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ELECTRICITY AND ECONOMIC GROWTH IN INDONESIA'S PROVINCE OF ACEH

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Abstract: This paper is distinguished from previous research in term of using sectoral electricity consumption data (residential, commercial, public, and industrial) rather than of using aggregate electricity consumption data in order to examine the relationship between electricity and economic growth. The vector error correction model is employed to scrutinize the linkage based on data covering time span 1995-2031 in Indonesia's Province of Aceh. The empirical evidences indicate that the long-run bidirectional relationship exists between, (1) commercial electricity consumption and economic growth and, (2) public electricity consumption and economic growth. In addition, the short-run bidirectional relationship exists between economic growth and all of the sectoral electricity consumption. The results imply that the government policy for power development is purposed to maintain the bidirectional causality between economic growth and electricity consumption.

Keywords: Sectoral Electricity Consumption, Economic Growth, Aceh, Vector Error Correction Model.

Introduction

The role of electricity in productivity growth is very perceptible; moreover, many new techniques and new arrangements which are able to increase labor productivity and to reduce capital needs have been introduced since 20th century as a result from rapid electrification in so many industries (Rosenberg, 2010). Even though electricity has an elastic energy form so that it may perform multiple tasks together in once time than if any other type of energies is used directly; recent empirical evidences that have observed electricity and economic growth are still presenting mixed result on causal relationship, see Ozturk (2010) and Payne (2010a,b) for a survey of the international evidence.

The interaction between electricity consumption and economic growth is crucial for policy implication; interestingly, the causation for the specific countries surveyed by Payne (2010a) found that 27.87% supported the conservation hypothesis where the economic growth causes electricity consumption, 22.95% the unidirectional causality from electricity to economic growth, 18.03% the bidirectional causality between economic growth and electricity consumption, and 31.15% supported the neutrality hypothesis where no causal relationship between the two variables.

To our knowledge, the previous studies both in Indonesia and in Aceh have only analyzed the relationship between electricity and economic growth at aggregate level (see Yoo (2006), Rizal and Nasir (2010)). The objective of this study is to examine such a relationship for Province Aceh, Indonesia between different sectors electricity consumption and economic growth. This is conducted by verifying cointegration and causality test by using time series data on sectoral electricity consumption and real gross regional domestic product in constant 2000 prices from 1995 to 2031. It is motivated by: firstly to our knowledge Governor Aceh is the pioneer in carry out the mandate as regulator in the power development affairs at provincial level than other regions in Indonesia; secondly, the projected electricity needs and real gross regional domestic product in the governor policy can express how local government see the role of electricity in the local economy.

The rest of the paper is composed as follows: section two deals with the overview of electricity condition and its legislation; section three present the relevant literature review and previous researches especially in Aceh; section four presents the data sources; section five discusses econometric methodology; section six reveals the empirical results; and the final section presents the summary of this study along with its conclusions and recommendations.

Overview of Electricity Condition and its Legislation

Recently, awareness of the importance of the electricity sector to the national economy has been increasingly grown in Indonesia. The new paradigm had been enacted through the national regulation no. 30 year 2009 (Government of Indonesia (GOI), 2009) in which designing electricity provision to be available in reasonable price without reducing its efficiency and reliability. This was probably driven by the condition before 2009 when the government spent more on electricity subsidies than it did on strategically expenditures such as defense spending, health, and social securities (IISD, 2012). By this legislation the central government believe that electricity is the key role in achieving a sustainable economic growth as one of the national goals; moreover, sufficient electricity supply is believed as the medium to create multiplier effect on economic development. the national regulation no. 30 year 2009 also puts the responsibility on local government shoulder to make sure the establishment of the national goals by power development project.

In 2012, the roadmap of power development at provincial level had been drawn by Aceh government through governor policy no. 95 year 2012 (Government of Province Aceh, (GOPA), 2012) in which was drawn the estimated electricity needs and real gross regional domestic product for period 2013-2031 base on the actual data from period 1995-2012. The relationship between the two variables from the actual and the estimated data may show how strong the Aceh government believes that electricity will affect its economy and vice versa.

Furthermore, recent data shows that 10.7% of households still have not been touched by electricity services; however, Aceh electricity consumption in 2012 is dominated by residential consumption about 1057 GWh; along with industrial, commercial, and public consumption respectively are around 58 GWh, 300 GWh, and 250 GWh (GOPA, 2012). It implies that the impacts of electricity used on economic growth is more relying on its ability to improve the labor efficiency through the direct impact on well-being rather than the direct impact on productive activity. The policy makers ought to thus consider it carefully if the national goals are to be achieved.

Literature Review

The econometric study of causality relationship between energy consumption and economic growth has fascinated extensive interest in the energy economics literature. The earliest study is conducted by Kraft and Kraft (1978) who has found unidirectional causality from GNP to energy consumption in US; unfortunately, the further studies show the miscellaneous empirical evidences. According to Payne (2010a), around 31% of studies on causality relationship between electricity and economic growth found that there is no relationship between them while only 18% of studies confirm bi-directional causality, the rest of studies merely prove unidirectional causality from electricity to economic growth or vice versa.

In the recent studies, Hou (2009) has discovered that the feedback effect occurs between energy consumption and economic growth based on data covering time span 1953-2003 in China, Adom (2011) found the existing of causality running from economic growth to electricity consumption in Ghana from 1980-2008. Unidirectional causality running from electricity to economic growth revealed by Sarker and Alam (2010) in Bangladesh for period 1973-2006, Adebola (2011) in Botswana for period 1997-2008, Shahbaz et al. (2012) in Romania based on data from 1980 to 2011, and Khan et al. (2012) in Kazakhstan derived from 1991 to 2011. Masuduzzaman (2012) also analyzed the causality between electricity and economic growth in Bangladesh using different time period that is from 1981 to 2011; fortunately, the result corroborates the previous research by Sarker and Alam (2010). Although most studies have a preference to analyze the relationship between electricity consumption and economic growth at aggregate level, Sami (2012) studied the causal relationship between different consumers of electricity and economic growth in Philippines using data from 1973-2008; moreover, the result confirm that unidirectional causality running from commercial electricity consumption to economic growth while economic growth causes industrial and residential electricity consumption without the feedback effect.

In particular, the most recent study regarding the relationship between electricity and economic growth in Aceh had been conducted by Rizal and Nasir (2010); moreover, using aggregate electricity consumption data from 1975-2007, they found the bidirectional between electricity consumption and economic growth in Aceh. In addition, they estimated that each 1 MWh increases in electricity consumption will be followed by the increase in GRDP around 0.36 to 19.03 Million IDR and each 1 Million IDR increases in GRDP will be followed by the increases in electricity consumption around 0.04 to 0.07 MWh

Data

Following Sami (2012) this study uses four variables, specifically, real gross regional domestic product (GRDP) per capita for Province Aceh, industrial electricity consumption, public electricity consumption, commercial electricity consumption, and residential electricity consumption obtained from the governor policy no. 95 year 2012 (GOPA, 2012). The time span of actual data is from 1995 to 2012 while during the period 2013-2031 as the government projection data. The unit of real GRDP is in 2000 Indonesian Rupiah per capita and electricity consumption is in KWh per costumer; furthermore, all variables are transformed into natural logarithm. The time period of study is from 1995-2031 combined the actual data and the government projection data as previously mentioned. The choice of the period was constrained by the availability of time series data on governor policy no. 95 year 2012 (GOPA, 2012).

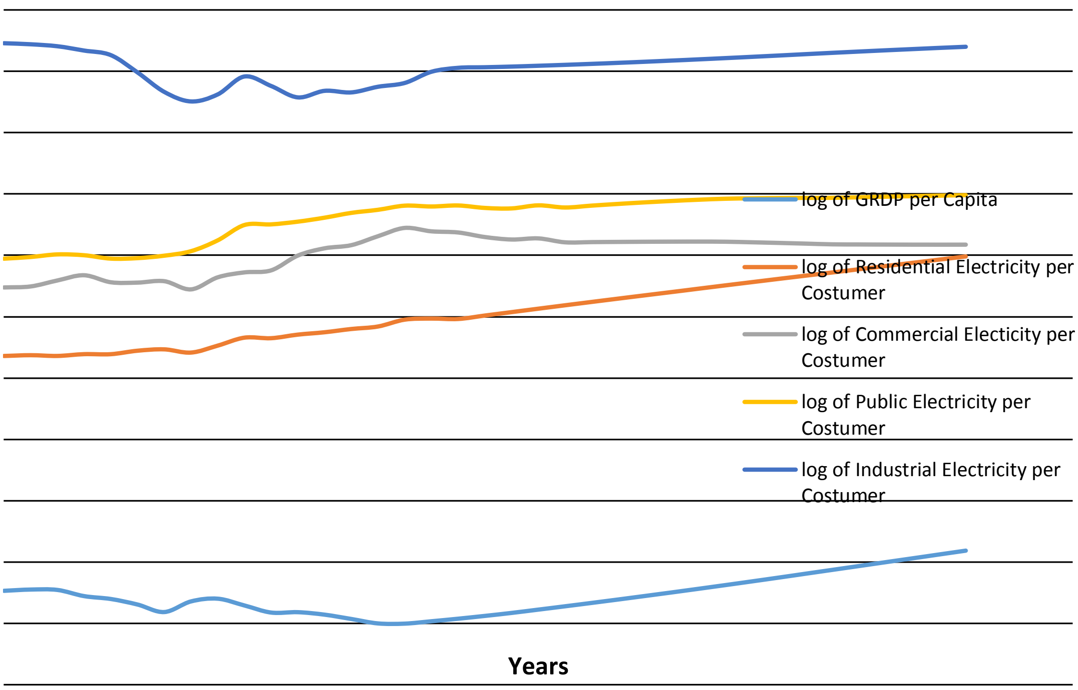

Figure 1. Evolution of Economic Growth and Electricity Consumption in Indonesia's Province of Aceh

Empirical Framework

Stationarity

Using non-stationary data in VECM or traditional Granger causality test is forbidden since it may turn the regression to become spurious. Non-stationarity or the presence of a unit root in this study is tested using Augmented Dickey Fuller test. For each variable in this study, ADF test is as follows:

$$\Delta X_t = \alpha + \beta X_{t-1} + \sum_{i=1}^{n} \Delta X_{t-i} + \varepsilon_t \qquad (1)$$

The core of this test is the null hypothesis that β=0, only if β≠0 the hypothesis that X contains a unit root is rejected. The optimum lag is obtained from SIC value.

Cointegration Test

The Johansen methodology is used in this study in order to prove the existence of a long-term equilibrium between dependent variable and independent variables. Johansen test has two test means. One is trace test and the other is max Eigen-value test. The summary of the test may conclude that if the variables are cointegrated, the causality test may reparametrize the model in the equivalent vector error correction model Asteriou and Hall (2007).

Sectoral Electricity Consumption and Regional Economic Growth Model

In this paper, the dynamic linear relationship between sectoral electricity consumption and real GRDP can be captured from the vector error correction model (VECM) as follows:

Model 1: Residential Electricity Consumption and Economic Growth

$$\Delta Y_t = \alpha_{yr} + \sum_{i=1}^{n} \beta_{yri} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{yri} \Delta CR_{t-i} + \theta_{yr} ECR_{t-1} \qquad (2)$$
$$\Delta CR_t = \alpha_r + \sum_{i=1}^{n} \beta_{ri} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{ri} \Delta CR_{t-i} + \theta_r ECR_{t-1} \qquad (3)$$

Model 2: Commercial Electricity Consumption and Economic Growth

$$\Delta Y_t = \alpha_{yc} + \sum_{i=1}^{n} \beta_{yci} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{yci} \Delta CC_{t-i} + \theta_y ECC_{t-1} \qquad (4)$$
$$\Delta CC_t = \alpha_c + \sum_{i=1}^{n} \beta_{ci} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{ci} \Delta CC_{t-i} + \theta_y ECC_{t-1} \qquad (5)$$

Model 3: Public Electricity Consumption and Economic Growth

$$\Delta Y_t = \alpha_{yp} + \sum_{i=1}^{n} \beta_{ypi} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{ypi} \Delta CP_{t-i} + \theta_y ECP_{t-1} \qquad (6)$$
$$\Delta CP_t = \alpha_p + \sum_{i=1}^{n} \beta_{pi} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{pi} \Delta CP_{t-i} + \theta_y ECC_{t-1} \qquad (7)$$

Model 4: Industrial Electricity Consumption and Economic Growth

$$\Delta Y_t = \alpha_{yp} + \sum_{i=1}^{n} \beta_{yi} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{yi} \Delta CI_{t-i} + \theta_y ECI_{t-1} \qquad (8)$$
$$\Delta CI_t = \alpha_p + \sum_{i=1}^{n} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta CI_{t-i} + \theta_y ECI_{t-1} \qquad (9)$$

Model 5: Aggregate Electricity Consumption and Economic Growth

$$\Delta Y_t = \alpha_{yp} + \sum_{i=1}^{n} \beta_{yi} \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_{yi} \Delta CE_{t-i} + \theta_y ECT_{t-1} \qquad (10)$$
$$\Delta CE_t = \alpha_p + \sum_{i=1}^{n} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta CE_{t-i} + \theta_y ECT_{t-1} \qquad (11)$$

In equation above, Δ is difference operator, Y is log of real GRDP, CR is log of residential electricity consumption, CC is log of commercial electricity consumption, CP is log of public electricity consumption, CI is industrial electricity consumption, and CE is log of aggregate electricity consumption. ECR, ECC, ECP, ECI and ECT are respectively the error correction terms derived from log-run cointegrating relationship. In addition, the optimum lag is chosen from the lowest AIC value.

Empirical Findings

Results from ADF Test

Table 1 shows the results of the ADF tests of the integration properties of the series, Y, CR, CC, CP, CI, and CE for Province Aceh. Results of the tests reveal that the series in their levels are non-stationary but they are stationary in their first differences. This implies that the integration of Y&CR, Y&CC, Y&CP, Y&CI, and Y&CE for Province Aceh is of order one.

Table 1. Unit Root Test

Variables	ADF Test	
	Level	First Difference
Y	-1.47	-4.23[a]
CR	1.73	-4.66[a]
CC	-1.78	-2.62[c]
CP	-1.69	-4.08[a]
CI	-1.18	-4.37[a]
CE	-0.51	-5.50[a]

Notes: Significance at 1%/5%/10% denoted by a/b /c

Results from Johansen Cointegration Test

As the ADF test confirmed that all variables are non-stationary and integrated order 1, I(0), the foregoing step for causality test is to scrutinize whether the combined series in Model 1, Model 2, Model 3, and Model 4 are cointegrated. Table 2 shows the results of the Johansen cointegration test for all model in which the null hypothesis of r=0 can be rejected in any case at 10% level of significance. It implies that there is cointegration relationship in all of the series.

Table 2. Cointegration Test

Series	Hypothesis No. Of CE(s)	Trace Test		Max. Eigenvalue	
		Test Stat.	0.1 Critical Value	Test Stat.	0.1 Critical Value
Model 1 (Y and CR)	None (r = 0)	26.38[a]	13.43	25.56[a]	12.3
	At Most (r ≤ 1)	0.82	2.71	0.82	2.71
Model 2 (Y and CC)	None (r = 0)	12.34	13.43	12.31[c]	12.30
	At Most (r ≤ 1)	0.03	2.71	0.03	2.71
Model 3 (Y and CP)	None (r = 0)	14.73[c]	13.43	14.68[b]	12.30
	At Most (r ≤ 1)	0.05	2.71	0.05	2.71
Model 4 (Y and CI)	None (r = 0)	19.48[b]	13.43	19.42[a]	12.30
	At Most (r ≤ 1)	0.06	2.71	0.06	2.71
Model 5 (Y and CE)	None (r = 0)	21.39[a]	13.43	20.31[a]	12.30
	At Most (r ≤ 1)	1.08	2.71	1.08	2.71

Notes: Significance at 1%/5%/10% denoted by a/b /c

Multicollinearity Test

Multicollinearity is a statistical problem in which two or more explanatory variables in a model are highly correlated so that the model will be not statistically robust. In order to avoid this kind of problem, multicollinearity test should be employed among the predictor variables in all models in VECM estimation. Multicollinearity problems can be detected by the correlation coefficient. When the correlation coefficient values exceed 0.9, it is concluded as multicollinearity.

Multicollinearity Test for Model 1

The following table presents the correlation coefficient among explanatory variables in model 1 and it justifies that multicollinearity problems do not exist among those variables.

Table 3. The Correlation Matrix for Model 1

	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔY_{t-4}	ΔY_{t-5}	ΔCR_{t-1}	ΔCR_{t-2}	ΔCR_{t-3}	ΔCR_{t-4}	ΔCR_{t-5}
ΔY_{t-1}	1.000	0.474	0.184	0.356	0.410	0.123	0.279	0.266	-0.243	-0.180
ΔY_{t-2}	0.474	1.000	0.497	0.184	0.342	0.299	0.304	-0.221	-0.124	0.463
ΔY_{t-3}	0.184	0.497	1.000	0.485	0.164	0.333	-0.115	-0.089	0.506	0.223
ΔY_{t-4}	0.356	0.184	0.485	1.000	0.478	-0.108	-0.070	0.509	0.231	-0.124
ΔY_{t-5}	0.410	0.342	0.164	0.478	1.000	-0.075	0.485	0.228	-0.124	0.245
ΔCR_{t-1}	0.123	0.299	0.333	-0.108	-0.075	1.000	-0.032	-0.291	0.268	0.068
ΔCR_{t-2}	0.279	0.304	-0.115	-0.070	0.485	-0.032	1.000	-0.083	-0.312	0.237
ΔCR_{t-3}	0.266	-0.221	-0.089	0.509	0.228	-0.291	-0.083	1.000	-0.118	-0.421
ΔCR_{t-4}	-0.243	-0.124	0.506	0.231	-0.124	0.268	-0.312	-0.118	1.000	-0.150
ΔCR_{t-5}	-0.180	0.463	0.223	-0.124	0.245	0.068	0.237	-0.421	-0.150	1.000

Multicollinearity Test for Model 2

Table 4 presents the correlation coefficient among explanatory variables in model 2 and it also proves that multicollinearity problems do not exist among those variables.

Table 4. The Correlation Matrix for Model 2

	ΔCC_{t-5}	ΔCC_{t-4}	ΔCC_{t-3}	ΔCC_{t-2}	ΔCC_{t-1}	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔY_{t-4}	ΔY_{t-5}
ΔCC_{t-5}	1.000	0.209	0.187	0.489	-0.187	-0.433	-0.125	-0.361	-0.205	0.104
ΔCC_{t-4}	0.209	1.000	0.156	0.142	0.469	-0.353	-0.351	-0.022	-0.325	-0.195
ΔCC_{t-3}	0.187	0.156	1.000	0.189	0.138	-0.244	-0.368	-0.372	-0.027	-0.318
ΔCC_{t-2}	0.489	0.142	0.189	1.000	0.201	-0.391	-0.298	-0.433	-0.415	-0.053
ΔCC_{t-1}	-0.187	0.469	0.138	0.201	1.000	-0.220	-0.380	-0.279	-0.430	-0.413
ΔY_{t-1}	-0.433	-0.353	-0.244	-0.391	-0.220	1.000	0.474	0.184	0.356	0.410
ΔY_{t-2}	-0.125	-0.351	-0.368	-0.298	-0.380	0.474	1.000	0.497	0.184	0.342
ΔY_{t-3}	-0.361	-0.022	-0.372	-0.433	-0.279	0.184	0.497	1.000	0.485	0.164
ΔY_{t-4}	-0.205	-0.325	-0.027	-0.415	-0.430	0.356	0.184	0.485	1.000	0.478
ΔY_{t-5}	0.104	-0.195	-0.318	-0.053	-0.413	0.410	0.342	0.164	0.478	1.000

Multicollinearity Test for Model 3
As presented in Table 5, the multicollinearity problems do not exist among explanatory variables in model 3.

Table 5. The Correlation Matrix for Model 3

	ΔCP_{t-1}	ΔCP_{t-2}	ΔCP_{t-3}	ΔCP_{t-4}	ΔCP_{t-5}	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔY_{t-4}	ΔY_{t-5}
ΔCP_{t-1}	1.000	0.364	0.147	0.077	-0.045	-0.306	0.018	-0.066	-0.523	-0.302
ΔCP_{t-2}	0.364	1.000	0.380	0.165	0.071	-0.427	-0.236	0.103	-0.040	-0.504
ΔCP_{t-3}	0.147	0.380	1.000	0.415	0.160	-0.238	-0.387	-0.177	0.119	-0.033
ΔCP_{t-4}	0.077	0.165	0.415	1.000	0.459	-0.376	-0.285	-0.434	-0.225	0.089
ΔCP_{t-5}	-0.045	0.071	0.160	0.459	1.000	-0.405	-0.365	-0.266	-0.429	-0.220
ΔY_{t-1}	-0.306	-0.427	-0.238	-0.376	-0.405	1.000	0.474	0.184	0.356	0.410
ΔY_{t-2}	0.018	-0.236	-0.387	-0.285	-0.365	0.474	1.000	0.497	0.184	0.342
ΔY_{t-3}	-0.066	0.103	-0.177	-0.434	-0.266	0.184	0.497	1.000	0.485	0.164
ΔY_{t-4}	-0.523	-0.040	0.119	-0.225	-0.429	0.356	0.184	0.485	1.000	0.478
ΔY_{t-5}	-0.302	-0.504	-0.033	0.089	-0.220	0.410	0.342	0.164	0.478	1.000

Multicollinearity Test for Model 4
The multicollinearity test for Model 4 as presented by Table 6 also justifies that the problems do not exist among explanatory variables in model 4.

Table 6. The Correlation Matrix for Model 4

	ΔCI_{t-1}	ΔCI_{t-2}	ΔCI_{t-3}	ΔCI_{t-4}	ΔCI_{t-5}	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔY_{t-4}	ΔY_{t-5}
ΔCI_{t-1}	1.000	0.393	-0.092	-0.099	0.049	0.182	0.566	0.350	-0.188	-0.115
ΔCI_{t-2}	0.393	1.000	0.400	-0.086	-0.096	-0.132	0.199	0.573	0.354	-0.191
ΔCI_{t-3}	-0.092	0.400	1.000	0.402	-0.084	0.036	-0.112	0.220	0.576	0.351
ΔCI_{t-4}	-0.099	-0.086	0.402	1.000	0.402	0.363	0.042	-0.095	0.221	0.576
ΔCI_{t-5}	0.049	-0.096	-0.084	0.402	1.000	0.352	0.360	0.044	-0.097	0.219
ΔY_{t-1}	0.182	-0.132	0.036	0.363	0.352	1.000	0.474	0.184	0.356	0.410
ΔY_{t-2}	0.566	0.199	-0.112	0.042	0.360	0.474	1.000	0.497	0.184	0.342
ΔY_{t-3}	0.350	0.573	0.220	-0.095	0.044	0.184	0.497	1.000	0.485	0.164
ΔY_{t-4}	-0.188	0.354	0.576	0.221	-0.097	0.356	0.184	0.485	1.000	0.478
ΔY_{t-5}	-0.115	-0.191	0.351	0.576	0.219	0.410	0.342	0.164	0.478	1.000

Multicollinearity Test for Model 5
Finally, the multicollinearity test for Model 5 also justifies that the problems do not exist among explanatory variables in model 5.

Table 6. The Correlation Matrix for Model 5

	ΔCE_{t-1}	ΔCE_{t-2}	ΔCE_{t-3}	ΔCE_{t-4}	ΔCE_{t-5}	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔY_{t-4}	ΔY_{t-5}
ΔCE_{t-1}	1.000	0.097	-0.081	0.295	-0.059	-0.225	0.232	-0.038	-0.313	0.223
ΔCE_{t-2}	0.097	1.000	0.090	-0.110	0.244	-0.440	-0.169	0.290	-0.021	-0.306
ΔCE_{t-3}	-0.081	0.090	1.000	0.095	-0.106	-0.054	-0.436	-0.166	0.292	-0.018
ΔCE_{t-4}	0.295	-0.110	0.095	1.000	0.122	-0.019	-0.095	-0.477	-0.191	0.278
ΔCE_{t-5}	-0.059	0.244	-0.106	0.122	1.000	-0.047	-0.047	-0.138	-0.480	-0.186
ΔY_{t-1}	-0.225	-0.440	-0.054	-0.019	-0.047	1.000	0.474	0.184	0.356	0.410
ΔY_{t-2}	0.232	-0.169	-0.436	-0.095	-0.047	0.474	1.000	0.497	0.184	0.342
ΔY_{t-3}	-0.038	0.290	-0.166	-0.477	-0.138	0.184	0.497	1.000	0.485	0.164
ΔY_{t-4}	-0.313	-0.021	0.292	-0.191	-0.480	0.356	0.184	0.485	1.000	0.478
ΔY_{t-5}	0.223	-0.306	-0.018	0.278	-0.186	0.410	0.342	0.164	0.478	1.000

VECM

VECM can be applied only if two variables are non-stationary, but they become stationary after first-differencing, and co-integrated. The optimum lag is determined by the lowest AIC value as shown by the bold font in Table 7 so that the causality test is performed only on the chosen number of lagged variables.

Table 7. AIC Value from different lag

No.	AIC Value									
	Model 1		Model 2		Model 3		Model 4		Model 5	
	ΔCR→ΔY	ΔY→ΔCR	ΔCC→ΔY	ΔY→ΔCC	ΔCP→ΔY	ΔY→ΔCP	ΔCI→ΔY	ΔY→ΔCI	ΔCE→ΔY	ΔY→ΔCE
5	**-3.327**	**-4.758**	-3.437	**-3.078**	**-3.232**	**-3.503**	**-2.960**	**-2.624**	**-4.503**	**-4.381**
4	-2.956	-4.172	**-3.477**	-2.861	-3.018	-3.448	-2.837	-2.615	-4.102	-3.829
3	-3.092	-4.115	-3.356	-2.599	-3.052	-3.358	-2.910	-2.408	-3.641	-3.327
2	-3.171	-4.172	-3.059	-2.264	-2.938	-3.052	-2.680	-2.355	-3.525	-3.247
1	-3.233	-4.101	-3.020	-2.284	-3.015	-3.136	-2.764	-2.416	-3.411	-3.312

Table 8 displays the results of the short-run and long-run Granger-causality tests. With respect to Eq. (2) and Eq. (3), residential electricity consumption has a positive and statistically significance impact in the short-run on economic growth whereas economic growth to residential electricity consumption is statistically insignificance. Moreover, the error correction term is statistically significant at 1% level with 16.6% adjustment to the short-run disequilibrium running from residential electricity to economic growth, but it is insignificant for the vise versa.

Table 8. Causality test results

Dependent Variable		Source of Causation Short-run						Long-run
		ΔY	ΔCR	ΔCC	ΔCP	ΔCI	ΔCE	ECT
Eq. 2	ΔY	-	0.374	-	-	-	-	-0.166[a]
	Constant	-	0.209	-	-	-	-	(0.001)
	F-stat	-	5.400[a]	-	-	-	-	
			(0.000)	-	-	-	-	
	R2	-	0.721	-	-	-	-	
	LM	-	1.856	-	-	-	-	
			(0.762)	-	-	-	-	
	HE	-	105.000	-	-	-	-	
			(0.186)	-	-	-	-	

	ΔCR	0.203	-	-	-	-	-	0.035
Eq. 3	Constant	0.012	-	-	-	-	-	0.094
	F-stat	5.901[a]	-	-	-	-	-	
		(0.000)		-	-	-	-	
	R2	0.738	-	-	-	-	-	
	LM	1.856	-	-	-	-	-	
		(0.762)		-	-	-	-	
	HE	105.000	-	-	-	-	-	
		(0.186)		-	-	-	-	
	ΔY	-	-	0.325	-	-	-	-0.078[a]
Eq. 4	Constant	-	-	0.090	-	-	-	(0.000)
	F-stat	-	-	8.505[a]	-	-	-	
		-	-	(0.000)	-	-	-	
	R2	-	-	0.746	-	-	-	
	LM	-	-	4.095	-	-	-	
		-	-	(0.393)	-	-	-	
	HE	-	-	70.185	-	-	-	
		-	-	(0.068)	-	-	-	
	ΔCC	1.334	-	-	-	-	-	-0.068
Eq. 5	Constant	-0.037	-	-	-	-	-	(0.017)
	F-stat	6.532[a]	-	-	-	-	-	
		(0.000)	-	-	-	-	-	
	R2	0.758	-	-	-	-	-	
	LM	4.278	-	-	-	-	-	
		(0.370)	-	-	-	-	-	
	HE	68.024	-	-	-	-	-	
		(0.408)	-	-	-	-	-	
	ΔY	-	-	-	0.065	-	-	-0.021
Eq. 6	Constant	-	-	-	0.082	-	-	(0.014)
	F-stat	-	-	-	4.720[a]	-	-	
		-	-	-	(0.001)	-	-	
	R2	-	-	-	0.693	-	-	
	LM	-	-	-	2.706	-	-	
		-	-	-	(0.608)	-	-	
	HE	-	-	-	73.062	-	-	
		-	-	-	(0.257)	-	-	
	ΔCP	0.259	-	-	-	-	-	-0.025[a]
Eq. 7	Constant	0.006	-	-	-	-	-	(0.009)
	F-stat	4.800[a]	-	-	-	-	-	
		(0.000)	-	-	-	-	-	
	R2	0.697	-	-	-	-	-	
	LM	2.706	-	-	-	-	-	
		(0.608)	-	-	-	-	-	
	HE	73.062	-	-	-	-	-	
		(0.257)	-	-	-	-	-	
	ΔY	-	-	-	-	0.100	-	-0.045[a]

Eq. 8	Constant	-	-	-	-	0.028	-	(0.010)
	F-stat	-	-	-	-	3.100[a]	-	
		-	-	-	-	(0.010)	-	
	R2	-	-	-	-	0.597	-	
	LM	-	-	-	-	10.669	-	
		-	-	-	-	(0.031)	-	
	HE	-	-	-	-	105.000	-	
		-	-	-	-	(0.060)	-	
	ΔCI	1.372	-	-	-	-	-	-0.125[a]
Eq. 9	Constant	-0.026	-	-	-	-	-	(0.000)
	F-stat	7.459[a]	-	-	-	-	-	
		(0.000)	-	-	-	-	-	
	R2	0.781	-	-	-	-	-	
	LM	10.669	-	-	-	-	-	
		(0.031)	-	-	-	-	-	
	HE	105.000	-	-	-	-	-	
		(0.060)	-	-	-	-	-	
	ΔY	-	-	-	-	-	0.674	-0.291[a]
Eq. 10	Constant	-	-	-	-	-	0.434	(0.000)
	F-stat	-	-	-	-	-	22.176[a]	
		-	-	-	-	-	(0.000)	
	R2	-	-	-	-	-	0.914	
	LM	-	-	-	-	-	2.887	
		-	-	-	-	-	(0.577)	
	HE	-	-	-	-	-	89.387	
		-	-	-	-	-	(0.029)	
	ΔCE	0.455	-	-	-	-	-	-0.015
Eq. 11	Constant	0.092	-	-	-	-	-	(0.726)
	F-stat	9.904[a]	-	-	-	-	-	
		(0.000)	-	-	-	-	-	
	R2	0.826	-	-	-	-	-	
	LM	2.887	-	-	-	-	-	
		(0.577)	-	-	-	-	-	
	HE	89.387	-	-	-	-	-	
		(0.029)	-	-	-	-	-	

Notes: The sum of the lagged coefficients reported with respect to short-run changes in the independent variables. Probability values are in parentheses. F-stat is partial F-statistic. LM is the multiplier test for serial correlation. HE is White's heteroscedasticity test. Significance at the 1% level is denoted by "a".

In Eq. (4), commercial electricity consumption is statistically significant at 1% level in both short-run and long-run but relatively has a low rate of adjustment to long-run equilibrium. With respect to Eq. (5), economic growth has a statistically significant impact to commercial electricity consumption in the short-run but it is insignificant in the long-run. In terms of Eq. (6), public electricity consumption is significant in the short-run but not in the long-run; however, the feedback effect from economic growth to public electricity consumption as presented by Eq. (7) is statistically significant in both short-run and long-run with merely 2.5% rate of adjustment.

Regarding Eq. (8) and Eq. (9), both industrial electricity consumption and economic growth have a positive and statistically significant impact to each other in both short-run and long-run. In regards to industrial electricity to economic growth relationship, the rate of adjustment toward to equilibrium is about 4.5% and 12.5% in the feedback effect.

On the subject of Eq. (10), it is not surprising that the aggregate electricity consumption has a positive and statistically significant impact on economic growth in the short-run with rate of adjustment to long-run equilibrium is about 29.1%. In Eq.(11), economic growth has statistically significant impact aggregate electricity consumption in the short-run but it is insignificant in the long-run.

Finally, the short-run and long-run causality tests reveal several interesting results. First, there is bidirectional causality from electricity consumption and economic growth in the short-run. Second, the long-run equilibrium running from electricity consumption to economic growth exists in all models except for public electricity consumption. Third, the long-run equilibrium running from economic growth to electricity consumption only exists in public and industrial electricity consumption. Fourth, the government policy for power development in Aceh supports the feedback hypothesis. This implies that the future energy policies will not reducing electricity consumption because of its adverse impact on economic growth.

Conclusions and Recommendation

In this paper, the short-run and the long-run causality between electricity consumption and economic growth in Aceh are examined by employing sectoral data covering the period 1995-2031. Tests for unit roots, cointegration, and vector error-correction model are provided. In the midst of the key results, it is found there is long-run bidirectional relationship between, (1) public electricity consumption and economic growth and, (2) industrial electricity consumption and economic growth. The short-run bidirectional relationship exists between, (1) residential electricity consumption and economic growth, (2) commercial electricity consumption and economic growth, (3) public electricity consumption and economic growth, (4) industrial electricity consumption and economic growth and, (5) aggregate electricity consumption and economic growth.

The government policy for power development is purposed to maintain the bidirectional causality between economic growth and electricity consumption. To preserve the local economy, electricity generation capacity must increase in step of the estimated increase in electricity consumption.

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