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Nonlinear Dynamic Impact of Electricity Consumption on Economic Growth in Odisha: A Disaggregated Causality Analysis

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Abstract

The paper examines the causal link between electricity consumption and Odisha's economic growth using linear and nonlinear causality tests in annual data from 1981 to 2020. The study uses both linear and non-linear causality on aggregate and sectoral data. Based on the empirical analysis, the study finds that electricity consumption strongly granger causes state's economic growth. Further, sectoral-level analysis shows that electricity consumption exhibits a strong causal relationship with the primary, secondary, and tertiary sectors. This finding is consistent for both linear and non-linear granger causality tests. Moreover, the estimation of long-run elasticity reveals that both secondary and tertiary sectors have greater than unity elasticity whereas the primary sector has less than unity elasticity. The rolling elasticity shows that elasticity is increasing over time and across the sectors, barring the tertiary sector. More mechanized activities in the primary sector will increase the consumption of electricity and more value addition to the economic growth of the state. The policy intervention would be to reduce electricity losses (leakages) as well as increase the production of electricity to increase economic growth. Considering the greater role of electricity in the state's economic progress, intervention from both the state government and the Odisha Electricity Regulatory Commission, the regulatory body of the state, is very much essential.

Keywords: electricity consumption, sectoral growth, causality, nonlinearity, elasticity

JEL Classifications: C10; C12, C51; E1.

1. Introduction

According to the classical production function, labor and capital are the two critical inputs responsible for production. But in modern times, energy acquired a pivotal place in the production process besides those two factors. A country's demand for greater electricity consumption indicates that economic activities are happening very actively. As a country/state grows faster, it increasingly relies on energy (Asafu-Adjaye, 2000; IAEA, 2009). Odisha is one of the fastest-growing states in the country. Over the last decade, the state registered a GSDP growth of around 8%, higher than the national average. The state witnessed a continuous rise in per capita electricity consumption in the previous four decades. The average per capita electricity consumption during 1980-1990 was Rs. 1223, which increased to Rs. 1374 in 1990-2000 and then Rs. 2184 in 2000-2010. Over the last decade, we observe a further rise in per capita electricity consumption to Rs. 3619. According to the Installed Capacity Report 2021 (Note 1) of the Central Electricity Authority of India, Odisha remained one of the top states in the installed capacity (MW) across the eastern region. As of 30.04.2021, around 25% of the total installed capacity was secured in Odisha, higher than 18% in Bihar and 7.5% in Jharkhand. Odisha was responsible for 8594.47 MW of the nation's installed power producing capacity as of April 2021. This shows that India's electrical sector has experienced substantial expansion throughout time.

The increasing role of electricity has been realized because of the expansion of economic activities in the state. A rise in economic growth/income level has been the determining factor for increasing demand for electricity consumption. There are two possible explanations for this: household demand and industrial demand. Currently, the industrial sector uses nearly half of all the electricity produced worldwide (Note 2). Several studies have confirmed the critical role of electricity in the growth of industry (Sullivan et al., 1997; Beenstock et al., 1997;

World Bank, 2004; Andersen & Dalgaard, 2013; Saxena et al., 2017; Cole et al., 2018). In Odisha, the industry sector contributes more than 36% to the Gross State Value Added (GSVA) (Note 3). As the economy progresses, industries are switching to efficient and environmentally friendly fuels from conventional fuels such as coal and oil. Electricity being an environmentally friendly fuel is in high demand by industrial sectors. It serves as a raw material for the creation of goods and services. Secondly, the increase in household income creates more demand for electricity consumption. As income rises, people tend to use more electric gadgets and increasingly rely on electricity. Further, the modernization of agriculture and the increasing transport sector is creating more demand for electricity consumption. Electricity supports other inputs like fertilizers and pesticides or directly contributes to agricultural productivity by supplying energy to irrigation systems and farm machinery (Jha et al., 2012; Dogan et al., 2016).

As a reform process, the state has proactively embraced privatization policy for its Power Distribution Companies (DISCOMS). Odisha began the process of power sector reform in India as the country's first state in 1996. Other states that followed it were Haryana (1997), Andhra Pradesh (1998), Uttar Pradesh (1999), Karnataka (1999), Rajasthan (1999), and Delhi (2000), Madhya Pradesh (2000) and Gujarat (2003). This reform was implemented to improve the operational and financial performances of its Power Distribution Companies and smoothen the electricity supply. All these steps help to strengthen the nexus between energy and economic growth; thereby, it becomes essential to study the energy-growth link. There is a sufficient reason for exploring the nexus between energy and economic growth. First, designing effective energy policies for generating rapid economic growth will require knowing the causal direction between the two. Second, it can further guide the state to prioritize the sectors to boost energy production. So far, the studies examining the linkages have focused on the national economy, ignoring a large part of stories that lie with Indian states (Cheng, 1999; Ghosh, 2002; Keppler, 2006; Tiwari, 2011a; Nain et al., 2012; Abbas & Choudhury, 2013; Ahmad et al., 2014; Nain et al., 2017a). Indian states significantly contribute to the national economy, and electricity plays an important role. To address the knowledge gap, it is crucial to look at the relationship between energy and growth at the sub-national level. Further, sub-sectoral analysis at the sub-national level is scant in the literature. This analysis can help better understand sectoral linkages at a state level. So, we have attempted to analyze the possible causal relationship between electricity consumption and growth at the sub-national level.

This paper examines the causal relationship between electricity consumption and economic growth in Odisha. The paper explores this linkage at an aggregate level and for three different sectors. The study uses a time series analysis utilizing a rich dataset from 1980-81 to 2019-20.

Our study contributes majorly in the following ways. Firstly, there has been very limited study at the sub-national level, and no such study exists in the literature for Odisha. With no study found, examining the possible linkage between electricity consumption and state economic growth is necessary. Second, no such study was attempted at the sub-national level, particularly for Odisha. There are two studies in the Indian context that examined the sectoral linkage at the national level (Nain et al., 2012; Abbas & Choudhury, 2013). Therefore, it is imperative to have a sectoral analysis at the sub-national level. Thirdly, the existing study needs to address the long-run elasticity of electricity at the sub-national and sectoral levels. Understanding the elasticity to assess the sensitivity of the economy and different sectors is important. The negative consequences of electricity deficits on business growth and manufacturing productivity have been recognized by the World Bank (2003). Therefore, it is essential to understand how sensitive a particular sector is toward such deficiencies. Moreover, we have calculated rolling elasticity to understand better the time-varying dependency of state economies and sectors. Fourthly, a nonlinear causal analysis is employed to understand the linkage better. It is argued that linear causality models cannot uncover the possible nonlinearity between the variables (Diks & Panchenko, 2006). Therefore, we have employed this test to find the causal relationship between electricity and economic growth.

The rest of the paper is as follows. Section 2 provides a trend analysis of electricity consumption and state growth. Section 3 gives an extensive survey of past literatures. Section 4 describes data and variables. Section 5 discusses empirical methodology. Section 6 provides analysis of empirical results. Concluding remarks are provided in the last section.

2. Trends in Electricity Consumption and GSDP Growth in Odisha

The CAGR calculation shows that during 1980-1990, GSDP reported 5% growth and electricity consumption at 5.8%. That growth in the next decade (1990-2000) declined to 4.7% in GSDP and 5.2% in electricity. However, during 2000-2010 the state economy achieved impressive growth in both GSDP and electricity consumption; both reported 8.3% and 8% growth, respectively. But in recent times, a worrying trend has been revealed as the demand for electricity consumption declined steeply to 4.6% though GSDP growth didn't fall substantially (reported 7% GSDP growth). If we analyze the movement between the two over the years, we can observe that from 1980-1990 there is no systemic pattern in the trend between growth and electricity consumption. When GSDP growth rose to 11% in 1985-86, electricity consumption growth reported a negative growth rate. The following year, electricity consumption registered a 15.6% growth, while economic growth exhibited a negative growth. However, after the 1990s, it seems the growth and electricity moved in the same direction, though that relationship is not that strong. For instance, in 1991-92, electricity consumption and economic growth registered a positive growth of 14.8% and 11.7%, respectively. Similarly, in 1996-97, both electricity and GSDP growth turned negative. Again, next year, electricity consumption registered an increase of 7.6% and GSDP growth at 13.4%.

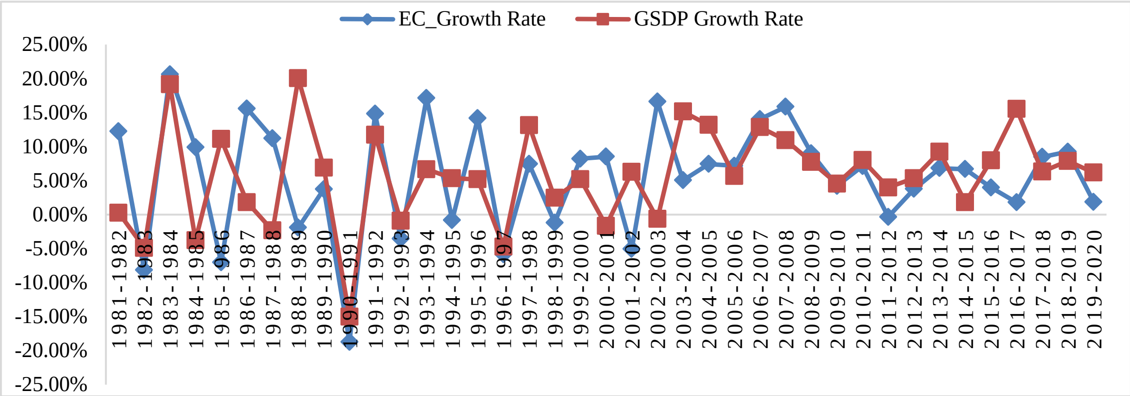

Figure 1. Trend between electricity consumption growth and state's economic growth

Source: Ministry of Statistics and Programme Implementation (Mospi) and Odisha Electricity Regulatory Commission(OERC).

3. Review of Past Literature

The literature has discovered significant variations in the empirical findings that have been grouped into four theories (Bah & Azam, 2017; Bhattacharya et al., 2016; Iyke, 2015).

1) The absence of a causal relationship between energy consumption and economic growth is supported by the neutrality hypothesis. Here, it is claimed that policies for energy saving won't have an impact on economic expansion. 2) The feedback hypothesis, which contends that there is a two-way causal relationship between economic growth and power use. 3) The conservation hypothesis, postulates that actions pertaining to power conservation will have little to no impact on economic growth. 4) The growth hypothesis, often known as the electricity-led growth hypothesis, postulates a one-way causal relationship between economic expansion and energy use. Energy conservation programmes that aim to minimise electricity consumption may have negative consequences on economic growth since this hypothesis supports the crucial role that electricity consumption plays in economic growth (Payne, 2010).

3.1 Studies at the International level

The link between energy consumption and economic growth has been studied to a considerable extent in energy economics. This area is very much important to both academicians and energy policy analysts. The groundbreaking study by Kraft and Kraft (1978) investigated the relationship between energy use and economic growth in the United States and established empirical evidence of a one-way causal relationship between energy consumption and gross national product (GNP). Since then, numerous studies have explored the initial findings of Kraft and Kraft (1978) using various methods and rich datasets. But those findings either supported what the pioneering work suggested, or some studies seemed to be departing from it. That group found contrasting evidence that electricity consumption does not induce economic growth (Murray & Nan, 1996; Wolde-Rufael, 2006; Karanfil & Li, 2015). On the other hand, some other groups observed a strong causal relationship between the two variables, though the direction of causation was a mixed type. When some found economic growth drives greater electricity consumption (Soytas & Sari, 2003; Ho & Siu, 2007; Narayan & Prasad, 2008; Narayan & Smyth, 2008; Hu & Lin, 2008; Ghosh, 2009; Balcilar et al., 2019), others observed electricity consumption to be a prime factor for economic growth (Yuan et al., 2007; Chandran et al., 2010; Ahamad & Islam, 2011; Bildirici & Kayıkçı, 2012; Iyke, 2015). A bi-directional causal link between these two variables was discovered in some other research (Ghali & El-Sakka, 2004; Polemis & Dagoumas, 2013; Sbia & Shahbaz, 2014).

3.2 Studies at the National Level

In the Indian context, several studies have explored the possible linkage between electricity consumption and economic growth. Early studies have shown a significant impact of economic growth on electricity consumption, but the relationship turns reversed or feedback as the economy grows. One early study by Cheng (1999) found that economic growth drives electricity consumption significantly. Using the vector error correction method and Hsiao's Granger causality from 1952 to 1995, the study observed that GNP has significant causal relation with electricity consumption in India. Ghosh (2002) observed that increasing economic growth is causing demand for electricity consumption. In his analysis, he used Johansen–Juselius likelihood cointegration tests for cointegration and the Granger Causality test for the direction of the causal relationship. Using data from 1950-51 to 1997-98, the study found a long-run relationship between and electricity consumption and GDP. A strong unidirectional causality is found from GDP to electricity consumption. He argued that an increase in economic activity needs electricity as input, and a rise in households' income also increases the electricity demand. Keppler (2006) used both the Granger causality and Error Correction Method for 1970–2006 and found similar evidence for India. The author argued that the presence of causality is justifiable when the economy grows, and economic activities slowly replace traditional energy sources with modern sources. Ghosh (2009) again studied the energy growth nexus using recent data and new methods. He used the ARDL model bounds test for cointegration and VECM for causality test for 1970–2006. However, despite current data and new techniques, the results remain unchanged. He found a causality running from GDP to electricity consumption.

However, as time passed, the role of electricity consumption became pivotal in the economic growth process. As recent time series data was made available and examined using varying time series methods, the result reveals that electricity consumption can cause economic growth. Studies by Tiwari (2011a), Abbas and Choudhury (2013), Ahmad et al. (2014) and Nain et al. (2017a) have confirmed that electricity consumption plays a significant role in economic growth in India. Tiwari (2011a) used VECM, Impulse Response Fund (IRF) and Variance Decomposition (VD) analysis and observed that electricity and GDP growth have a long-run relationship and electricity consumption is significantly causing economic growth. Nain et al. (2012) make an aggregate and disaggregated analysis to examine the energy growth nexus in India. Using the ARDL method for 1971-2010, they found that electricity consumption has a long-term relationship with economic growth. Further, at a disaggregated level, they observed that electricity consumption, agriculture, industry, and commercial sectors are cointegrated. Moreover, MWALD based causality test confirms that electricity consumption is causing economic growth at aggregate and disaggregated levels. Economic growth in agriculture, industry, and commercial sectors is significantly energy dependent. Nain et al. (2017a) revisited the energy growth nexus using the ARDL model and Toda and Yamamoto Causality test. Using data from 1971 to 2011, they found that electricity consumption and growth have a significant long-run relationship and a unidirectional causality exists between electricity consumption and growth.

Furthermore, Tiwari (2012) observed that electricity consumption and growth are interdependent. There exist a feedback relationship between these two. With the help of Granger-causality, VECM, IRF, and VD, and taking data from 1970 to 2005, the author found that electricity consumption is helping accelerate economic growth and economic growth creates demand for greater electricity consumption. The causality test confirms a bi-directional causality between these two. Ahmad et al. (2014) used an updated dataset of 1970–71 to 2009–10 and employed both sets of cointegration and causality analysis. Their findings were in a similar line as described above- a bidirectional causality between electricity consumption and growth. Economic growth accelerates economic activities, demanding greater use of electricity in production and consumption; thus, electricity becomes a prime factor of production. In a panel data analysis, Nain et al. (2017b) found a weak connection in the electricity consumption- growth nexus. Using data from 1980 to 2012 and with the help of Panel Cointegration and Panel Causality, they observed that causality from NSDP to electricity consumption is strong, but the other way round is weak. Abbas and Choudhury (2013) found that growth in the agriculture sector is energy-dependent and energy sector demand comes from higher economic growth. According to Sethi et al. (2019), India's fiscal deficit has a negative impact on GDP. They came to the conclusion that, for the years 1970 to 2016, the fiscal deficit had a detrimental effect on the nation's economic growth using the ARDL and FMOLS techniques.

4. Data and Variables Description

The study uses annual data of electricity consumption (Mega Unit), Real GSDP, Real GSDP of the Primary Sector, Real GSDP of the Secondary Sector, and Real GSDP of the Tertiary Sector for Odisha from 1980-81 to 2019-20. Electricity consumption data consists of the consumption of Wesco, Nesco, Southco, and CESU- the four power discoms of Odisha. The variables are expressed in natural logarithms. All the variables are sourced from the Odisha Electricity Regulatory Commission (OERC), Handbook of Statistics on Indian States (RBI), and

Ministry of Statistics and Programme Implementation (MOSPI).

5. Empirical Methodology

5.1 Linear Granger Causality

We employ the linear Toda-Yamamoto (TYM) test in a bivariate VAR model to examine the dynamic link between real GSDP and electricity consumption. The same has been extended to investigate the impact of electricity consumption on primary and secondary sectoral growth. The TYM uses a modified Wald Chi-square test to test causality, which is better than Granger's (1969) causality. It is given as follows:

$$X_t = \alpha_0 + \sum_{i=1}^{k+d_{max}} a_{1i} X_{t-i} + \sum_{i=1}^{k+d_{max}} \delta_{1i} Y_{t-i} + \mu_{1t} \quad (2)$$

$$Y_t = \beta_0 + \sum_{i=1}^{k+d_{max}} \beta_{1i} Y_{t-i} + \sum_{j=1}^{k+d_{max}} \emptyset_{1i} X_{t-j} + \mu_{2t} \quad (3)$$

Where, X_t stands for log of real GSDP and Y_t strands for log of electricity consumption. μ_{1t} and μ_{2t} are two residuals of the models. K is number of lags used in the model and d_{max} is the additional lag included as exogenous depending upon the order of integration of the variables. Now if Y is said to be granger cause X, it means $\delta_{1i} \neq 0$, for i=1, 2, 3…..k. Similarly, if X Granger cause Y then $\emptyset_{1i} \neq 0$, for i=1, 2, 3,…….k.

5.2 Non-Linear Granger Causality

Traditional linear causality test sometimes fails to uncover the true causal relationship due to possible nonlinearity in the relationship between variables. Therefore, in response to it, some nonlinear causality models were developed, Hiemstra and Jones (1994) being one of them. However, it was claimed that this model has limitations that fail to detect the true nonlinear causal relationship. Diks–Panchenko (2006) argued that the test has low power, leading to the model's failure in capturing the nonlinearity. Therefore, we have used Diks–Panchenko (2006) (hereafter, D-P test) to understand the energy-growth nexus. As D-P argues that this model has several advantages over earlier models. The test addresses over rejection problem, which was encountered by Hiemstra and Jones (1994), D-P has developed a nonparametric test version of causality. The following can be used to define the D-P test. If neither the past nor the present value of the X variable contains any new information about the future value of Y, then X is said not to be causing Y according to the Granger causality test. The following describes the null hypothesis that there is no Granger causality:

$$H_0\colon\ Y_{t+1} | \,(X_t^{l_x};\, Y_t^{l_y}) \ \sim\ Y_{t+1} | Y_t^{l_y} \quad (4)$$

Where ($l_x\ l_y \geq 1$) are the lag length of X and Y variables. $X_t^{l_x} = (X_{t+1} \dots \dots \dots X_t)$ and $Y_t^{l_y} = (Y_{t+1} \dots \dots \dots Y_t)$ are two delay vectors. The $\sim$ denotes the distribution's homogeneity. The joint probability density function $f_{X,Y,Z\,(x,y,z)}$ of $W_t = (X_t^{l_x}, Y_t^{l_y}, Z_t)$ can be found in the following connection, assuming $Z_t = Y_{t+1}$ and $l_x = l_y = 1$:

$$\frac{f_{X,Y,Z\,(x,y,z)}}{f_Y\,(y)} = \frac{f_{X,Y\,(x,y)}}{f_Y\,(y)} * \frac{f_{Y,Z\,(y,z)}}{f_Y\,(y)} \quad (5)$$

Equation (5) demonstrates that, subject to Y=y for each constant value of y, X and Z are independent of one another. Therefore, the updated null hypothesis could be expressed as follows:

$$q \equiv [f_{X,Y,Z}(X,Y,Z)\, f_Y\,(Y) - f_{X,Y}(X,Y) f_{Y,z}(Y,Z)] = 0 \quad (6)$$

The details about the methodology has been given in Diks–Panchenko (2006).

5.3 Long-Run Elasticity of Economic Growth and Electricity Consumption

To understand the elasticity of the state economy and different sectors, a ARDL bound test has been used to find long-run elasticity. The advantage of using this model in the elasticity estimation is that it has an estimate that captures dynamic impacts in the relationship. A simple double-long regression model fails to address such time-varying aspects while estimating the elasticity. Rolling elasticity is also calculated using this model to observe the time dependency of elasticity over the years.

The ARDL model for this study is specified as follows:

$$\Delta Ln\ GSDP_t = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i}\, \Delta Ln\ GSDP_{t-i} + \sum_{i=j}^{m} \gamma_{2j}\, \Delta LnEC_{t-j} + \gamma_3 Ln\ GSDP_{t-1} + \gamma_4 LnEC_{t-1} + \mu_t$$

Where, γ_4 measures the long run elasticity of state economy to electricity consumption. The null hypothesis of $\gamma_4 = 0$ must be rejected to find significant elasticity. Through hypothesis testing the statistical significance of the said coefficient is tested. A higher value of said coefficient indicates greater elasticity. A similar replica has been adopted for three different sectors.

6. Empirical Analysis and Discussion

6.1 Unit Root Test Results

A battery of unit root tests is used as a preliminary check to ensure the sequence of integration of the time series data before verifying the linear causality proposed by Toda and Yamamoto (1995). The findings of Dickey and Fuller (1979), Phillips and Perron (1988), and Kwiatkowski et al. (1992) are presented in Table 1. According to all tests, variables are stationary at the first difference [I(1)].

Table 1. Unit root test result of LEC and LGSDP (Both at Aggregate and Sectoral levels)

	Intercept and Trend		
	ADF	PP	KPSS
LEC	-1.51(0.80)	-2.05(0.55)	0.161
ΔLEC	-4.44(0.00)***	-9.24(0.00)***	0.080
LGSDP	-1.11(0.91)	-1.54(0.79)	0.194
ΔLGSDP	-8.94(0.00)***	-9.13(0.00)***	0.041
LGSDP_PS	-3.13(0.11)	-3.03(0.13)	0.184
ΔLGSDP_PS	-10.78(0.00)***	-13.63(0.00)	0.247
LGSDP_SS	-2.05(0.55)	-2.07(0.54)	0.156
ΔLGSDP_SS	-6.69(0.00)***	-6.70(0.00)***	0.054
LGSDP_TS	-1.22(0.89)	-1.48(0.81)	0.200
ΔLGSDP_TS	-7.06(0.00)***	-7.01(0.00)***	0.079

Note. LGSDP_PS is log of primary sector GSDP; LGSDP_SS is log of secondary sector GSDP; LGSDP_TS is log of tertiary sector GSDP. LEC is log of electricity consumption; LGSDP is log of total GSDP.

6.2 Linear Granger Causality Analysis (Aggregate and Sectoral levels)

The Toda-Yamamoto linear causality test is shown in Table 2. The result indicates that electricity consumption in Odisha is significantly granger causes economic growth. The null hypothesis of “electricity consumption does not granger cause GSDP” is rejected at the 1 % level. It suggests that electricity has been one of the important drivers of economic growth in the state. Using electricity as input in producers’ production and utility by consumers significantly causes economic activities. There has been an inter-fuel substitution, and electricity has emerged as one of the most efficient forms of energy not because it reduces environmental damage but because it has greater utility. It is not restricted to industry’s use for economic activities, but households now use it. This is quite evident as the per capita electricity consumption has gone up in an increasing trend. This supports the findings of Ahmad et al. (2014) and Nain et al. (2017a) who found that electricity has been an important factor for economic growth in India.

The sectoral analysis confirms a similar finding. Electricity consumption has a strong causal relationship with agriculture, industry and service sectors. The causality result is depicted in table 3. It shows that the null hypothesis of “electricity consumption does not granger cause agriculture GSDP” is rejected at the 1 percent level, suggesting significant causal impact of electricity consumption on state’s GDP in the agriculture sector. The state’s agricultural sector has been heavily dependent on electricity due to inadequate expansion of irrigation facilities and water-intensive crop cultivation. The sector depends heavily on groundwater for irrigation purposes. Installation of an electric pump set helps lift the groundwater by reducing human labour and serves the irrigation demand easily. As the state diversifies its agricultural practices, more cash crops are being produced besides seasonal crops. Therefore, the demand for energy is increasing; hence, there is a strong causal relationship. This evidence supports the findings of Jha et al. (2012), Abbas and Choudhury (2013), and Dogan et al. (2016), who observed that electricity consumption is significantly causing agriculture sector growth in India.

Similarly, we observe that electricity consumption is significantly causing secondary sector growth or industry growth. The null hypothesis of “electricity consumption does not granger cause secondary sector GSDP” is rejected at the 1 percent level. As industries are replacing the traditional forms of energy, electricity becomes a crucial factor to be used as an input in production. The expansion of economic activities is creating greater electricity demand. Further, increasing construction activities is adding growth momentum in the state. The increasing use of electricity in that sector is causing it to play an important role in the growth process. Also, as the union government is becoming more vigilant about the violation of pollution norms, industry bodies find electricity a more suitable form of energy to be used in production.

A similar causal relationship is observed for the tertiary sector. The null hypothesis of “electricity consumption does not granger cause tertiary sector GSDP” is rejected at the 1 percent level, indicating a strong causal flow from electricity to growth. Increasing transport demand due to the heavy mobility of people has been met with increased use of electricity. This is particularly useful in the case of a railway which uses a huge volume of electricity. Increased urbanization demand is fulfilled by greater electricity use.

Table 2. Toda–Yamamoto linear causality of log EC and log GSDP (Aggregate level)

Direction of causality	M-Wald statistics
Log of EC does not Granger cause log of GSDP	19.54(0.00)***
Log of GSDP does not Granger cause log of EC	3.51(0.47)

Note. ***and ** indicate statistical significance at 1% and 5% respectively.

Table 3. Toda–Yamamoto linear causality of log EC and log of GSDP (Sectoral level)

Direction of causality	M-Wald statistics
Log of EC does not Granger cause log of GSDP_PS	21.14(0.00)***
Log of GSDP_PS does not Granger cause log of EC	1.14(0.88)
Log of EC does not Granger cause log of GSDP_SS	12.28(0.01)***
Log of GSDP_SS does not Granger cause log of EC	5.15(0.27)
Log of EC does not Granger cause log of GSDP_TS	8.51(0.07)*
Log of GSDP_TS does not Granger cause log of EC	7.34(0.11)

Note. ***denotes significant at 1 percent level.

6.3 Non-Linear Granger Causality Analysis (Aggregate and Sectoral levels)

According to the nonlinear causal analysis, there is a one-way causal relationship between economic growth and electricity consumption. The calculated statics is lower than the critical value, therefore, the null hypothesis of no causality is rejected in the range of 1% to 5% level, respectively (see table 4). We found a one-way causal relationship between electricity consumption and the expansion of the sector for agriculture and related activities at the sectoral level. But in the case of the secondary sector, it is found to be a bi-directional causality. We see that in the industry sector, electricity helps economic activities, and greater economic activities increasingly use electricity to produce goods and services. But we saw a one-way causation from power use to the expansion of the service sector (see table 5).

Table 4. Diks–Panchenko non-linear Granger causality of LEC and LGSDP (At Aggregate level)

Null Hypothesis	T-Statistics					
	$L_x = L_y$	1	2	3	4	5
Log of EC does not Granger cause log of GSDP		2.33 (0.00)***	1.84 (0.03)**	1.82 (0.03)**	1.47 (0.07)*	1.47 (0.07)*
Log of GSDP does not Granger cause log of EC		1.29 (0.09)*	0.82 (0.20)	0.82 (0.20)	0.83 (0.20)	0.84 (0.20)

Note. The causality test is conducted using an epsilon value of 1.5 for all five lags. L_x *and* L_y represent lags of the variables. ***, ** and * denote statistical significance at 1 percent, 5 percent and 10 percent levels.

Table 5. Diks–Panchenko non-linear Granger causality of LEC, LGSDP_PS, LGSDP_SS and LGSDP_TS (At sectoral level)

Null Hypothesis	T-Statistics					
	$L_x = L_y$	1	2	3	4	5
Log of EC does not Granger cause log of GSDP_PS		1.72 (0.04)**	1.15 (0.12)	1.12 (0.11)	1.16 (0.14)	1.13 (0.11)
Log of GSDP_PS does not Granger cause log of EC		1.92 (0.02)**	1.35 (0.08)*	1.34 (0.09)*	1.34 (0.08)*	1.32 (0.09)*
Log of EC does not Granger cause log of GSDP_SS		2.16 (0.01)***	2.08 (0.01)***	1.70 (0.04)**	1.44 (0.07)*	1.46 (0.07)*
Log of GSDP_SS does not Granger cause log of EC		1.75 (0.04)**	1.30 (0.09)*	1.30 (0.09)*	1.31 (0.09)*	1.31 (0.09)*
Log of EC does not Granger cause log of GSDP_TS		1.68 (0.04)**	1.69 (0.04)**	1.71 (0.04)**	1.72 (0.04)**	1.74 (0.04)**
Log of GSDP_TS does not Granger cause log of EC		1.02 (0.15)	0.82 (0.20)	0.82 (0.20)	0.83 (0.20)	0.83 (0.20)

Note. The causality test is conducted using an epsilon value of 1.5 for all five lags. L_x *and* L_y represent lags of the variables. ***, ** and * denote statistical significance at 1 percent, 5 percent and 10 percent levels.

To check the further robustness of the results, a structural break test by Bai and Perron (2003) is employed. This is a multiple structural break test where 1 to 5 breaks can be identified on time series data. The test result indicates no significant structural break in the data. The null hypothesis of zero structural break vs. one break is not rejected as the calculated F-statistics 0.497 is less than the critical value of 8.58. Therefore, we roll out the possibility of any biases in the results due to structural break (Note 4).

6.4 Long-Run Elasticity of Electricity Consumption

The estimated long run elasticity is greater than 1 (1.15), indicating a more significant role of electricity in the state's economic progress. The state's GSDP responds greater than when there is a 1 percent increase in electricity consumption demand. As evident, the secondary sector is heavily energy dependent. The state's manufacturing, construction, and other industrial activities are highly dependent on electricity, and a 1 percent increase in electricity consumption raises 1.14 percent growth in these sub-sectors. As expected, agriculture and allied activities are not that much dependent on industry. We find an elasticity of 0.67 for this sector, indicating that if there is a 1 percent rise in electricity consumption, the state's agriculture sector will grow by 0.67 percent. The service sector elasticity is estimated at 1.44 (See table 6).

Further, a five-year analysis of rolling elasticity shows that elasticity is increasing over time. It was 1.08 from 2007 to 2011, which increased to 1.18 from 2017 to 2020. But elasticity in agriculture and allied sectors has continued growing over the years. It was 0.53 during 2002-2006, which increased to 0.63 during 2012-2016 and later increased to 0.66 during 2017-2020. In contrast, the tertiary sector has been experiencing a decline in energy elasticity. The elasticity in the secondary sector, which was 0.92 during 2002-06, has increased to 1.23 during 2007-2011. However, in recent years, this sector's elasticity has declined. During 2017-2020, the elasticity remained at 1.14 (see figure 2).

Table 6. Long run elasticity

	Long-run Elasticity			
Variables	Aggregate Sector Coefficient	Primary Sector Coefficient	Secondary Sector Coefficient	Tertiary Sector Coefficient
LEC	1.157	0.669	1.146	1.445
	(12.76)***	(31.17)***	(15.67)***	(17.14)***
C	1.685	4.805	0.444	-1.571
	(2.42)**	(25.72)***	(0.706)	(-2.664)***

Note. *** and ** indicate statistical significance at 1 percent and 5 percent levels.

Source: Author's calculation.

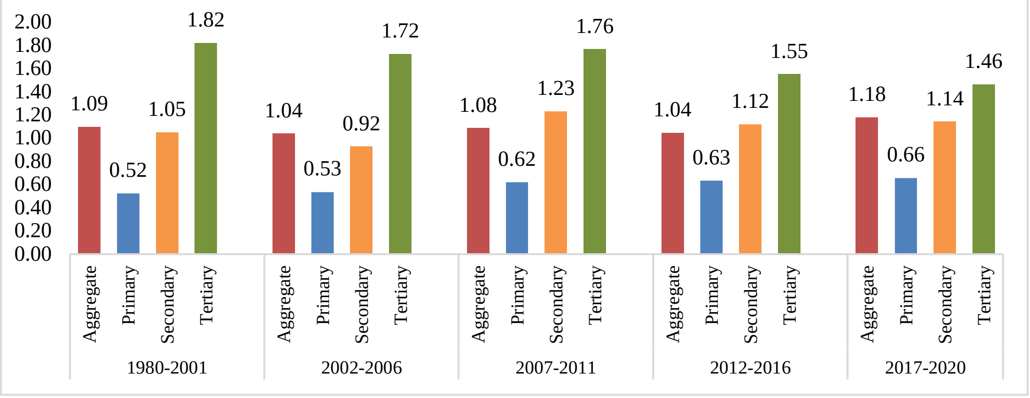

Figure 2. Rolling Elasticity (Sector-wise and Aggregate)

Source: Author's calculation.

7. Conclusion and Policy Suggestions

The study examines the causal relationship between electricity consumption and economic growth in Odisha. Towards this objective, both an aggregate and a sectoral analysis are carried out. From the analysis, three main conclusions are derived. First, there is strong evidence that electricity consumption granger causes economic growth, both at aggregate and sectoral levels. Electricity consumption exhibits a strong causal relationship with primary, secondary, and tertiary sectors. This finding holds for both linear and non-linear granger causality tests. Second, the long-run elasticity calculation confirms that the state's economy is highly responsive to electricity consumption. Among the sectors, the elasticity is more than unity in cases of both tertiary and secondary sectors. However, the elasticity is less than unity in the case of the primary sector. Third, the rolling long-run elasticity in both primary and secondary sectors along with the aggregate level has been increasing, whereas elasticity in the service sector has been declining.

These findings have important policy implications for Odisha. There is a need to increase both electricity generation capacity and electricity consumption in Odisha to raise economic growth. The present level of distribution loss (leakages) needs to be reduced before the supply reaches the consumption point so that all these three sectors can consume more electricity. Specifically in Primary sector, the electricity consumption will increase if more mechanical farming is adopted. Mechanical farming will induce higher productivity in the agriculture sector with higher value addition. In turn, it will augment the economic growth in Odisha.

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Author's Contribution

Mr. Upendra Nath Behera is responsible for conceptualization, data analysis and interpretations. Prof. Asit Ranjan Mohanty is responsible for conceptualization, data collection, data analysis and interpretations.

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Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Notes

Note 1. https://cea.nic.in/installed-capacity-report/?lang=en

Note 2. https://corporate.exxonmobil.com/Energy-and-innovation/outlook-for-energy/Energy-demand#Threedriversofenergydemand

Note 3. http://www.desorissa.nic.in/pdf/Odisha%20Economic%20Survey%202020-21-1.pdf

Note 4. The result can be made available upon request to the authors.