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# The Dynamic Link of Electricity Consumption, Internet Access and Economic Growth in 33 Provinces of Indonesia

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## ABSTRACT

The dynamic causal relationship between electricity consumption, internet access, and economic growth has been widely studied in many countries both developed and developing countries. However, the debate about these issues continues due to the empirical finding results are mixed and have not reached a consensus. This study highlights the pattern of dynamic causal linkage between electricity consumption, internet access, and economic growth both in the short-term and long-run by employing PVECM, and panel DOLS. The type of data used is secondary data in the panel data set of 33 provinces of Indonesia during the period 2009-2018. All data were collected from the Central Bureau of Statistics of Indonesia (BPS) and the Ministry of Energy and Mineral Resources. The empirical finding of this study found strong evidence to support the long-run feedback hypothesis in the case of the energy-growth nexus, energy-ICT nexus, and ICT-growth nexus. The proponents of the feedback hypothesis argued that increasing energy consumption favorably affects ICT usage and economic growth acceleration, conversely, the acceleration of the high economic growth and the improvement of ICT require more energy consumption. Nevertheless, in the short-run, this study only found the empirical result to corroborate the neutrality hypothesis.

**Keywords:** Electricity, Internet, Economic Growth, Causality, PVECM, Panel DOLS

**JEL Classifications:** O33, O47, Q43

## 1. INTRODUCTION

In the last decade, the electricity sector in Indonesia has played a strategic role in economic development and contributed significantly as one of basic sector that provides the foundation for achieving goals development, such as accelerating Information and Communication Technology (ICT), creating opportunities for employment, increase national income, change the structure of the economy, and improve welfare of the people. Indonesia's electricity consumption continues to show improvement with increasing access to electricity and changes in people's lifestyles.

Based on Indonesia's Central Bureau of Statistics (BPS), in 2009, electricity consumption was 0.67 Megawatt-hour (MWh) per capita and then increased significantly in 2018 to 1.06 MWh per capita or grew by an average of 5.33% per year while household

access to electricity in 2009 was 67.15% then increased in 2018 to 98.30%. However, regarding equity and fulfillment of energy consumption, Indonesia's electricity consumption is still not evenly distributed to all regions, especially in some underdeveloped regions of eastern Indonesia. Currently, Indonesia's electricity consumption is still lagging behind Vietnam and Malaysia. On the other hand, adequate electricity supply is one of the supporting elements in accelerating economic growth which in the past 5 years has been able to achieve an average economic growth of 5% per year while household access to internet in Indonesia has increased from 11.59% in 2009 to 66.22% in 2018 (BPS, 2019).

In terms of the empirical study, since the initial empirical findings by Kraft and Kraft (1978) about the existence of energy-growth nexus, have attracted greater attention among economists, researchers, decision-makers and academic circles to conduct

more extensive research with accurate econometric analysis. These issues have been widely examined, both developed and developing countries, however, the debate about the energy-growth nexus continues due to the empirical finding results are mixed and have not reached a consensus might be caused by differences in methodologies, data type, country characteristic, and development policy. The center of the debate lies in the direction of causality, both in short-term and long-term relationships, as a consequence of this debate, some several views or hypotheses require testing and verification i.e. growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis.

In a review of the literature regarding energy-growth nexus, Payne (2010) found that 31.15% of the country studies support or corroborate the neutrality hypothesis, 27.87% corroborate the conservation hypothesis, 22.95% corroborate the growth hypothesis, and 18.03% support or corroborate the feedback hypothesis. Recently, several studies found that electricity consumption and economic growth only have a one-way causality (uni-directional causality) running from electricity consumption to economic growth which supports the energy-led growth hypothesis (Inani and Tripathi, 2017); (Wolde-Rufael, 2014); (Iyke, 2015); (Karanfil and Li, 2015). This hypothesis has been challenged by the empirical findings that have demonstrated the evidence of unidirectional causality running from economic growth to electricity usage, which support the conservation hypothesis (Salahuddin and Alam, 2015); (Adom, 2011); (Shaari et al., 2013).

The debate about energy-growth nexus has gained fresh prominence with many empirical findings that electricity consumption and economic growth have a feedback or bi-directional causal relationship (Kasperowicz, 2014); (Wolde-Rufael, 2014); Gurgul and Lach, 2012); (Hamdi et al., 2014); (Tang and Tan, 2013); (Cowan et al., 2014). In the framework of the feedback hypothesis, argue that an increase in electricity usage encourages accelerated economic growth and vice versa, accelerating economic activities requires adequate electricity consumption usage. Nevertheless, in the context of energy-growth nexus, the neutrality hypothesis also has argued that the electricity usage related policies have no effect or have no causal relationship towards the level of real output (economic growth) (Acaravci and Ozturk, 2010); (Cowan et al., 2014).

Furthermore, other researchers have highlighted the existence of energy-ICT nexus and ICT-growth connection. Salahuddin and Alam (2015); Afzal and Gow (2016) Sadorsky (2012) showed that internet access has a positive impact on electricity usage or in other words, there was an evidence of uni-directional causal linkage running from ICT to electricity usage which supports the existence of ICT-led energy hypothesis while Inani and Tripathi (2017) and Salahuddin and Gow (2016) support the ICT-led growth hypothesis.

This study aims to examine and analyze the pattern of dynamic relationship between electricity consumption, internet access, and economic growth both in the short-run and long-run for 33 provinces of Indonesia over the period 2009-2018.

The rest of this paper is organized as follows: Section 1 explains the introduction, section 2 summarizes and briefly explains the relevant literature review (see also Ozturk, 2010). The research methods in section 3 contain an explanation of data sources and variables measurement, testing data and stages of data analysis. Section 3 also contains the explanation of the PVECM and panel DOLS method. Section 4 explains the results and discussion. The final section (section 5) consists of a conclusion and recommendation.

## 2. LITERATURE REVIEW

Since the initial empirical findings by Kraft and Kraft (1978) about the existence of energy-growth nexus have attracted greater attention among economists, researchers, and decision-makers to conduct more extensive research with accurate econometric analysis.

The recent study of Inani and Tripathi (2017) employed ARDL approach to examine the relationship of ICT, economic performance, and electricity usage in India for the period 1991-2014. The main finding of their study demonstrated that electricity usage has a significant and positive impact on economic acceleration in the long-run and short-run, which corroborated the energy-led growth hypothesis.

Wolde-Rufael (2014) examined the dynamic causal linkage of electricity usage and economic growth in 15 transition economies for the period 1975-2010. The study used the quantitative approach namely bootstrap panel causality for allowing cross-sectional dependency and heterogeneity across countries. The empirical finding of the study concluded a one-way causation flowing from electricity usage to economic performance (unidirectional causality) only in Belarus and Bulgaria. The evidence of unidirectional causality was found in the case of the link from economic performance to electricity usage in Latvia, Czech Republic, Lithuania, and the Russian Federation while the evidence to support the feedback hypothesis was found in Ukraine. However, in Albania, Macedonia, Moldova, Poland, Romania, Serbia, Slovak Republic, and Slovenia did not find any evidence for the Granger causality direction. These results showed that there was not a great deal of support for the previous work in the field of electricity-led growth hypothesis.

Iyke (2015) highlighted the dynamic causal relationship between electricity usage and economic performance in Nigeria by employing a VECM approach, for the period 1971-2011. The results of this research show that there was a different causal link from electricity usage to economic performance both in the short-term and the long-term. This finding of these empirical results corroborated the electricity-led growth hypothesis that has been described in the literature.

Salahuddin and Alam (2015) highlighted the effects of internet usage and economic acceleration on electricity consumption both in the short and long-run using annual time series macro data for Australia for the period 1985-2012. The ARDL bounds test was employed for testing the existence of cointegration and

Granger causality test for examining the causal linkage among three variables. The empirical results demonstrated that Internet usage and economic performance positively affect electricity usage in Australia. Internet usage and economic performance did not have a significant effect on electricity consumption. In terms of the short-run relationship, application of multivariate Granger causality test confirmed the presence of unidirectional causal linkage flowing from Internet usage to economic performance and electricity consumption.

The Study of Shaari et al. (2013) examined the nexus between energy consumptions and economic performance in Malaysia by using Johansen co-integration test over the period 1980-2010. The findings of the empirical study found that energy usage was positively related to economic acceleration while oil and coal consumption did not Granger cause economic performance and vice versa. This study showed the evidence of unidirectional causality running from economic performance to electricity usage. A unidirectional linkage also exists between gas and economic performance, with causation running from electricity usage to economic performance.

Kasperowicz (2014) investigated the nexus between electricity usage and economic performance in Poland for the period 2000-2012. The empirical study result demonstrated the evidence of bi-directional causal linkage between electricity usage and economic performance in Poland, which supported the feedback causality hypothesis.

Cowan et al. (2014) studied in BRICS countries for highlighting the dynamic causal linkage between electricity usage, economic performance and CO<sub>2</sub> emissions over the period 1990-2010. This study employed a panel causality analysis for examining the causality and accounting for dependency and heterogeneity across countries. In terms of the electricity-economic growth connection, the most interesting finding was the presence of bi-directional causality which supported the feedback hypothesis for Russia. Another finding supported the conservation hypothesis for South Africa. However, in the case of Brazil, India, and China only corroborated the findings of the neutrality hypothesis.

Study of Tang and Tan (2013) in Malaysia over the period 1970-2009, reported that there was a short-run and long-run bi-directional causality relationship between electricity usage and economic performance while Gurgul and Lach (2012) conducted a study to examine the causal link between electricity usage and economic performance (GDP) in Poland using time-series data for the period 2000Q1-2009Q4. The findings of the study are: firstly, the feedback causal linkage between electricity usage and economic performance as well as between electricity usage and employment. Secondly, the existence of unidirectional causality running from industrial electricity usage to employment, thirdly, there was no direct causal link between industrial electricity usage and economic growth.

The study of Sadorsky (2012) applied the dynamic panel data to investigate the impact of information communication technology (ICT) on electricity usage in emerging economies. The study

provided several empirical results from dynamic panel showed that statistically, ICT has a positive and significant impact on electricity usage as well as mobile phones and the number of PCs towards electricity usage.

The hypotheses of this study are:

- H<sub>1</sub>: There is a short-run causal link between electricity consumption, internet access, and economic growth.
- H<sub>2</sub>: There is a long-run causal link between electricity usage, internet access, and economic growth.
- H<sub>3</sub>: Electricity consumption has a long-term significant effect and positively affects economic growth, and vice versa.
- H<sub>4</sub>: Internet access has a long-term significant effect and positively affects economic growth, and vice versa.
- H<sub>5</sub>: Internet access has a long-term significant effect and positively affects the electricity consumption and vice versa.

### 3. DATA AND METHODOLOGY

#### 3.1. Data and Variable Measurement

This study employed the secondary data in the panel data set of 33 provinces in Indonesia during the period 2009-2018. Using the panel-based tests enables us to focus on more than one province which would provide us more data and more stability in estimations. The secondary data was collected from the Central Bureau of Statistics of Indonesia (BPS) and Indonesia's Ministry of Natural Resources and Mineral. The research data in this study consists of 3 (three) variables, i.e.: (1) The natural logarithm of Gross Regional Domestic Product per capita (IDR million) used as a measure of Economic growth variable (EG), (2) Electricity consumption (EC), measured by the natural logarithm of electricity consumption per capita (KWh), (3) Internet access variable (IA), measured by the percentage of the number of population that access the internet (percent).

#### 3.2. Panel Unit Root Test

One of the main advantages of using panel unit root tests in panel data is providing more observations to increase variability and data information which will ultimately be able to produce more efficient estimates. The panel unit root test is applied to investigate the amount of the integration among study variables as well as the investigation of the stationarity properties of all variables used. The stationary data is the basic assumption of the time series data which tends to approach and fluctuate around the average value. A stationary data means the mean, variance, and autocorrelation structure unchanged or tends constantly over time. As a consequence, using non-stationary time series data of econometric models produces unreliable, and spurious results (biased estimator).

This study employs the various method of panel stationary tests i.e.: Levin, Lin and Chu t-test, ADF (Augmented Dickey-Fuller)-Fisher test and Philips-Perron (PP)-Fisher test (Amaluddin, 2019). These methods are the most important references of panel unit root tests that rely on cross-sectional independence. The unit root test by Levin et al. (2002) has a panel-based proposition based on the augmented dickey-fuller (ADF) test which examines the presence of homogeneity in the dynamics of the autoregressive coefficients.



Levin et al. (2002) in Baltagi (2005) used the panel data unit root test by considering the following ADF specifications:

$$DY_{it} = \alpha Y_{it-1} + \sum_{j=1}^p \beta_{it} DY_{it-j} + X_{it} \delta + \varepsilon_{it} \quad (1)$$

Where  $Y_{it}$  = Panel data.  $DY_{it}$  = Difference form of  $Y_{it}$ ,  $\alpha = p-1$ ,  $p_i$  = Number of lags adjusted for first difference.  $\varepsilon_{it}$  = Error term.

Im, Pesar, Shin (IPS) designed a panel data unit root test that combines the dimensions of the time series data with the cross-section dimension. This test was popularized by IPS and had a powerful property for investigating panel unit root especially used by researchers of economics to analyze the long-run relationships in panel data. However, to obtain more accurate and valid results requires a fewer amount of time observation.

### 3.3. Panel Cointegration Test

The cointegration test is used to check the long-run relationship between the variables used. The presence of a cointegration relationship indicates the existence of a causal connection between economic variables. Cointegration is a long-term relationship between variables examined involving the stationary data. However, the linear combination of variables enables us to produce a cointegration with the non-stationary data (Gujarati and Porter, 2009). However, all variables used (electricity consumption, internet access, and economic growth) require the same order or integrated in the same level (Amaluddin, 2019).

Pedroni (1999; 2004) introduced and popularize seven powerful statistic tests for investigating the cointegration with heterogeneity in panel data. Four statistics are based on within dimension including Panel parametric ADF-statistic, Panel non-parametric PP-Statistic, Panel rho, and Panel v-Statistic while three others are based on between dimension namely group ADF-Statistic, group PP-Statistic, and group rho-Statistic panel (Neal, 2014).

$$Y_{it} = \alpha_i + \delta_{it} + \beta_{1i} x_{1it} + \dots + \beta_{Mi} x_{Mit} + e_{it} \quad (2)$$

$$\Delta Y_{it} = \Delta \beta_{1i} x_{1it} + \dots + \Delta \beta_{Mi} x_{Mit} + e_{it} + \eta_{it} \quad (3)$$

$$\hat{e}_{it} = \hat{\gamma}_{1i} \hat{e}_{it-1} + \hat{u}_{it} \quad (4)$$

$$\hat{e}_{it} = \hat{\gamma}_{1i} \hat{e}_{it-1} + \sum_{k=1}^k \gamma_{ik} \Delta \hat{e}_{it-k} + u_{it} \quad (5)$$

Kao (1999) in Baltagi (2005) proposed two powerful cointegration tests under the null hypothesis of no cointegration. One of the two tests is based on dickey-fuller type test (df) and another one is based on the augmented dickey-fuller type test (ADF). The ADF panel cointegration test is assumed to be homogeneous. The estimated residual ( $\varepsilon_{it}$ ) from the following panel regression specification:

$$y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it} \quad (6)$$

The Kao test is based on a version of the ADF test on the residual ( $\varepsilon_{it}$ ) of the auxiliary regression  $\varepsilon_{it} = \rho \varepsilon_{it-1} + v_{it}$ , or on the augmented version of the pooled specification can be written as:

$$\varepsilon_{it} = \rho \varepsilon_{it-1} + \sum_{j=1}^p \lambda_j \Delta \varepsilon_{it-j} + v_{it} \quad (7)$$

Since the ADF test is applied to the estimated residual: Where  $p$  is chosen, the residual  $v_{it}$  contains the serially uncorrelated. The ADF test statistic is the usual t-statistic in the previous equation. The null hypothesis of no cointegration at the ADF test statistics can be written as:

$$ADF = \frac{t_{ADF} + \left( \frac{\sqrt{6N\hat{\sigma}_v}}{2\hat{\sigma}_{0v}} \right)}{\sqrt{\left( \frac{\hat{\sigma}_{0v}^2}{2\hat{\sigma}_v^2} + (10\hat{\sigma}_{0v}^2) \right)}} \quad (8)$$

Where  $\hat{\sigma}_v^2 = \sum_{\mu\epsilon} - \sum_{\mu\epsilon} \sum_{\epsilon}^1 \hat{\sigma}_{\mu\epsilon}^2 = \Omega \mu \epsilon - \Omega \mu \epsilon \Omega^{-1} \epsilon \Omega$  is the long-run covariance matrix and  $t_{ADF}$  is the t-statistic of the ADF regression. The ADF test for cointegration converges to a standard normal distribution  $N$ . The t-statistic of the Kao panel data cointegration test (ADF) compared with the t-statistic (the Probability value). The statistical value is greater than the critical value or the probability value is  $<0.05$ , indicating that the null hypothesis is rejected (the presence of cointegration).

### 3.4. Panel Vector Error Correction Model

One of the quantitative methods widely used in previous studies for investigating the economic causality is Panel Vector Error Correction Model (PVECM) (Amaluddin, 2019). Application of PVECM enables us to examine the dynamic causal linkage between electricity consumption, internet access, and economic growth as well as the direction of the causal relationship between electricity consumption, internet access, and economic growth both in the short and long-run.

PVECM is an econometric model that applied for the dynamic nature for the panel data under consideration. It is designed as the development of the time-series VAR/VECM and panel data approach which treats all the variables as endogenous and accommodating for the non-stationary data to produce to the parameter and specify the existence of cointegration (Zaki et al., 2019). In addition, the PVECM specification treats the long-run behaviour of the endogenous variables to converge to their cointegrated relationships through the equilibrium adjustment process, while simultaneously accommodating for the short-run dynamics as well (Zaki et al., 2019).

This paper uses the panel-based error correction model (PVECM). PVECM requires the variables are integrated of the same order and the presence of cointegration. This requirement distinguishes it from the VAR and ARDL approaches. The determination of a cointegration relationship (cointegrated vector) indicates the presence of a long-term behaviour and capture the causality relationship (Rachev et al., 2007), Gujarati and Porter, 2009; Ekananda, 2019).

PVECM treats the three variables examined (ELC, IAC, and EGR as endogenous variables involving the lag value of each variable

and ECT on the right-hand side of the equation. The specification of Panel VECM model can be written as follows:

$$\Delta IAC_{it} = \alpha_2 + \sum_{i=1}^p \beta_{21} IAC_{it-1} + \sum_{i=1}^q \beta_{22} \Delta ELC_{it-1} + \sum_{i=1}^r \beta_{23} EGR_{it-1} + \lambda_1 ECT_{it-1} + \mu_{2it} \quad (9a)$$

$$\Delta EGR_{it} = \alpha_3 + \sum_{i=1}^p \beta_{31} \Delta EGR_{it-1} + \sum_{i=1}^q \beta_{32} \Delta ELC_{it-1} + \sum_{i=1}^r \beta_{33} IAC_{it-1} + \lambda_2 ECT_{it-1} + \mu_{3it} \quad (9b)$$

$$\Delta ELC_{it} = \alpha_1 + \sum_{i=1}^p \beta_{11} \Delta ELC_{it-1} + \sum_{i=1}^q \beta_{12} \Delta IAC_{it-1} + \sum_{i=1}^r \beta_{13} EGR_{it-1} + \lambda_3 ECT_{it-1} + \mu_{1it} \quad (9c)$$

Where *ELC* is the electricity consumption variable, measured by the natural logarithm of electricity consumption per capita (Kwh). *IAC* is the internet access variable, measured by the natural logarithm of household access to the internet (percent) and *EGR* is an economic growth variable, measured by the natural logarithm of product domestic regional bruto (PDRB) per capita (thousand IDR).  $ECT_{it-1}$  is the estimated lagged error correction term derived from the long-run cointegrating relationship of equation (1),  $t$  is time (the year 2009-2018) and  $i$  is cross-section data (33 provinces of Indonesia). The *ECT* coefficients also mirror the speed of adjustment of the  $i$ th endogenous variable in the long-run equilibrium and contains information about the long-term relationship (Asteriou and Hall, 2011; Ekananda, 2019).

The coefficient of *ECT* ( $\lambda_1, \lambda_2, \lambda_3$ ) are expected to  $-1 < ECT \leq 0$  or expected to  $0 \leq ECT < 1$  (Asteriou and Hall, 2011). *ECT* in equation (9a) is expressed as  $ECT_{it} = ELC_{it} - \beta_0 - \beta_{12} IAC_{it} - \beta_{13} EGR_{it}$ .

### 3.5. Vector Error Correction Granger Causality/Wald Test

The lags of PVECM provide information of the dynamic short-run causality link. In the framework of PVECM, the VEC Granger causality test/Wald test is used to check the short-run causality nexus among three variables. The Wald test estimates a test statistic based on the unrestricted regression. The standard Wald statistic has an asymptotic  $\chi^2$  distribution under the regularity condition that the covariance matrix of the vector of restrictions is non-singular under the null hypothesis and the Granger non-causality is characterized by zero restriction on the panel VECM coefficient.

### 3.6. Dynamic Ordinary Least Squares (DOLS)

The use of the OLS method for estimating the long-run equation in the co-integrated panel data set can cause a biased estimator of the parameters unless the regressors are exactly exogenous. Thus, the OLS estimation technique is unable to produce a valid estimation. For this reason, Philips and Hanson (1990) in Kao and Chiang (2000) proposed a dynamic OLS (DOLS) method to estimate the long-run cointegration in non-stationary panel which considered

to have power for removing the endogeneity and serial correlation of the standard ordinary least squared (OLS).

Starting to estimate DOLS, let us take the following fixed effect panel regression:

$$z_{it} = \alpha_i + g_{it} \beta + \mu_{it} \quad i=1, N \quad t=1, \dots, T \quad (10)$$

Where  $\beta$  is a vector of slope ( $k, 1$ ) dimension,  $z_{it}$  represents the matrix (1,1),  $\mu_{it}$  denotes the stationary disturbance term and  $\alpha_i$  represents the individual fixed effect. It is presumed that  $g_{it}$  ( $k, 1$ ) vector is the integrated schemes of order one for all  $i$ , where:

$$g_{it} = g_{it-1} + \varepsilon_{it} \quad (11)$$

The specification of equation (10-11) demonstrates a structure of cointegration regression, i.e.  $z_{it}$  is co-integrated with  $g_{it}$ . In the context of investigating the limited distribution of DOLS estimators of cointegrated regressions. The study of Kao and Chiang (2000) found that it is asymptotically normal. DOLS estimator is quite useful and powerful for correcting the endogeneity and autocorrelation. The DOLS model uses parametric correction to the errors including future and past values of first differenced regressors for obtaining an impartial estimator of long-run parameters. Following equation can be used for obtaining the DOLS estimators:

$$\lambda DOLS = \sum_{i=1}^N \left( \sum_{t=1}^T P_{it} P_{it} \right)^{-1} \left( \sum_{t=1}^T P_{it} y_{it} \right) \quad (12)$$

Where  $P_{it} = [x_{it} - \Delta x_{it}, -q, \dots, \Delta x_{it}, q]$  is  $2(q+1) * 1$  regressor's vector.

For computing the pooled DOLS estimator in heterogeneity panel data. This study employs the pooled (weighted) estimation accounts for heterogeneity by using cross-section specific estimates of the conditional long-run residual variances to reweight the moments for each cross-section thus, enables us to produce the unbiased estimator.

## 4. RESULT AND DISCUSSION

### 4.1. Data Description

Table 1 displays an overview of the panel data statistic including the average (mean), median, maximum-minimum, skewness, kurtosis, Jarque-Bera, Jarque-Bera probability, and total observations of three data/variables. Data of electricity consumption and economic growth which is measured by product domestic regional bruto (PDRB) per capita were converted or transformed into a natural logarithm. The mean of electricity consumption (ELC), internet access (IAC), and economic growth (EGR) is 6.11, 3.39 and 10.27 respectively. The number of cross-section units is 33 provinces of Indonesia and the total time-series data is 10 years (2009-2018) so that a total of 330-panel data observations are obtained.

Table 1 also provides information that three variables are not normally distributed which indicated by the Jarque-Bera indicator

is statistically significant at an alpha of 1%, hints the possibility of outliers in the panel data. In terms of normality tests, three variables indicate leptokurtic (with a kurtosis of more than three). The Jarque-Bera statistic estimates the difference of the skewness and kurtosis of the data-series with those from the normal distribution.

Table 2 presents the Pearson correlation which indicating the correlation matrix of the three variables used in this study. As expected, the correlation internet access (IAC) and economic growth (EGR) towards electricity consumption variable (ELC) demonstrate the negative correlation coefficients of 0.605 and 0.651, respectively. Furthermore, the correlation coefficient between internet access (IAC) and economic growth variable (EGR) is 0.42. This suggests that IAC (internet access) and economic growth variable (EGR) in this observation move in the same direction or are positively correlated.

## 4.2. The Result of Panel Unit Root Test and Panel Cointegration Test

The application of panel VECM as one of the econometric model enables us to obtain important information regarding the causal link of electricity consumption, internet access, and economic growth both in the short-run and long-run. The first stage of using PVECM analysis is testing stationary (unit root test) of three variables. The three variables should be integrated in the same order dan have a cointegration relation as required by PVECM model. Concerning the stationary test (unit root test), this study

employs the powerful methods of Levin, Lin and Chu (LLC), im, pesaran and shin (IPS), augmented dickey-fuller (ADF)-fisher, and philip-perron (PP)-fisher.

Table 3 displays the results of panel unit root test to check the non-stationary and amount of variables integration in panel data by using the powerful methods namely Levin, Lin and Chu-Fisher denoted LLC, Im, Pesaran, Shin method (IPS), Augmented Dickey Fuller-Fisher and Philips Perron-Fisher. As shown in Table 3, testing data in level demonstrates that three variables tested (ELC, IAC, EGR) are not stationary or fail to reject the null hypothesis (there is unit root), thus, the differencing process is one of econometric method to make data stationary. In the first difference, all variables tested are significant at alpha 1% ( $P < 0.01$ ) or reject the null hypothesis indicate that all first difference variables are stationary or have no unit root. In other words, all variables are integrated in the same order, I(1).

As explained in the previous stationary test that all variables are integrated of order 1. The second step is testing cointegration with the purpose to investigate the presence of a long-term relationship between variables in the model by applying the Pedroni and Kao residual cointegration test shown in Table 4. Lag 2 is selected as an optimal lag with considers the Akaike information criterion (AIC) and Schwarz criterion (SIC).

Table 4 displays Pedroni and Kao residual cointegration tests. The result of Pedroni residual cointegration test shows that the three variables tested have cointegration which indicated by significant four-statistic indicator of Pedroni at alpha 1%. The consistent cointegration test also demonstrated by Kao cointegration test which supports the presence of cointegration which indicating the long-term relation of three variables.

## 4.3. Panel Vector Error Correction Model and Wald Test

The third step is estimating panel vector error correction model (PVECM) to acquire essential information concerning the dynamic pattern of the causal link between electricity consumption (ELC), internet access (IAC), and economic growth (EGR) both in the short and long-run.

Based on the PVECM estimation results summarized in Table 5, provides some expected information that the ECT (error correction term) coefficients are negative and show significant statistically at alpha 1% for three dependent variables (ELC, IAC, EGR) or there would be speed of adjustment process towards the long-term equilibrium.

The significant ECT in the framework of panel VECM indicates the presence of long-term two-way linkage (bi-directional/feedback)

**Table 1: Description of data**

Indicators	ELC	IAC	EGR
Mean	6.110	3.389	10.273
Median	6.095	3.462	10.175
Maximum	8.312	4.489	12.019
Minimum	4.417	1.423	9.112
SD	0.670	0.613	0.565
Skewness	0.573	-0.712	1.058
Kurtosis	4.230	3.167	4.174
Jarque-Bera	38.857	28.267	80.523
Probability	0.000	0.000	0.000
Sum	2016.153	123.662	3390.248
Observation	330	330	330

All variables were transformed into natural logarithm

**Table 2: Correlation matrix**

Variable	ELC	IAC	EGR
ELC	1.000	0.605	0.651
IAC	0.605	1.000	0.422
EGR	0.651	0.422	1.000

Source: Data processed

**Table 3: Panel unit root test**

Panel unit root test types	Variables in level			Variables in first difference		
	ELC	IAC	EGR	ELC	IAC	EGR
LLC	0.940 (0.826)	-0.452 (0.326)	0.312 (0.623)	-8.418 (0.000)*	-33.997 (0.000)*	-29.648 (0.000)*
IPS	-1.432 (0.076)***	17.553 (1.000)	0.518 (0.698)	-12.524 (0.000)*	-3.279 (0.000)*	-4.234 (0.000)*
ADF-Fisher	34.048 (0.9996)	50.964 (0.914)	32.968 (0.999)	211.945 (0.000)*	509.199 (0.000)*	403.921 (0.000)*
PP-Fisher	37.974 (0.998)	51.257 (0.909)	35.318 (0.999)	278.093 (0.000)*	231.164 (0.000)*	416.903 (0.000)*

causal link flowing from all independent variables to dependent variables (ELC, IAC, EGR).

Table 5 also presents the ECT coefficients indicating the speed of the adjustment process or the correction process for equilibrium adjustments in the short-run towards the long-run equilibrium. The speed of adjustment towards the long-run equilibrium from electricity consumption (ELC) and internet access (IAC) to economic growth variable (EGR) is 4.01%, meanwhile, the speed of adjustment from economic growth (EGR) and internet access (IAC) to electricity consumption variable (ELC) is 2.2%. Additionally, when IAC treats as the dependent variable, the highest ECT of 3.591 is obtained that indicates the process of correction from the short-run toward long-run equilibrium or the speed adjustment toward the long-run equilibrium of 35.91%. Although the result of PVECM shows that coefficient ECT for all dependent variables are significant (reject the null hypothesis), indicating there is long-term causality, these results require further confirmation with the DOLS methods so that a valid and more accurate estimation result can be obtained.

Basically, the lags of PVECM provide information about the dynamic short-run causality linkage. The next procedure is testing the short-run causal link using the Wald test/VEC Granger causality test as set out in Table 6.

Table 6 demonstrates the statistic summary of the framework of the Wald test/VEC Granger causality test which indicating a short-run causal link. The Chi-square statistic for all independent variables are insignificant or fail to reject the null-hypothesis, indicated by the probability value (P-value) > alpha of 1%, 5% and 10%. Thus, the results of this test empirically cannot provide any evidence of the short-run relationship in the case of energy-growth nexus, energy-ICT nexus, and ICT-growth nexus.

#### 4.4. Panel Long-run Coefficient

The use of the OLS method for estimating the long-run equation in the cointegrated panel data set can cause a biased estimator of the parameters unless the regressors are exactly exogenous. Thus, the OLS estimation technique is unable to produce a valid estimation. For this reason, Philips and Hanson (1990) in Kao and Chiang (2000) proposed a Dynamic OLS (DOLS) method to estimate the long-run cointegration in non-stationary panel which considered to have power for removing the endogeneity and serial correlation in OLS.

Table 7 presents the statistic summary of the long-run DOLS coefficient. The estimation of DOLS for three equations has the expected sign and consistent with several previous studies. In detail, these empirical results explain the existence of the long-run feedback causality linkage between electricity consumption (ELC), internet access (IAC) and economic growth (EGR). The electricity consumption (ELC) and internet access variable (IAC) have the significant long-term effect and positively affects economic growth at the significance level of 1% with the coefficient regression of 0.045 and 0.221, interpreted that a 1% increase of electricity usage and internet access would enhance economic growth by 0.05% and 0.22%, respectively. Conversely, the long-term effect of economic

**Table 4: Panel cointegration test**

Pedroni cointegration test (ELC as dependent variable)		
Indicator	t-statistic	Probability
Within-dimension		
Panel v-statistic	-3.578	0.998
Panel rho-statistic	0.948	0.828
Panel PP-statistic	-11.035	0.000
Panel ADF-statistic	-8.439	0.000
Between-dimension		
Group rho-statistic	3.494	0.999
Group PP-statistic	-9.106	0.000
Group ADF-statistic	-4.392	0.000
Kao residual cointegration test (ELC as dependent variable)		
Indicator	t-statistic	Probability
ADF	-8.202	0.000

Source: Data processed

**Table 5: Panel VECM estimation results**

Independent variables	Dependent variables		
	ΔELC	ΔIAC	ΔEGR
Long-run coefficient			
ECT	-0.030*	-0.036*	-0.004*
Short-run coefficient			
ΔELC(-1)		0.014	-0.001
ΔELC(-2)		0.009	-0.006
ΔIAC(-1)	-0.002		0.013***
ΔIAC(-2)	0.024		0.006
ΔEGR(-1)	0.979	-0.183	
ΔEGR(-2)	-0.371	0.279	

Source: Data processed. \*, \*\*, \*\*\*Significant at alpha 1%, 5%, 10%

**Table 6: Wald test/VEC Granger causality test**

Dependent variable	Independent variable	Chi-square	Df	P-value
ELC	IAC	0.225	2	0.894
	EGR	1.468	2	0.480
IAC	ELC	0.702	2	0.704
	EGR	1.731	2	0.421
EGR	ELC	0.799	2	0.670
	IAC	3.042	2	0.219

Source: Data processed

**Table 7: Panel DOLS estimation**

Dependent variable	Independent Variable	DOLS		Expected sign
		Coefficient	t-stat.	
ELC	IAC	0.282	12.878*	+
	EGR	0.315	3.360*	+
IAC	ELC	0.251	3.361*	+
	EGR	2.847	23.116*	+
EGR	ELC	0.045	3.657*	+
	IAC	0.221	34.450*	+

Source: Data processed. \*, \*\*, \*\*\*Significant at  $\alpha = 1\%$ , 5%, 10%

growth on electricity consumption and internet access yield the regression coefficient of 0.315 and 2.847, interpreted as a 1% increase of economic growth would boost electricity consumption and internet access by 0.31% and 2.85%, respectively.

Furthermore, Table 7 also demonstrates the long-run bidirectional causal relationship between electricity consumption (ELC) and the internet access variable (IAC). The electricity consumption



variable (ELC) has a significant long-term impact and positively related to internet access (IAC) at the significance level ( $\alpha$ ) of 1%, with the coefficient regression of 0.251, interpreted that a 1% increase of electricity consumption would enhance internet access by 0.25%. Conversely, as expected, internet access has a significant long-term effect and positively related to electricity consumption at the significance level ( $\alpha$ ) of 1%, with the coefficient regression of 0.282, interpreted as an increase in internet access of 1% would boost electricity consumption by 0.28%, respectively.

#### 4.5. Discussion

In terms of empirical study in 33 province of Indonesia using PVECM and Wald test/VEC Granger causality did not find any evidence of the short-run relationship in the case of energy-growth nexus, energy-ICT nexus, and ICT-growth nexus, indicated by all independent variables are insignificant or fail to reject the null-hypothesis of H1 at  $\alpha$  of 1%, 5%, and 10%. The conclusions of energy-growth nexus in the short-run are consistent with the neo-classical argument that energy has no impact on output growth. Regarding the empirical study in the field of energy-growth nexus and ICT-growth nexus, the short-run empirical findings of this research were consistent with the study of Salahuddin and Alam (2015), Acaravci and Ozturk (2010) and Cowan et al. (2014). The proponents of the neutrality hypothesis argued that electricity usage has no impact or relation on the level of real output in the short and long-run.

As regards of long-run linkage in the framework of ECT and panel DOLS, this study could not reject the alternative hypothesis of  $H_2$ ,  $H_3$ ,  $H_4$  and  $H_5$  which found strong evidence to support the feedback hypothesis for the case of energy-growth nexus, ICT-growth nexus and energy-ICT nexus. The feedback hypothesis argues that increasing energy consumption adversely affects ICT usage and economic growth acceleration, conversely, the achievement of the high economic growth and the improvement of ICT require more energy consumption. The strong evidence of feedback causality link indicated by the significant ECT, and DOLS coefficients, which corroborated several previous studies. For instance, study of Cowan et al. (2014) supported the evidence of the long-run feedback hypothesis for Russia as well as Tang and Tan (2013) concluded that electricity consumption and its determinants were cointegrated, then, the empirical result revealed that electricity consumption and economic growth Granger-cause each other both in the short and long run. In terms of energy-ICT nexus, the findings of this study were in line with the study of Afzal and Gow (2016) and Rahimi and Alavi Rad (2017).

## 5. CONCLUSIONS AND RECOMMENDATIONS

This study attempt to highlight the pattern of dynamic linkage between electricity consumption, internet access, and economic growth in 33 provinces of Indonesia by using VECM and DOLS. This empirical study found strong evidence to support the short-run neutrality hypothesis regarding the energy-growth nexus, energy-ICT nexus, and ICT-growth nexus. In the long-run, there was a two-way relationship (bi-directional/feedback causality) between

electricity usage and economic growth, the long-run feedback causality between internet access and economic growth as well as the long-run feedback causality linkage between electricity usage and internet access. Thus, in the case of energy-growth nexus, ICT-growth nexus and energy-ICT nexus, the empirical findings of this study supported the feedback hypothesis which argued that increasing energy consumption favorably affects ICT usage and economic growth acceleration, conversely, the acceleration of the high economic growth and the improvement of ICT require more energy consumption. However, in the short-run, only find the evidence to support the neutrality hypothesis.

This study recommends greater attention to improving the infrastructure and electricity-internet access evenly throughout the Indonesian provinces, which in turn can simultaneously accelerate the long-term sustainable economic growth.

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