

ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH: A CAUSALITY EVIDENCE FROM INDONESIA, 1984-2010¹

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ABSTRACT

The relationship between electricity consumption and GDP has become a primary topic and controversial issue in the US, Europe, and Asia, since 1970s. Indonesia is an excellent laboratory for testing which directions of causality between electricity consumption and GDP occur. One of the most striking issues is that generating electric capacity growth in Indonesia has lagged behind the pace of electricity demand growth, leading to power shortages and a low electrification ratio. Using modified Granger causality tests with Error Correction Model (ECM) to time series data within the period of 1984-2010, we examine the nature of the causal relationship between electricity consumption and economic growth. We found that there was a uni-directional short run relationship moving from electricity consumption per capita to GDP per capita for Indonesia. Our finding does support the finding of Chen, et al. (2006), whereas the causal relationship is uni-directional moving from electricity consumption to GDP. However, the finding of our study shows short run relationship, whilst the relationship found by Chen (2006) is long run. Our finding also challenges the finding of Yoo (2006) and Murry & Nan (1996) in which both findings show uni-directional relationship moving from economic growth to electricity consumption growth. Finally, the findings suggest that fundamental changes in electricity and regional development policies are required.

Keywords: Electricity Consumption, GDP, Granger Causality, ECM

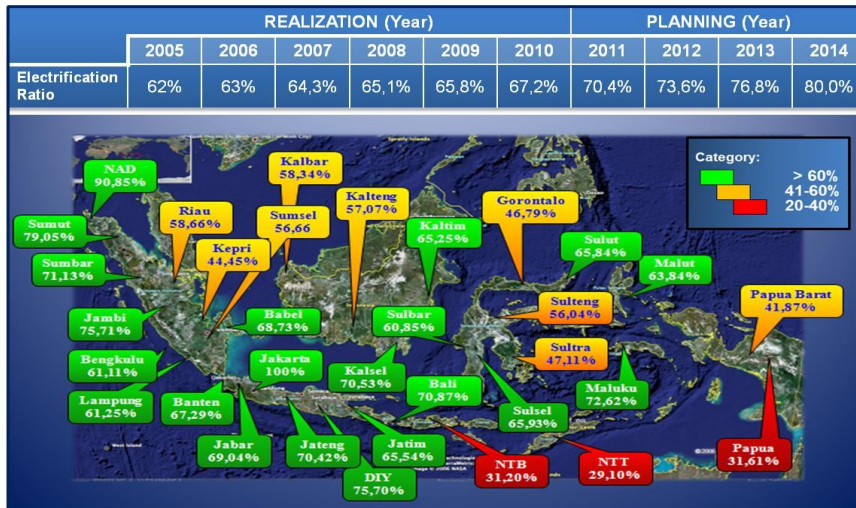
1. INTRODUCTION

The relationship between electricity consumption and economic growth has become a primary topic and controversial issue in the US, Europe, and Asia, since 1970s (e.g. Kraft & Kraft, 1978; Altinay & Karagol, 2005; Shiu & Lam, 2004; Jumbe, 2004; Yoo, 2005). The empirical studies found some controversial results with respect to the causal relationship between electricity consumption and economic growth that can be summarized into four types, as follows (Chen, et al. 2007): First, the uni-directional causality moving from electricity consumption to economic growth implies that restrictions on the use of electricity may affect economic growth adversely while increases in electricity supply may contribute to economic growth. Second, the uni-directional causality moving from economic growth to electricity consumption would suggest that a permanent increase in economic growth may result in a permanent increase in electricity consumption. Third, a bi-directional causal relationship implies that electricity consumption and economic growth are jointly determined and affected at the same time. Fourth, the absence of causal relationship implies that: (1) the electricity consumption is not correlated with economic growth; (2) neither conservative nor expansive policies related to electricity consumption have any effect on economic growth.

Indonesia is an excellent laboratory for testing which directions of causality between electricity consumption and economic growth occur. One of most striking issues is that generating electric capacity growth in Indonesia has lagged behind the pace of electricity demand growth, leading to power shortages and a low electrification ratio. Although Indonesia's generating capacity has increased by more than a quarter in the last decade, the country has a low electrification ratio compared to similar income countries. In 2013, around 76% of Indonesia's population had access to electricity. Indonesian Eastern Regions (Kawasan Timur Indonesia, KTI) have lagged behind the Indonesian Western Region (Kawasan Barat Indonesia, KBI), with some provinces only providing electricity to a third of the population (Figure 1).

¹ Earlier version of this paper has been presented at the Kuala Lumpur International Business, Economics, and Law Conference KLIBEL 2013, Kuala Lumpur Malaysia, 8-9 April 2013. I am grateful for the comments from the anonymous reviewers of KLIBEL 2013. Our appreciation also goes to our assistants, Fatkhu Ridho FEP, M. Irka Irfa'Darojat, and Raushanfikr Muthahhari.

Figure 1. Electricity Ratio By Province, Indonesia 2005-2014



Source: Ministry of Energy and Mineral Resource (MEMR) (2011)

US-EIA (2013) indicates two important features of electricity supply. First, state-owned electric utility company, PT PLN (Perusahaan Listrik Negara), is the most significant company in the electric power sector. PLN owns and operates about 90% of the country's generating capacity through its subsidiaries, and maintains an effective monopoly over distribution activities. Although the most recent 2009 Electricity Law has stated its objective to secure the sufficient availability of electricity with affordable price, however there is still lacks of sufficient regulations to enforce this law. Indonesia had an estimated 44 gigawatts (GW) of installed capacity in 2011 and generated 192 billion kilowatt-hours (kWh). In addition, 86% of the power came from conventional thermal sources, with the rest coming from hydroelectric (9 percent), geothermal (5 percent), and other renewable sources. Coal accounted for just over half of conventional thermal power.

The outline of this paper is as follows. First, it will highlight some surveys of literature on causality tests between electricity consumption and GDP. The relationship between electricity consumption and GDP in Indonesia has been examined by some previous studies (Murry & Nan, 1996; Yoo, 2006; Chen, *et al.*, 2006). Second, it will discuss briefly the data and methodology used in our study. Third, our analysis of the relationship between electricity consumption and economic growth in Indonesia will cover the causal relationship between national electricity consumption and Gross Development Product (GDP). Concluding remarks and policy implications are given in the final section.

2. LITERATURE REVIEW

The electricity Law No. 30 year 2009, in particular article 2.2, indicates that the essentially purpose of this law is to secure the availability of sufficient and good quality electric power with affordable price to increase the welfare of all Indonesian people (MEMR, 2011b). The PLN is a state owned company and mandated by the law to provide electricity service as a single operator. Essentially, the main objectives of the electricity law is to support the improvement of people's welfare and promote economic growth. In order to achieve these objectives, the government has prioritized to fulfill electricity demand of household and industrial sector (MEMR, 2010). In the last few years, the electrification ratio has increased significantly from 62% (2005) to 67.2% (2010). In 2014, it is projected to reach 80%. The supply of electricity for industry and business sectors is closely related to economic growth. On the other hand, the infrastructure development required to increase the electricity supply needs huge amount of investment. So far, the electricity policies and regulations has been focused more on the supply side, rather than serving the demand side.

The policy implementation are incorporated in some official documents, such as Energy Outlook 2008-2010, Annual State Budget and Expenditure Report (*Nota Keuangan & RAPBN*), and MP3EI. The general policy in energy sector (including electricity) is mostly supply and price oriented. The electricity price is driven by subsidy level, which is mostly aimed to control the inflation level.

The electricity consumption per annum is increasing rapidly in line with the increasing national economic growth and the changes of paradigm in the society to meet their day to day life style needs, especially in household and industrial sector (Table 1). The electricity demand during 2006-2010 had been increasing with average growth of 6.3% annually. While the electricity infrastructure development can only provide additional supply with an average growth of 4.4% in the same period.

Table 1. Electricity Consumption and Economic Growth, Indonesia 2000-2010

Year	Population		GDP perCapita		Economic Growth (%)	Electricity Consumption per Capita	
	Quantity	Annual Growth (%)	In Million Rp	Annual Growth (%)		kWh	Annual Growth (%)
2000	205,132.00	1.12	6.70	6.25	4.92	389	3.20
2001	208,900.60	1.84	7.20	7.46	3.64	405	4.11
2002	212,003.50	1.49	7.60	5.56	4.50	411	1.48
2003	215,152.38	1.49	8.30	9.21	4.78	420	2.19
2004	217,854.10	1.26	10.64	28.19	5.03	459	9.29
2005	220,553.07	1.24	12.45	17.01	5.69	485	5.66
2006	223,013.78	1.12	15.03	20.72	5.50	505	4.12
2007	225,642.50	1.18	17.60	17.10	6.35	579	14.65
2008	228,523.30	1.28	21.70	23.30	6.01	565	-2.42
2009	231,369.50	1.25	24.30	11.98	4.55	560	-0.88
2010	237,641.00	2.71	27.22	12.02	6.50	619	10.54
Average			14.44	5.22			4.72

Source: Compiled from BPS (2013); MEMR (2010b)

The disequilibrium between actual demand and the supply of electric power has created shortage of electricity supply in certain regions, especially those regions outside PLN interconnective region of Jawa-Madura-Bali. The 1998 economic crisis has slowed down the development of electricity infrastructure in Indonesia. During the period of economic recovery, the growth of the installed electric power capacity was only increased by the rate of 1.13% (MEMR, 2010b).

Electricity consumption of Indonesia increased from 112,609 *giga watt hour* (Gwh) in 2006 to 147,297 GWh in 2010, with average increase of 6.6%. Such increase of electricity consumption mainly is driven by the increase of consumption households and industrial sectors. Table 1 shows the trend of electricity consumption increase was not always followed by economic growth within the period of 2000–2010. This condition seems to be correlated with the finding of Yoo (2006) which argued that the consumption of electricity in Indonesia did not significantly impact the economic growth. This condition may be caused by the fact that the consumption of electricity in Indonesia are used more to meet the need of household sector, while less portion of electric power are allocated to fulfill the demand of industrial sector and other economic activities that can strongly stimulate the economic growth (see Table 2).

Table 2. Electricity Demand By Group of Users (Gwh), 2006-2010

Group of Users	Electric Power Consumption (Gwh)				
	2006	2007	2008	2009	2010
Household	43.754	47.324	50.184	54.945	59.825
Commercial	18.415	20.608	22.926	24.638	27.157
Industry	43.615	45.802	47.969	46.017	50.985
Others	6.825	7.510	7.940	8.607	9.330
Total	112.609	121.246	129.019	134.207	147.297

Source: MEMR (2010b)

Causality tests between electricity consumption and GDP in Indonesia have been examined earlier by Murry & Nan (1996) using 1970-1990 period and Yoo (2006) using 1971-2002 period (Table 3). Yoo (2006) used the standard Granger causality test and found uni-directional relationship moving from GDP to electricity consumption. This finding shows a conformity to the finding of Murry & Nan (1996).

In contrast to the finding of Yoo (2006) and Murry & Nan (1996), the causality test performed by Chen, *et al.* (2006) using Granger causality test and Error Correction Model (ECM) found a long run relationship moving from electricity consumption to economic growth (Table 3). These studies used single country data set for each country and also applied data panel for 10 selected countries in Asia.

Table 3. Previous Causality Tests Related to Electricity Consumption and GDP in Indonesia

Authors (Year)	Methodology	Time Period	Causal Relationship
Murry & Nan (1996)	Standard Granger causality test	1970–1990	Income → Electricity
Yoo (2006)	Standard Granger causality test	1971–2002	Income → Electricity
Chen (2006)	Granger Causality and Error Correction Model	1971-2001	Electricity → Income

Our study uses modified Granger causality test with ECM applied to time series data within the period of 1984-2010. This model is applied to find the nature of the causal relationship between electricity consumption and economic growth.

3. METHODOLOGY

3.1. Data

This study will use annual time series data for Indonesia as one single country data. The annual data for real GDP is obtained from Badan Pusat Statistik (BPS) and the annual data for electric power consumption is obtained from PLN. The data period

(1984-2010) is determined based on the availability of regional electricity consumption and regional income data. The real GDP is expressed in rupiah at constant price of year 2000 while the electric power consumption is expressed in unit of Kilowatt hours (KWh). The real GDP as well as National Electricity Consumption (NEC) are transformed into natural logarithms to reduce heteroscedasticity. The logarithm variables have its economic meaning since they are approximated to be viewed as the growth of the respective differenced variables. The unit roots, cointegration tests, Granger causality tests, and ECM model estimation are performed by Eviews 6.0.

3.2. Causality Test

This study will use Granger causality test and ECM including stationary and co-integration test. Prior to applying Granger causality test, it is imperative to ensure that time series data related to electricity consumption and economic growth are stationary. The stationarity test is done by applying unit roots tests to find out whether the two variables (NEC and GDP) are stationary at 0 level, first difference, or second difference. If both variables are not stationary at all level, then the result of the time series data regression will be spurious, which is indicated by time series data regression with a high R2 value but the regression coefficient is not significant (Gujarati, 2003).

In order to make sure the data of two variables are stationary, Augmented Dickey Fuller (1981) model is used to perform unit root tests. This model is as follows:

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \sum_{i=2}^p \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad (1)$$

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \alpha_2 t + \sum_{i=2}^p \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad (2)$$

whereas, y is the variable to be tested and t is the time trend. The first equation uses no time effect while the second one uses a fixed time effect. The lag length, i , are chosen using Akaike's Information Criterion (AIC). When the null hypothesis $H_0: \rho = 0$ is accepted, this implies that the variable has unit root and is not stationary. The first difference is thus taken to test for the stationarity of the data set before the Granger-causality test is implemented (Chen, *et al.*, 2006).

ADF model is applied to test the stationary using time fixed effects and no time effects methods. The time fixed effects methods with trend and intercept is used to find out at what level the data is stationary. Trend and intercept are to show the result of unit root test using Random Walk Model (RWM) which indicates the deterministic trend and the time shift. No time effects method is to show the result of unit root test without using trend and intercept, hence it does not indicate the time shift. The result of ADF test will be compared to McKinnon critical value at certain level (α) to find out if the data is stationary.

It is important to select the optimal lag to be applied in this model because if the lag used in this stationarity test is too small, then the residual of the regression will not show white noise process. At this point, the ADF model cannot estimate the error accurately. In the contrary, if the selection of lag is too big, it may reduce the capability to reject the null hypothesis (H_0), because if the parameter value is too big then it will reduce the degree of freedom (Harris, 1995: 65). The selection of optimal lag can lead to the most appropriate finding with uncorrelated residual.

ADF model applied in this study is to emphasize more on the consistency rather than efficiency. Therefore, the automatic selection method is performed using EViews 6.0 to determine the optimal lag by using the value of AIC as reference. The AIC value is used because it is more consistent compared to the value obtained using Schwarz Information Criteria (SIC) and Hannan-Quinn Information Criteria (HQIC) (Shatland, 2008).

Johansen cointegration test is applied to find out whether NEC and GDP has a long run relationship. The optimal lag for each corridor is selected based on each of its AIC value. If the NEC and GDP variables are stationary at the first difference, then both variables are most probably cointegrated, hence, Error Correction Terms is applied to perform modified ECM causality test to find out whether there is any long run causal relationship.

The relationship between electricity consumption and GDP will be examined by applying Granger causality test and ECM as has been performed by Chen (2006). These methods are used to show the relationship between electricity consumption (NEC) and economic growth (GDP) in Indonesia, as well as in each of those 6 economic corridors. The characteristic of the relationship includes: (1) Is there any uni-directional relationship moving from NEC to GDP?; (2) Is there any uni-directional relationship moving from GDP to NEC?; (3) Is there any bi-directional relationship between GDP and NEC?; (4) Is there no relationship at all between GDP and NEC? (5) Is the nature of the relationship (if any) of both variables show a long run or short run relationship. It is imperative to understand the characteristic of the relationship between electricity consumption and the economic growth since the nature of such relationship has different policy implication toward both sectoral related to electricity and regional policy. The result of this causality tests implies that the past events have impacted on the present events, not the future ones.

In the case NEC and GDP variables are not stationary, but become stationary after unit roots test at the first difference, and after further Johansen cointegration test both variables are not cointegrated, then standard Granger causality test is applied, as shown in the following equations:

$$\Delta NEC_t = \alpha_{10} + \sum_{i=1}^{q_{11}} \alpha_{11i} \Delta NEC_{t-i} + \sum_{j=1}^{q_{12}} \alpha_{12j} \Delta GDP_{t-j} + \mu_{1t} \quad (3)$$

$$\Delta GDP_t = \alpha_{20} + \sum_{i=1}^{q_{21}} \alpha_{21i} \Delta GDP_{t-i} + \sum_{j=1}^{q_{22}} \alpha_{22j} \Delta NEC_{t-j} + \mu_{2t} \quad (4)$$

If the Johansen cointegration shows that both variables are cointegrated, then modified ECM Granger causality test is applied by using Error Correction Term, as follows:

$$\Delta NEC_t = \alpha_{10} + \sum_{i=1}^{q_{11}} \alpha_{11i} \Delta NEC_{t-i} + \sum_{j=1}^{q_{12}} \alpha_{12j} \Delta GDP_{t-j} + \alpha_{13} \varepsilon_{t-1} + \mu_{1t} \quad (5)$$

$$\Delta GDP_t = \alpha_{20} + \sum_{i=1}^{q_{21}} \alpha_{21i} \Delta GDP_{t-i} + \sum_{j=1}^{q_{22}} \alpha_{22j} \Delta NEC_{t-j} + \alpha_{23} \varepsilon_{t-1} + \mu_{2t} \quad (6)$$

whereas, NEC is national electricity consumption and GDP is Gross Domestic Product in the form of natural logarithm, Δ is

difference operator, q is the lag, α is the parameter to be estimated, μ is serially uncorrected error term, and ε_{t-1} is error correction term which is obtained from cointegration test. In case the unit roots and the cointegration test show that the data is stationary and cointegrated, then modified ECM causality test is used.

Equations 3 and 4 show that ΔNEC has short run effects on ΔGDP if the estimated coefficient (α_{12s}) is statistically significant as shown by the value of statistic F . Equations 5 and 6 show the application of ECM by including the dependent variables with each

of its lag and the disequilibrium of the previous error correction term, ε_{t-1} . The long run causal relationship can be determined

by the level of significance of the coefficient (α_{13}) for error correction term based on t statistic test. By going through the same procedure as defined in equation 5, we can test the long run causal relationship from ΔGDP to ΔNEC (equation 6).

4. FINDINGS AND ANALYSIS

4.1. Unit Roots and Cointegration Tests

The result of ADF test using No Time Effects model shows that the NEC variable is not stationary at level as well as at first difference with significance of 5%. However, NEC variable becomes stationary at the first difference with significance of 5% if time fixed effects is applied. On the other hand, the ADF test using both No Time Effects and Time Effects model shows that the GDP variable is not stationary at level with significance of 5%, however, GDP variable becomes stationary at the first difference with significance of 5% (Table 4).

Table 4. Result of Unit Roots Test between NEC and GDP Variables in Indonesia, 1984-2010

Region	Variable	ADF							
		No Time Effects				Time Fixed Effects			
		Lag	Level	Lag	Δ	Lag	Level	Lag	Δ
Indonesia	NEC	1	1.54 (0.9664)	0	-1.59 (0.1025)	0	-0.98 (0.9291)	0	-4.34* (0.0106)
	GDP	0	1.93 (0.9846)	0	-4.17* (0.0002)	1	-3.35 (0.0800)	3	-3.64* (0.0491)

Notes: Δ denotes first differences. All variables are in natural logarithms; NEC and GDP in per capita; ADF = Augmented Dickey Fuller; * Means that the null of the unit root in the ADF tests is rejected; The lag lengths are selected using AIC; Number in parentheses are P -value

The result of stationary test using ADF model with time fixed effect as well as no time effects show that the data of NEC and GDP is stationary at the first difference, and therefore we can proceed with Johansen cointegration test. Table 5 shows the result of cointegration tests between NEC and GDP variables. This test shows that the trace statistic value and maximum Eigenvalue is smaller than the significance of 5%. This result shows no cointegration between NEC and GDP. In this case, we cannot proceed by applying ECM to find whether there is any long run relationship between the two variables. At this point, standard Granger causality test is applied to examine whether there is any short run relationship.

Table 5. Results of Cointegration Test between NEC and GDP Variable in Indonesia, 1984-2011

Region	Null Hypothesis	Lag	Johansen Test Statistic		Cointegration
			Trace	Max-eigen	
Indonesia	R=0	1	15.99982	15.1362	No
	R≤1		0.863584	0.863584	

Notes: NEC and GDP in per capita; r = the number of the vector cointegration; * means that the null hypothesis of no cointegration relationship is rejected at the 5% level; The optimal lag lengths are selected using Akaike's information criterion

4.2. Causality Tests

The results of Granger causality test for Indonesia is obtained by applying data within the period of 1984-2010 (Table 6). The result of F statistic shows the evidence of short run uni-directional relationship moving from economic growth per capita (ΔGDP per capita) to electric consumption growth per capita (ΔNEC per capita).

Table 6. Results of Causality Test between NEC and GDP Variable in Indonesia, 1984-2010

Region (1)	Null Hypothesis (2)	Sources of Causation				
		Short run (3)		Long run (4)	Joint (short run/long run) (5)	
		F-statistics		t-statistics	F-statistics	
		Δ NEC	Δ GDP	ε_{t-1}	Δ NEC, ε_{t-1}	Δ GDP, ε_{t-1}
Indonesia	Δ NEC does not cause Δ GDP	3.1785** (0.0884)		1.369681 (0.2988)	0.00388 (0.9509)	
	Δ GDP does not cause Δ NEC		1.51130 (0.2319)	1.065393 (0.1853)		0.10093 (0.7540)

Notes: NEC and GDP in per capita; The lag length are selected using Akaike's information criterion; * Means that the null hypothesis of no causation is rejected at the 5% level; ** Means that the null hypothesis of no causation is rejected at the 10% level; The number in parentheses are *P-value*.

The short run causal relationship between Δ NEC per capita and Δ GDP per capita can be seen at Table 6 column (3). The statistic F shows that the probability of Δ NEC per capita does not have any influence to Δ GDP per capita is only 0.0884 or smaller than the significance of 10%, therefore the null hypothesis which states that Δ NEC do not have any influence on Δ GDP is rejected. In the contrary, the probability of Δ GDP per capita does not influence Δ NEC per capita is 0.2319 or it is greater than significance of 10%. This finding shows that the growth of electricity consumption in Indonesia has influenced the growth of GDP. In other words, the findings shows that the electricity consumption in Indonesia tend to be demand driven.

Table 6 column (4) shows that the result of *t* statistic test does not prove any long run relationship both from electricity consumption growth per capita (Δ NEC per capita) to economic growth per capita (Δ GDP per capita) or from economic growth to electricity consumption growth. This is reflected by the insignificant *t*-value between those two variables.

The result of F statistic test does not show any joint short run/long run relationship moving from electricity consumption growth per capita to economic growth per capita. This F statistic test also does not show joint short/long run relationship from the opposite direction. The absence of joint short run/long run relationship, is shown by Table 6 column (5), whereas the result of F statistic test indicates that the probability of Δ NEC per capita does not influence the Δ GDP per capita is 0.9509 or it is greater than the significant level of 5%. This test also shows that the probability of Δ GDP per capita does not influence the Δ NEC per capita is 0.7540 or it is greater than the significant level of 5%.

The finding of causality test in this study does support the finding of Chen, et al. (2006), whereas the causal relationship is uni-directional moving from electricity consumption to GDP. However, the finding of this study shows short run relationship, whilst the relationship found by Chen (2006) is long run. On the other hand, the finding in this study challenges the finding of Yoo (2006) and Murry & Nan (1996) in which both findings show uni-directional relationship moving from economic growth to electricity consumption growth.

The finding in this study shows the presence of short term relationship moving from electricity consumption per capita to economic growth per capita. This finding suggests that in short run, the implementation of conservation policy by limiting electricity consumption may negatively impact the economic growth. Whilst the increase of electricity demand can lead to an increase the consumption level which will give positive contribution to the economic growth.

5. CONCLUSIONS

Using Granger causality tests and Error Correction Model (ECM), applied to the quantitative data within the period of 1984-2010, our empirical findings shows that there is uni-directional short run relationship moving from electricity consumption per capita to GDP per capita for Indonesia as a single country data set. Our finding does support the finding of Chen, et al. (2006), whereas the causal relationship is uni-directional moving from electricity consumption to GDP. However, the finding of our study shows short run relationship, whilst the relationship found by Chen (2006) is long run. Our finding also challenges the finding of Yoo (2006) and Murry & Nan (1996) in which both findings show uni-directional relationship moving from economic growth to electricity consumption growth.

The finding in this study shows the presence of short term relationship moving from electricity consumption per capita to economic growth per capita. This is proved by the results that there was no cointegration between NEC and GDP. In other words, there was not any long run relationship between the two variables. This is in line with F statistic of causality test that does not show any joint short/long run relationship moving from electricity consumption growth per capita to economic growth per capita. The last implies that electricity policy in Indonesia is short-sighted and ad-hoc, rather than has long-term perspective. This finding suggests that in short run, the implementation of conservation policy by limiting electricity consumption may negatively impact the economic growth. Whilst, the increase of electricity demand can lead to an increase the consumption level which will give positive contribution to the economic growth. Finally, the findings suggest that fundamental changes in electricity policy are required. The electricity policy in Indonesia need to be oriented more toward the condition of regional economic development.

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