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Electricity generation and economic growth in Indonesia

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Abstract

To cope with the increasing electricity demand and to overcome the supply shortage of electricity, it is imminent that investments be made on the electricity generation sector on a large scale in Indonesia. This paper attempts to investigate the causal relationship between electricity generation and economic growth in Indonesia, using time-series techniques for the period of 1971–2002. The results indicate that there is a uni-directional causality running from economic growth to electricity generation without any feedback effect. Thus, economic growth stimulates further electricity generation, and policies for reducing electricity generation can be initiated without deteriorating economic side effects in Indonesia.

Keywords: Electricity generation; Economic growth; Causality; Indonesia

1. Introduction

In the past two decades, numerous studies have been conducted to examine the relationship between electricity consumption and economic growth. The overall findings show that there is a strong relationship between electricity consumption and economic growth [1]. In addition, there is a number of evidence supporting the bi-directional or uni-directional causality between electricity consumption and economic growth [2–5].

However, the causal relationship between electricity generation and economic growth has been rarely investigated in the literature. The relationship may very well run from electricity generation to economic growth, and/or from economic growth to electricity generation. These causality issues, therefore, suggest the need to carry out a more in-depth investigation. A major question concerning this issue is which variable should take precedence over the other—is electricity generation a stimulus for economic growth or does economic growth lead to an increase in electricity generation?

Evidence on either side shall have a significant bearing upon policy. If, for example, there is uni-directional causality running from electricity generation to economic growth, reducing electricity generation could lead to a fall in economic growth. On the other hand, if a uni-directional causality runs from economic growth to electricity generation, it could imply that policies for reducing electricity generation may be implemented with

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little or no adverse effects on economic growth. Lastly, no causality in either direction would indicate that policies for increasing electricity generation do not affect economic growth.

Public policy makers in Indonesia have shown a great deal of interest in the role that electricity generation plays in economic growth. The electricity infrastructure of the country is becoming an increasingly important component of the economy. According to the Association of South East Asian Nations (ASEAN) Center for Energy, energy consumption in ASEAN countries is estimated to increase from 280 million tons of oil equivalent (MTOE) in 2000 to about 583 MTOE by 2020. Thus, the ASEAN countries need as much as 323 billion US dollars in investments to be injected into the electricity sector from 2001 to 2020 to sustain economic growth. Among the 10 member countries of the ASEAN, the most investment will need to be injected into Indonesia.

As it is generally known, electricity enhances the productivity of capital, labor, and various other factors of production. In addition, greater use of information and communications technologies is causing worldwide transition toward a digital society that may require further electricity generation [6]. To proactively cope with increasing electricity demand accompanying economic growth, it is imminent that Indonesia endeavor to uncover the causal relationship between electricity generation and economic growth and to develop appropriate electricity generation policy. This task is currently one of the most important issues that Indonesian government must resolve [7–8].

The purpose of this paper is, therefore, to investigate causality between electricity generation and economic growth, and to find out the policy implications from the results. To this end, the following procedures are undertaken. First, stationarity and co-integration are tested; second, error-correction models are estimated if co-integration is detected and the standard Granger causality method is performed otherwise; finally, the *F*-test is performed to gauge the joint significance levels of causality between electricity generation and economic growth.

The remainder of the paper is organized as follows. Section 2 briefly explains the current status of electricity generation in Indonesia. An overview of the methodology adopted here is presented in Section 3. The penultimate section describes the data employed and reports the empirical findings. Some concluding remarks are made in the final section.

2. Current status of electricity generation in Indonesia

Fig. 1 describes electricity generation and consumption, and real gross domestic product (GDP) over the period from 1971 to 2002. It can be seen from this figure that the amount of electricity generated has been gradually increasing. It should be noted that Indonesia suffered from drastic economic depression during the period from 1998 to 1999 because of the 1997/98 Asian financial crisis. The International Monetary Fund

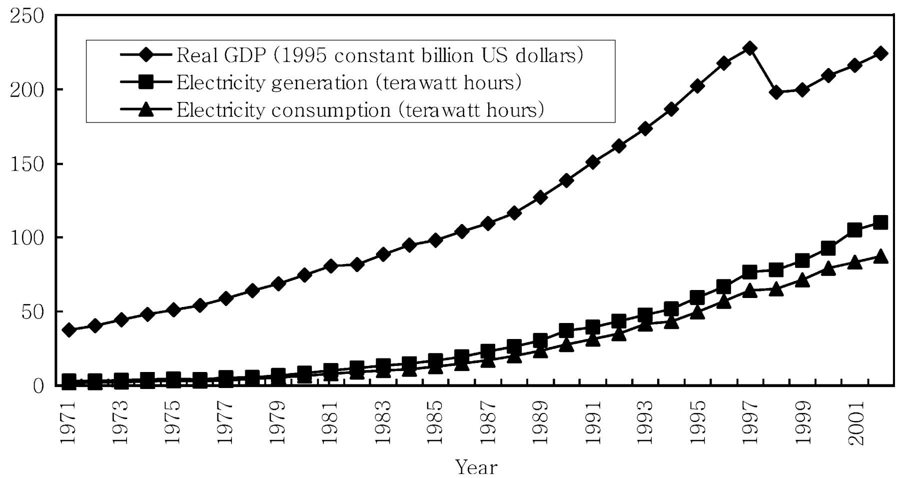

Fig. 1. Real GDP, and electricity generation and consumption for Indonesia.

assistance program designed to pull Indonesian economy out of its crisis situation ended in 2003. Thus, the economy is expected to grow continuously in the future and the economic growth requires further electricity generation.

The Energy Information Administration [9] provides a good overview of the current status of electricity generation in Indonesia. Indonesia has installed electrical-generating capacity estimated at 21.4 GW, with 87.0% generated from thermal (oil, gas, and coal), 10.5% from hydropower, and 2.5% from geothermal sources. Prior to the Asian financial crisis, Indonesia initially planned to dramatically expand electricity generation within the nation, mainly by opening up Indonesia's electricity market to Independent Power Producers (IPPs). Unfortunately, the Asian financial crisis put severe financial strains on state-utility Perusahaan Listrik Negara (PLN), which made it difficult to make payments for all of the electricity generation volume for which it had signed contracts with IPPs. PLN is currently over $5 billion in debt, which has further increased as result of the decline in the value of the rupiah. Meanwhile, the Indonesian government has been unwilling to take over the commercial debts of PLN.

Indonesia is currently facing an electricity supply crisis. Intermittent blackouts are already an issue across Java. Demand for electrical power is expected to grow by approximately 10% per year over the next 10 years. The majority of Indonesia's electricity generation is currently fueled by oil, but efforts are underway to shift generation to lower-cost coal and gas-powered facilities. Geothermal energy and hydropower are also being investigated. For example, the World Bank-supported project of improving the power sector on Java-Bali which uses approximately 80% of Indonesia's power generation capacity, includes support for a corporate and financial restructuring plan for PLN and technical assistance for a restructuring program for state gas company, Perusahaan Gas Negara, that will provide for increased natural gas supplies for electricity generation.

3. Methodology

3.1. Granger-causality and stationarity

The first attempt to investigate the direction of causality was proposed by Granger [10]. The Granger-causality test is a convenient and very general approach for detecting any presence of a causal relationship between two variables. A time-series (X) is said to Granger-cause another time-series (Y) if the prediction error of current Y declines by using past values of X in addition to past values of Y. The Granger-causality test method is selected to be used in this study over other alternative techniques because of the favorable Monte Carlo evidence reported by Geweke et al. [11], particularly for small samples in empirical works.

In order to conduct the Granger-causality test, a series of variables need to be stationary. It has been shown that using non-stationary data in causality tests can yield spurious causality results [12]. Therefore, following Engle and Granger (EG) [13], we first test the unit roots of X and Y to confirm the stationarity of each variable. This is done by using the Phillips–Perron (PP) [14] test over alternative tests, in that the PP test is known to be robust for a variety of serial correlations and time-dependent heteroscedasticities. If any variable is found to be non-stationary, we must take the first difference and then apply the causality test with differenced data.

3.2. Co-integration

The concept of co-integration can be defined as a systematic co-movement among two or more economic variables over the long run. According to EG [13], if X and Y are both non-stationary, one would expect that a linear combination of X and Y would be a random walk. However, the two variables may have the property that a particular combination of them $Z = X - bY$ is stationary. Thus, if such a property holds true, then we say that X and Y are co-integrated.

If X and Y each are non-stationary and co-integrated, then any standard Granger-causal inferences will be invalid. Accordingly, a more comprehensive test of causality based on an error-correction model, should be adopted [13]. However, if X and Y are both non-stationary and the linear combination of the series of two variables is non-stationary then the standard Granger-causality test should be adopted [15]. Therefore, it is necessary to test for the co-integration property of the series of electricity consumption and economic growth prior to performing the Granger-causality test. If both series are integrated of the same order, we can proceed to test for the presence of co-integration. The EG [13] co-integration test procedure is used for this purpose.

3.3. Standard Granger-causality test

To test for Granger-causality between X and Y, two bi-variate models are specified, one for X and another for Y. If two variables are non-stationary but they become stationary after first differencing, the standard form of the Granger-causality test can be specified as follows:

$$\Delta Y_t = \alpha_{11} + \sum_{i=1}^{L_{11}} \beta_{11i} \Delta Y_{t-i} + u_{11\mathrm{t}}, \tag{1}$$

$$\Delta Y_t = \alpha_{12} + \sum_{i=1}^{L_{11}} \beta_{11i} \Delta Y_{t-i} + \sum_{j=1}^{L_{12}} \beta_{12j} \Delta X_{t-j} + u_{12t}, \tag{2}$$

$$\Delta X_t = \alpha_{21} + \sum_{i=1}^{L_{21}} \beta_{21i} \Delta X_{t-i} + u_{21t}, \tag{3}$$

$$\Delta X_t = \alpha_{22} + \sum_{i=1}^{L_{21}} \beta_{21i} \Delta X_{t-i} + \sum_{j=1}^{L_{22}} \beta_{22j} \Delta Y_{t-j} + u_{22t}, \tag{4}$$

where X_t and Y_t represent natural logarithms of electricity generation and real GDP, respectively, Δ is the difference operator, L is the number of lags, α and β are parameters to be estimated, and u_t is the error term.

Eqs. (2) and (4) are in unrestricted forms, while Eqs. (1) and (3) are in restricted forms. However, Eqs. (1) and (2) are made a pair to detect whether the coefficients of the past lags of X can be zero as a whole. By the same token, Eqs. (3) and (4) are made other pair to detect whether the coefficient of the past lags of Y can be zero as a whole. Stated differently, if the estimated coefficient on lagged values of X in Eq. (2) is significant, it indicates that it explains some of the variance of Y that is not explained by the lagged values of Y itself. This implies that X is causally prior to Y and said to Granger-cause Y. Thus, F-statistics is calculated to test whether the coefficients of lagged values can be zero. Similar reasoning is possible for examining whether Y Granger-cause X.

3.4. Hsiao version of the Granger-causality method

The causal results are sensitive to the lag structure of the independent variables. The arbitrariness in choosing lags can distort the estimates and yield misleading causality inferences. Hsiao's [16] procedure, which combines the Akaike's [17] final prediction error (FPE) criterion with Granger-causality test, will be employed in this study to guide the selection of the appropriate lag specifications. This FPE rule rewards good fit but penalizes the loss of degree of freedom. The Akaike's FPE criterion is quite appealing because "it balances the risk due to bias where a lower-order is selected and risk due to the increase of variance when a higher-order is selected" [16, p. 88].

Hsiao's procedure consists of two steps. The first step is to estimate Eq. (1) to compute the residual sum of squares by varying the lag order (l_{11}) from 1 to l_{11}. The $FPE(l_{11})$, which represents the lag consideration, is computed as

$$FPE(l_{11}) = \left[\frac{T + l_{11} + 1}{T - l_{11} - 1}\right] \frac{RSS(l_{11})}{T}, \tag{5}$$

where T is the sample size and RSS is the residuals sum of squares from (1). Thus, if l_{11} in Eq. (1) is set at 5, then there will be 5 FPEs. The smallest $FPE(l_{11})$ decides the optimal lag (l_{11}^{*}).

The second step is to estimate Eq. (2). For additional variable X, one varies again the lag order (l_{12}) from 1 to l_{12} and calculates the modified two-dimensional FPE as follows:

$$FPE(l_{11}^{*}, l_{12}) = \left[\frac{T + l_{11}^{*} + l_{12} + 1}{T - l_{11}^{*} - l_{12} - 1}\right] \frac{RSS(l_{11}^{*}, l_{12})}{T}, \tag{6}$$

Again, the smallest $FPE(l_{11}^{*}, l_{12})$ decides the optimal lag (l_{12}^{*}). Thus, the appropriate lags (l_{11}^{*}, l_{12}^{*}) are determined. If $FPE(l_{11}^{*}, l_{12}^{*})$ is smaller than the $FPE(l_{11}^{*})$, it implies that X Granger-cause Y. Subsequently, causality from Y to X may also be estimated by repeating the same procedure for Eqs. (3) and (4). Thus, by combining the FPE criterion and Granger's definition of causality, Hsiao's method would allow two variables to enter the equation with different number of lags. As a result, the number of lags to be estimated can be reduced.

The maximum order l_{11}, l_{12}, l_{21} and l_{22} can be set to be sufficiently large in order not to miss the global minimum FPE. In actual practice, the researchers' choice of the maximum lag length order is likely to be influenced by the length and nature (annual or quarterly) of time-series and the number of variables to be considered in the equation. Since annual time-series data employed in this study do not exceed 32 years for the variables, the maximum order is set to six.

4. Empirical results

4.1. Data

As mentioned above, this study examines the causal relationship between electricity generation and economic growth in Indonesia. Data covering the period 1971–2002 are used. The choice of the starting period was constrained by the availability of data on electricity generation. Electricity generation is measured at the terminals of all alternator sets in a station. In addition to hydropower, coal, oil, gas, and nuclear power generation, it covers electricity generation by geothermal, solar, wind, and tide and wave energy, as well as that from combustible renewables and waste. It includes the output of electricity plants that are designed to produce electricity only as well as that of combined heat and power plants. Electricity generation is expressed in terms of terawatt hours. Real GDP is used as a proxy for economic growth. The nominal GDP series in local currency units are transformed into real GDP in constant 1995 US dollar.

The use of GDP, rather than gross national product, may be more appropriate in the analysis of the causal relationship, because the country's total electricity generation depends upon goods and services produced within the country, not outside the country. The variables used in the models are: *LEG*, natural logarithm of electricity generation; and *LGDP*, natural logarithm of real GDP. The data on the two variables were obtained from World Bank [18], BP [19], and ASEAN Secretariat [20].

4.2. Results of unit roots and co-integration tests

When testing for unit roots and co-integration, a probability value of 0.10, which is an appropriate level of significance to be used with small sample sizes, is used in this study. The results of the unit root tests for the series of *LEG* and *LGDP* variables are shown in Table 1. All p-values corresponding to PP-values calculated for the two series are greater than 0.1. This indicates that the series of all variables are non-stationary at 10% level of significance and thus any causal inferences from the two series in levels are invalid. However, non-stationarity can be rejected for first differences of these series at 10% level of significance. Hence, the Granger-causality models are estimated with first-differenced data.

The results of the EG co-integration test for the series *LEG* and *LGDP* are reported in Table 2. The test statistics are calculated under the null hypothesis of absence of co-integrating relation. AS shown in the table, both p-values corresponding to the test statistics are greater than 0.10. This means that there does not exist a long-run relationship between electricity generation and real GDP. In addition, the results of the Johansen co-integration test [22] for the series *LEG* and *LGDP* are reported in Table 3. The likelihood ratio tests show that the null hypothesis of absence of co-integrating relation ($R = 0$) cannot be rejected at 10% level of significance, and that the null hypothesis of existence of at most one co-integrating relation ($R \leqslant 1$) cannot be

Table 1
Results of Phillips–Perron (PP) unit root tests

	LEG		*LGDP*	
	PP-values	*p*-values	PP-values	*p*-values
Levels	−6.107[2]	0.737	−2.911[3]	0.940
First-differences	−34.724[2][a]	0.003	−21.763[2][a]	0.049

Notes: The numbers inside the brackets are the optimum lag lengths determined using Akaike's information criterion described in Pantula et al. [21].
[a]Represents the rejection of the null hypothesis of non-stationarity at 10% level of significance.

Table 2
Results of Engle–Granger co-integration tests

Dependent variables	Test statistics	*p*-values
LGDP	−3.037[5]	0.248
LEG	−1.841[5]	0.832

Notes: The number inside the brackets is the optimum lag determined using Akaike's information criterion described in Pantula et al. [21]. The test statistic is computed under the null hypothesis of absence of co-integrating relation.

Table 3
Results of Johansen co-integration tests

Null hypotheses	Likelihood ratio test statistic	*p*-values
The number of co-integrating equation is zero ($R = 0$).	11.192	0.363
The number of co-integrating equation is at most one ($R \leqslant 1$)	1.669	0.192

Notes: The optimal lag length is chosen by using Akaike's information criterion described in Pantula et al. [21]. The *p*-values are calculated under the corresponding null hypothesis. R denotes the number of co-integrating equation.

either rejected at 10% level of significance. This also implies that there is no co-integrating equation at 10% level of significance. Evidence in this study indicates that the integrated variables have no inherent co-movement tendency over the long run. Based on this, it is concluded that electricity generation and real GDP are not co-integrated in Indonesia. As stated previously, if the series of two variables are non-stationary and the linear combination of them is also non-stationary, then standard Granger-causality test rather than error-correction modeling should be employed. Therefore, the standard Granger-causality test is appropriate, as shown in Eqs. (1)–(4).

4.3. Results of Hsiao's version of the Granger-causality tests

The results from Hsiao's version of the Granger-causality tests are presented in Table 4 with the optimal lag lengths (l^*_{11}, l^*_{12}, l^*_{21}, and l^*_{22}) and F-values computed under the null hypothesis of no causality. As stated above, if $FPE(l^*_{11}) > FPE(l^*_{11}, l^*_{12})$, then electricity generation Granger-cause economic growth. As illustrated in the table, for the GDP equation, since $1.871 \times 10^{-3} < 1.981 \times 10^{-3}$ one can reject the hypothesis that electricity generation causes economic growth. This means that the inclusion of past values of electricity generation in the GDP equation does not provide a better explanation of current values of real GDP than when excluded. The results are further corroborated by the F-value of 0.276, as shown in the fifth column of Table 4, which indicates that electricity generation does not affect economic growth for Indonesia at the 10% level.

Table 4
Results of Granger's-causality tests between electricity generation and real GDP

	Regression results			
	l_{11}^{*}/l_{21}^{*}	l_{12}^{*}/l_{22}^{*}	FPE[a] $\times 10^3$	F-values (p-values)
GDP equation				
Eq. (1)	1		1.871	0.276
Eq. (2)	1	1	1.981	(0.604)
Electricity generation equation				
Eq. (3)	5		3.707	4.030*
Eq. (4)	5	1	3.320	(0.059)

Notes: *denotes statistical significance of the F-value, computed under the null hypothesis of no causality, at 10% level of significance.
[a]FPE represents Akaike's [17] final prediction error.

Conversely, for the electricity generation equation, as shown in Table 4, $3.707 \times 10^{-3} > 3.320 \times 10^{-3}$. Thus, it can be concluded that real GDP causes electricity generation. This implies that the inclusion of past values of real GDP in the electricity generation equation provides a better explanation of current values of electricity generation than when excluded. The result is further confirmed by the F-value of 4.030, as shown in Table 4, which reveals that it is statistically significant at the 10% level. That is, economic growth affects electricity consumption for Indonesia.

To sum up, *LGDP* in electricity generation equation is statistically significant at the 10% level, but *LEG* in the GDP equation is not. This implies that there exists a uni-directional causality running from economic growth to electricity generation without any feedback effect for Indonesia.

4.4. Investigation of the causal relationship between electricity consumption and economic growth

This study focuses on the causal relationship between real GDP and electricity generation. However, most previous studies dealt with the causal relationship between real GDP and electricity consumption rather than electricity generation [e.g., 2–5]. Information on electricity consumption would be more important than that on electricity generation since it enables the policy maker to plan cost-effective investment and operation of the existing and new power plants so that the supply of electricity can be adequate enough to meet the demand and its variation. Thus, as a final exercise we try to investigate the causality between real GDP and electricity consumption.

For convenience, natural logarithm of electricity consumption is denoted as *LEC*. The two time-series, *LEG* and *LEC* are described in Fig. 2, which shows no significant difference between the two series. The PP values for the series of *LEC* variable in the level and first difference forms are −0.133 and −25.010, respectively. Considering that the corresponding p-values are 0.966 and 0.025, respectively, the series is non-stationary in level and stationary in the first difference at the 10% level. Both results of the EG co-integration test and the Johansen co-integration test for the series *LEC* and *LGDP* reveals that neither of the series are co-integrated at 10% of significance (the detailed results are omitted here to save space).

By following the estimations based on Hsiao's version of the Granger-causality tests described above, one can reach the results of the causality test reported in Table 5. The results indicate that economic growth causes electricity consumption as shown by the electricity consumption equation, where $2.586 \times 10^{-3} > 2.150 \times 10^{-3}$. On the other hand, by observing the GDP equation we see that electricity consumption does not leads to economic growth. This implies that there exists uni-directional causality running from economic growth to electricity consumption without any feedback effect for Indonesia. This finding is consistent with the finding of Yoo's [23] study, which is based on per capita value instead of the total value. More interestingly, the direction of causality between electricity consumption and economic growth coincides with that between electricity generation and economic growth.

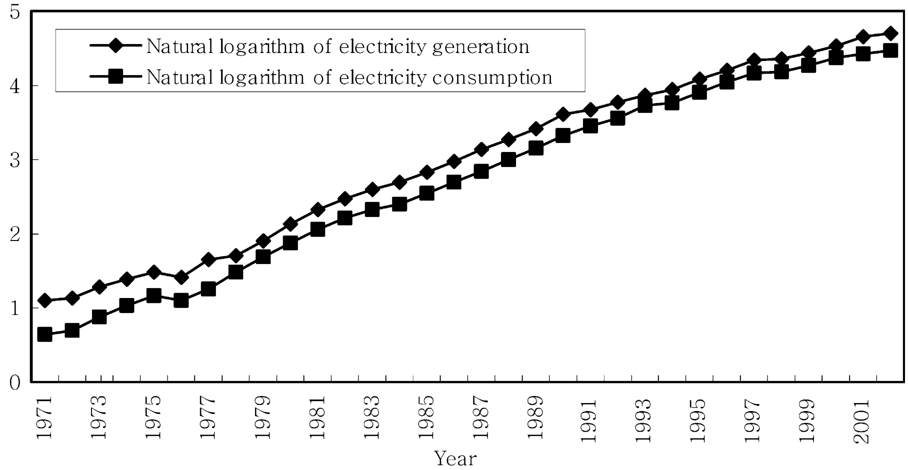

Fig. 2. Natural logarithms of electricity generation and consumption for Indonesia.

Table 5
Results of Granger's-causality tests between electricity consumption and real GDP

	Regression results			
	l^*_{11}/l^*_{21}	l^*_{12}/l^*_{22}	FPE[a] $\times 10^3$	*F*-values (*p*-values)
GDP equation				
Eq. (1)	1		1.871	0.039
Eq. (2)	1	1	1.998	(0.845)
Electricity consumption equation				
Eq. (3)	9		2.586	3.885*
Eq. (4)	9	1	2.150	(0.074)

Notes: * denotes statistical significance of the *F*-value, computed under the null hypothesis of no causality, at 10% level of significance.
[a]FPE represents Akaike's [17] final prediction error.

5. Concluding remarks

The purpose of this study was to investigate the causal relationship between electricity generation and economic growth for Indonesia, and to obtain policy implications of the results. To this end, causality tests have been performed using time-series techniques. With the data availability and the techniques adopted, the investigation covered the period 1971–2002. In summary, time-series properties of the data were analyzed by way of unit root and co-integration tests before applying Granger's-causality tests and several models were estimated to test for the direction of Granger-causality.

The results of the study show that uni-directional causality runs from economic growth to electricity generation without any feedback effect. Thus, a growth in real GDP is responsible for the high level of electricity generation in Indonesia. Economic growth results in a higher proportion of real GDP spent on electricity generation, thereby stimulating further electricity generation. This result can be interpreted as follows. With the advancement of the country's economy, there has been a rapid growth in electricity generation for its consumption in various sectors. Households, because of their higher disposal income, have come to consume more and more electricity. Economic growth causes the industrial and commercial sectors, where electricity has been used as basic input, to increase. Newly constructed large-scale plants and factories have also made electricity consumption to accelerate to keep pace with economic growth. Basically, economic growth enhances electricity generation.

Moreover, the empirical results indicate that there is no causality running from electricity generation to economic growth in Indonesia. Indonesia's electricity authority has been suffering from chronic supply shortage and environmental problems associated with electricity supply based on fossil-fueled power plants [8]. As explained above, Indonesia requires large-scale investment to be injected in the electricity sector and needs to take another electricity supply action in the near future to bridge its future demand–supply gap. The authority is also planning to initiate a major electricity conservation and efficiency improvement program as a part of the ongoing reform processes because of electricity saving potentials. While electricity conservation aims to reduce the need for electricity without reducing the end-use benefit, it provides a range of personal as well as social rewards also.

In this situation, the absence of a uni-directional causality running from electricity generation to economic growth in the country has important policy implications for decision-makers, because electricity conservation policies through rationalizing the tariff structure, efficiency improvement and demand side management, which aim at curtailing waste of electricity and thereby reducing the electricity generation without affecting the end-use benefits, can be initiated without inflicting damaging effects on the economic growth of the country.

We think of this work as the beginning of a long-term effort to completely disclose causal linkages between electricity generation and economic growth in Indonesia. Two extensions of the present framework in future study would be fruitful. First, it would be interesting to do a similar causality analysis for a country that implemented some of the policy changes. For example, considering that some European countries have significantly raised energy prices, one can raise the question: did the causal relationship change after these energy price-raising policies were instituted? Two causality analyses for the periods before and after a rise in price could answer the question. Second, this analysis, based on bi-variate system, can be readily extended to other multi-variate systems, where electricity generation and real income are exposed to be determined by other economic factors such as price, employment, exports etc. Such an analysis could reveal the structural channels by which real income and electricity generation are inherently causal [24]. It is hoped that as better data becomes available, further light can be shed on this important issue of the causality between electricity generation and economic growth in Indonesia.

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