13 is still higher than private sector share (42%) (CEA, 2014). Thus, the generation needs to increase, both by public and private sector, along with the capacity utilisation in order to remove power shortage in the state. Hence, the supply side must be planned efficiently to meet such consumption levels in future.

Alongside, it is high time the demand-side management is also given due attention and effectively used to curb wasteful and inefficient usage of electricity and assist in meeting the demand-supply gap in the state. Also, to generate enough revenue from the sales, the current consumption pattern as seen above, where the revenue-generating industries are consuming lesser of the grid supply, and the higher share of agriculture sector, is not favourable for the financial gains of the electricity industry. This issue is of grave importance.

Conclusion

Karnataka witnessed the most important power sector reform in 1999 (KERA, 1999), after which the power utility, KEB, was unbundled, KPTCL was formed to handle transmission and distribution, and regulatory body KERC was constituted. Electricity consumption is a very crucial element for faster growth of an economy. The paper highlights the major trends and patterns in electricity consumption by main consumer categories before and after reform, as this reflects the change in revenue generating capacity of the utilities after reform. The Average Annual Growth Rate (AAGR) of 'Total Electricity consumption' increased from 6.8% in pre-reform period (1980-81 to 1998-99) to 8.8% after reform (1999-2000 to 2012-13). The AAGR of consumption by 'Commercial' and 'Industry (High Voltage)' consumers rose from 8.8% and 0.6% before reform to 19.5% and 11.7% after reform respectively jumped a leap after reform, although that of Industry (Low and Medium voltage) fell from 5.4% to 3.1%. The AAGR for 'Agriculture' fell from 20.1% to 7% after reform, which is most probably due to the sudden high growth rate in electricity consumption by this category in 1980s when it was de-metered. The overall recent trend shows slight fall in share of agricultural consumption and rising share of industrial consumption. This would help improve the finances of the utilities as the industries pay higher tariff, and cross subsidises the agricultural and domestic consumption, which are provided power at highly subsidised rate. The government provides subsidy for the agricultural consumption, and increasing consumption by this category, therefore, would also increase the burden on the government finances over time. On the other hand, the industries mostly resort to captive generation and reduces consumption from grid supply because of the unreliable and low quality of power from grid and the high tariff, which further deteriorates the financial health of the utilities, and thereby affect future investment environment.

The causality result checks the relation between the Gross State Domestic Product (GSDP) and total electricity consumption of Karnataka, to observe its significance (or, otherwise) in the economic growth of an economy. According to the Granger Causality Test, there is unidirectional causality from economic growth to electricity consumption in Karnataka. It reiterates that rising economic growth in Karnataka will induce electricity consumption to increase over time. This result is in conformity with some studies, including Ghosh (2002) for India(1950-1996), Abbas and Choudhary (2013) for India (1972-2008), Fatai *et al* (2004) for New Zealand and Australia, so on. A possible explanation for not observing the reverse direction is that industries, which account for large share in state GSDP (28.3%), have resorted mostly to its own captive generation for the production process, which is not reflected in this data. Since the data under study is only for the grid supply of electricity (excluding captive generation by industries), and the overall power deficit is still high in the state, the unidirectional causality result might have pointed towards the implication that conservation of electricity consumption would not affect economic growth severely in Karnataka. However, further probe is necessary before making such a concrete policy implication for Karnataka. The rising urbanization and fast growth leads to demand for higher standard of living and higher growth of all economic sectors, which are unachievable without electricity.

The purpose of forecasting is to throw light on a broad figure of electricity consumption level in future, that can be seen as a target and consequently, to address the issues in the electricity industry which can be problematic in achieving this target. The total electricity consumption in Karnataka is expected to be about 90645 billion units by 2020, according to the ARIMA model. The data used for this calculation is the 'Total electricity sales', which does not include data on the load shedding, power cuts, or deficit in the state. The actual electricity demand by consumers are, thus, higher than the quantity of electricity sold to them, as they ideally want electricity 24 hours every day without power cuts. Thus, the demand for electricity would most likely be higher than these consumption figures. Hence, in order to meet this level of consumption, without power cuts or load shedding, much larger investment would be required for adequate and efficient supply of electricity in Karnataka. This is out of scope of the present paper, however, it is very important to investigate the amount and nature of investment required to fully meet the demand for electricity in the state. With a total installed capacity in Karnataka of about 12000.19 MW, and the total electricity generation of 46338.36 GWh in 2012-13, the power shortage is about 13.9%. Also, the share of public sector in total generation (58%) in 2012-13 is still higher than the private sector share (42%) (CEA, 2014). Thus, the generation needs to increase, both by public and private sector, along with the capacity utilisation in order to remove power shortage in the state. Hence, the supply side must be planned efficiently to meet such consumption levels in future.

The study brings out important issues in power sector which hinder smooth functioning and high growth in Karnataka power sector. Firstly, the electricity consumption level in 2012-13 was not optimal, in the sense that the deficit in power supply was as high as 13.9% in that year. To increase the total sales to consumers, the electricity generation must increase at a higher rate and the utilisation of the existing capacity also needs to improve. This requires large investments, both from public and private sector. Much of the government finances in the power sector goes to agricultural subsidy, as the agricultural consumers pay no/ less-than-cost tariff, largely owing to the political economy at play since 1980s. Hence, the persisting high consumption by Agriculture is a heavy burden on the utilities, the subsidizing consumers (Industries and Commercial) as well as the government. Another crucial side-effect of cross subsidization is that the revenue generating consumers-Industries- have been resorting to captive generation of their own due to the high cost and low quality power of grid supply, thereby enhancing the cost of production. However, the paper shows that the trend of electricity consumption by the consumer categories in recent years is improving slightly, in favour of industrial consumers.

In addition, given the predicted consumption values, the questions that arise are first, whether it would be adequate, efficient and cost effective for the state to supply it with its own resources, or through other states, or exchanges; second, whether the mix of electricity generation by public sector and private sector would be adequate and third, what role the private sector should play in reducing power shortage in the state. The modes of generation - thermal, hydel, or renewable energy sources - are also very crucial elements in the decision-making process, as their costs of production differ vastly and the availability of resources varies from state to state. In these circumstances, the demand-side management would help in improving the power shortage situation by contributing in efficiency and conservation measures. Hence, the consumption analysis throws open several crucial issues in the power sector of Karnataka for which this paper provides a comprehensive base.

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