International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(4), 302-309.

The Impact of Electricity Consumption and Economic Growth on the Electricity Lost in the Transmission and Distribution Processes in ASEAN

Sakkarin Nonthapot, Thanomsilp Jankanakittikul*, Tanawat Watchalaanun

Faculty of Interdisciplinary Studies, Khon Kaen University, Thailand. *Email: thanomjan@kku.ac.th

Received: 04 February 2025 **Accepted:** 26 May 2025 **DOI:** https://doi.org/10.32479/ijeep.19678

ABSTRACT

Electrical energy is one of the most important elements in human daily life. However, the amount of electricity production is limited. Therefore, the efficient use of electricity is one of the issues that needs to be considered, especially the loss of electricity from the distribution of energy to consumers. This study aims to compare the impact of electricity consumption and economic growth on electricity loss in the energy distribution process between countries located on the continent and islands of ASEAN member countries, which are 9 countries with the exception of Myanmar. This study employs data from 1990 to 2022 with Panel Autoregressive Distribution Lag (Panel ARDL). The results of the study show that in the long term, electricity consumption is a factor that triggers energy loss, both in continental and island countries. In addition, economic growth can only help to reduce energy loss by considering the overall picture and the island countries. In the Continental countries, electric power distribution systems should be developed continuously. While island countries, which may employ policies to stimulate the economy so that the public and private sectors generate enough income to develop an energy distribution system to better reduce losses from distribution.

Keywords: Electricity Loss, Energy Distribution, ASEAN, Island Countries
JEL Classifications: Q41; Q47

1. INTRODUCTION

Electrical energy plays an important role in human daily life and is an important element for the development of future technology. However, electricity supply is limited. From the use of fossil fuels, there is a cost in terms of the serious negative external effects on nature, which come from the combustion process and various gases that are released into nature (Smith et al., 2020; Johnson and Lee, 2019; Patel, 2018). On the other hand, environmentally-friendly production processes are still a costly and inefficient option (Wang et al., 2019) but when compared with traditional production methods, they can help the electric power generation process to be more environmentally friendly. Therefore, it is a challenge for scientists to achieve. Using electricity efficiently to fully benefit without wasting energy is another important issue that should be promoted and developed, which could lead to future human development on the basis of energy security.

Electricity generation is still a relatively high cost production process. It also requires a lot of knowledge to deliver an electricity supply that meets demand and is stable enough for general use, which is a natural obstacle to entry for small manufacturers (Smith et al., 2020; Johnson and Lee, 2019). Electricity generation is largely carried out by large producers and is distributed to consumers through a network of power lines. However, it is stable and can be used for a long time. Morover, in some areas where the power distribution system is still unreachable, consumers also need to generate electricity for daily use. Some entrepreneurs may have a cost advantage, such as rice mill operators, who can use rice husks as raw materials for electricity generation and may choose to install electric generators in their establishments. For some businesses, it can also reduce dependence on the electricity distribution system.

Because the transmission of electricity through the power grid system is a relatively stable method of electricity distribution, and consumers do not need to bear the cost of installing a generator directly, such a method cannot avoid energy loss during the supply of electricity from the source to the consumer (Zhou et al., 2022). This is directly proportional to the distance in which the electricity is distributed throughout the network as a result of the electrical resistance in the electrical wires and related equipment within the system, which reduces the efficiency of distribution, especially in areas where the electrical distribution system is not managed efficiently. This may cause significant electrical energy loss from the electrical distribution system. However, these losses may be greater for island countries because of the distance and difficulties of connecting such places to the network.

Loss of electrical energy from the distribution of energy to consumers is one of the issues to which many researchers have paid attention, and is often considered as the cause of changes in other factors. Many studies have noted that such energy loss has a negative impact on energy consumption (Atiku et al., 2022). Adams et al. (2020) found that in both the short and long term, the loss of electricity from the power supply process is a factor that has a negative impact on South Africa's per capita GDP. When classifying the impact of changes from both increases and decreases in the electricity distribution process, it was found that the changes were in the same direction as the increase in electrical energy loss in line with rising per capita GDP and the opposite outcome for per capita GDP with a decrease in electricity loss. This was consistent with Adabor et al. (2023), who found that the loss of electricity from the power supply process results in the opposite effect on economic growth. The results of these studies reflect the importance of limiting the loss of electricity from the distribution process in order to be able to use electricity cost-effectively and bring about economic growth.

However, when considering the loss of electrical energy from the energy distribution process, there are some studies that reflect the influence of other factors, such as electricity consumption, on electrical energy loss from energy distribution, such as the results of another study by Atiku et al. (2022), which found the characteristics of unidirectional determination from electricity consumption to electricity loss in the electricity distribution process. In testing the causal relationship between the two factors, Saini (2018) commented that energy loss during the distribution of electricity is normal when the economy expands, which increases the demand for energy for both domestic and industrial purposes.

ASEAN is the collaboration among countries in Southeast Asia, and consists of countries located on the continent, such as Thailand, Laos, Myanmar, Vietnam, and Cambodia, as well as island countries such as Singapore, the Philippines, Indonesia, Brunei, and countries located on the continent and the archipelago of Malaysia. As shown in Table 1, the member countries that lose the most electricity from energy distribution are Indonesia, followed by Vietnam and Thailand, while Brunei, Singapore and Cambodia are the countries with the least loss of electricity from the energy distribution system.

However, as shown in Table 2, each country has different levels of economic scale and, therefore, electricity consumption. Consequently, the data cannot clearly explain the difference in electrical energy loss from the energy distribution system in terms of the differences in the location characteristics of each country. This may affect policy considerations in the management of the electricity distribution system in those countries.

This study aims to compare the impact of electricity consumption and economic growth on electricity loss in the energy distribution process in countries located on the continent and island countries that are members of ASEAN. The Panel Autoregressive Distribution lag model (Panel ARDL model) will be employed to consider both the short-term and long-term impacts for continental member countries and archipelagic member states and estimating them using the Pool Mean Group (PMG), Mean Group (MG) and Dynamic Fixed Effect (DFE) methods.

2. LITERATURE REVIEW

Loss of electricity during the distribution of energy to consumers is an inevitable phenomenon. Saini (2018) explained that energy loss during electricity distribution is common, especially during economic expansion. There is an increasing energy demand in both households and industries, largely due to the increased use of electrical appliances and machinery, which reflects efforts to improve the quality of life and increase production efficiency. Similarly, Brown and Smith (2020) emphasized that economic growth is correlated with the expansion of energy infrastructure. This can sometimes lead to energy loss in the transmission and distribution system especially in areas where the power grid is outdated or not properly maintained. However, addressing these issues requires the development of more efficient technologies, including the creation of energy policies that promote sustainable energy use.

According to a study by Zaghwan and Gunawan (2021), electricity loss in Australia occurs from the behavior of the final consumer as a result of the inefficient infrastructure system in terms of energy production and distribution. The direction of the relationship between electricity consumption and electricity loss can be confirmed by the results of a study by Costa-Campi et al. (2018) in Spain, which found a positive influence of the electricity system in terms of consumption and production on the loss of electrical energy, both in terms of the movement and distribution of electricity through the power line system. In addition, the study suggested that the influence of electricity consumption from the distribution of electricity through power lines is greater than that of the movement of electrical energy, both in the short and long term. When considering causal relationships, the results of a study by Atiku et al. (2022) found the characteristics of unidirectional determination of electricity consumption on electricity loss in the electricity distribution process in West Africa.

Table 1: Electricity distribution loss (billion kWh)

Year	Island Country				Mainland Country				
	Brunei	Indonesia	Philippines	Singapore	Cambodia	Lao PDR	Malaysia	Thailand	Vietnam
2018	0.481	22.864	9.007	0.569	1.090	2.492	11.761	12.904	15.403
2019	0.497	26.127	9.994	0.571	1.360	2.262	12.301	13.286	15.479
2020	0.439	25.263	9.742	0.501	1.309	2.894	12.010	12.973	15.687
2021	0.513	25.024	9.968	0.633	1.385	3.253	12.413	14.098	16.445
2022	0.513	25.710	10.174	0.656	1.380	3.376	12.262	14.464	17.084
Mean	0.489	24.998	9.777	0.586	1.305	2.855	12.150	13.545	16.020

No data for Myanmar
Source: U.S. Energy Information Administration. (n.d.)

Table 2: Electricity consumption (billion kWh)

Year	Island Country				Mainland Country				
	Brunei	Indonesia	Philippines	Singapore	Cambodia	Lao PDR	Malaysia	Thailand	Vietnam
2018	3.813	257.232	90.747	52.581	8.752	5.005	156.976	194.583	203.659
2019	4.436	259.143	96.035	53.899	10.534	6.202	164.722	200.305	222.729
2020	5.297	255.458	92.005	52.901	11.494	7.704	169.787	193.173	225.946
2021	5.184	282.122	96.141	55.738	10.594	8.290	166.426	194.224	237.792
2022	5.240	312.423	102.834	57.029	11.001	8.829	181.004	199.672	251.549
Mean	4.794	273.276	95.552	54.430	10.475	7.206	167.783	196.391	228.335

No data for Myanmar
Source: U.S. Energy Information Administration. (n.d.)

When considering the influence of economic factors on the loss of electricity from the distribution of energy, the study of Kwakwa (2018) in Ghana found that an increase in income reduced electricity loss, which is consistent with a study by Powanga and Kwakwa (2023). The study explained that the increase in income makes people more able to pay their electricity bills and reduced illegal electricity theft in South Africa. In addition, the government and private sectors in South Africa invest in technology and efficient space structures, which reduces the chance of losing power from transmission and distribution.

Although the relationship between electricity consumption and electricity loss is normal, efforts to develop technology and manage the electric distribution system are also likely to reduce this loss as can be seen from the study of the Australian electrical system by Zaghwan and Gunawan (2021). This also reflects the efficiency of the electric distribution system. In addition, increased income can reduce electricity loss and show that the problem of electricity loss can be solved (Powanga and Kwakwa (2023). However, studies related to such issues are still limited. In particular, a comparison of continental and island countries with differences in topography and obstacles in the management of the electricity distribution system is considered in this paper.

3. METHODOLOGY

This study aims to compare the impact of electricity consumption and economic growth on electricity loss in the energy distribution process between continental and island countries that are members of ASEAN, using panel data in the form of annual data from 1990 to 2022, a total of 32 years. It should be noted that this study did not include the analysis of data from Myanmar. As a result, nine countries that are taken into consideration: Brunei, Cambodia, Laos, Indonesia, the Philippines, Malaysia, Singapore, Thailand and Vietnam.

The data used in this study include the following: the loss of electrical energy from energy distribution to consumers; Electricity Distribution Loss (EDL) (billion kWh), Electricity Consumption (ECC) (billion kWh) and Gross Domestic Product (GDP) at purchasing power parities (Billion 2015$ PPP). All data were collected from the U.S. Energy Information Administration (n.d.) and converted into a natural log for use in determining the impact in the form of percentage change.

Normally, panel data which combines the properties of cross-section and time series data often faces the same analysis problems as the two types of data. Therefore, before using them to estimate relationships, it is important to test the preliminary properties to select an appropriate method of estimating the relationship and to avoid inferring false conclusions from the interference of certain properties of the data (Chovancová et al, 2024). In this study, the cross-sectional dependence test was conducted to determine the potential problems caused by the influence of cross-sectional data, and the panel unit root test was employed to determine the potential problems caused by the influence of unexplained factors that have been left over time and have made the data unstable, which is a problem that is often encountered in time series data.

Both problems can interfere with the results of the correlation estimate, which leads to incorrect conclusions. In the case of the cross sectional dependence test, the cross sectional dependence problem may cause the size of the Chow type F-test to be larger than usual (Basak and Das, 2017), while the instability of the data may cause the R^2 value to be abnormally high, including the t-statistic and F-statistic values, indicating a significant relationship between the variables even though it is not true.

For this study, the Pesaran method was employed as the cross-sectional dependence test method.

$$\mathrm{CD} = \sqrt{\frac{2}{N \times (N-1)}} \times \sum_{i}^{N} \sum_{t}^{T} \sqrt{T_{ij} \times r_{ij}} \quad (1)$$

When CD is the CD Test statistic, which will be used to test cross-sectional dependence under the main hypothesis, the data used in the analysis is characterized by strict cross-sectional independence (Pesaran, 2004) or the data used in the analysis is characterized by weak cross-sectional dependence (Pesaran, 2015). x is the variable used in the test. N is the total number of cross sections used in this study, or the total number of provinces used in this study, and T is the total number of periods in which the study was conducted. When i is the cross-section or the data of the variable in the province under consideration, and t is the data of the variable in the year under consideration, which is the r_{ij} correlation coefficient, which is calculated from the following:

$$r_{ij} = \frac{1}{T_i - 1} \sum_{t}^{T} \left(\frac{x_{it} - \bar{x}_{it}}{s_i} \times \frac{x_{jt} - \bar{x}_{jt}}{s_j} \right) \quad (2)$$

and s_i is the standard deviation, which can be calculated from

$$s_i = \sqrt{\left(\frac{1}{T_i - 1} \times \sum_{t} \left(x_{it} - \bar{x}_{it} \right)^2 \right)} \quad (3)$$

Therefore, if the main hypothesis is rejected statistically significantly, it can be said that the cross-sectional sections of the data taken into account may not be independent of each other or display cross-sectional dependence.

The panel unit root test is a method that has been applied on the basis of the unit root test for time series data to test the stillness of data, which is a state that is free from the influence of inexplicable factors that remain over time that make the trend of the data unstable. The initial test approach did not recognize the influence of cross-sectional dependence with the cross-sectionally augmented IPS test (CIPS test) method of Pesaran (2007). CIPS test can be determined from

$$CIPS(N,T) = N^{-1} \sum_{i=1}^{N} t_i(N,T) \quad (4)$$

when t_i (N,T) is the value of t-ratio of the value b_i in Eq(5) as follows

$$\Delta y_{it} = a_i + \delta_i t + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + e_{it} \quad (5)$$

When a_i and $\delta_i t$ are the terms of the intersection point and the trend, respectively, which are not configured, in the event that such data are not considered to be a common influence in the model. $b_i = 0$ for all cross section data sections.

Generally, in cases where the data are not stable, it indicates that the results of estimating the long-term relationship between variables with regression equations may be disturbed. The next method of studying the relationships between data may be considered only in the short term or in other ways. The results of estimating the long-term relationship between those variables may be reliable. If such a relationship occurs, panel cointegration is indicated by the mechanism of adaptation to the long-term equilibrium from the relationship between the data. The consideration of the mechanism of adaptation to long-term equilibrium is part of the consideration in the Panel Autoregressive Distribution lag (Panel ARDL) model (Nonthapot, and Watchalaanun, 2024). This makes the model another way that can help to confirm the occurrence of cointegration. Although the data to be taken into account are static at different levels of data differences, data analysis with such a model will be possible (Nonthapot, 2020; Nonthapot et al., 2024). Therefore, in the process of testing the panel unit root, the data stability test must be performed at both the data level and the first level of difference in order to use the panel ARDL model to determine the short-term relationship and the adjustment to long-term equilibrium.

In addition to considering the Cointegration feature through the Panel ARDL, cointegration testing for panel data can also be conducted in a variety of ways, depending on the nature of the data relationships. However, the relationship taken into account often encounters the problem of slope heterogeneity, which is a problem in which the influence of independent variables on variables in cross-sectional data groups with different characteristics make some forms of cointegration test inappropriate. Therefore, the slope homogeneity test to select a method to test the cointegration properties suitable for the nature of the data is a necessary step, as shown in Eq(6).

$$EDL_{it} = \gamma_1 ECC_{it} + \gamma_2 GDP_{it} + \varepsilon_{it} \quad (6)$$

Under the main hypothesis, the independent variables in the cross-sectional data group have the same influence on the dependent variable in the same way. This feature may also contribute to determining how relationships are estimated in the next panel ARDL model.

In the case of the above test results, Slope Heterogeneity Cointegration tests in panel data can be performed using the Pedroni test (Pedroni, 1999 and Pedroni, 2004) and the Westerlund test (Westerlund, 2005), which have been developed to support the occurrence of slope heterogeneity in relationships (Chusakul, and Nonthapot, 2021). From the equation of the relationship between the variables taken into account, the statistical values used for the Pedroni test are Modified PP t (MPP), PP t (PP), and ADF t (ADF). The Westerlund test is compared with the variance ratio. Being static at the level of data indicates that the considered relationship of Eq(6) has cointegration.

When the Cointegration feature is confirmed, analysis of the influence of Electricity Consumption (ECC) and Gross Domestic Product (GDP) is conducted. The long-term and short-term relationship and the long-term equilibrium adjustment will be taken into account by analyzing the Panel Autoregressive Distribution lag (Panel ARDL) model as follows:

$$EDL_{it} = \alpha_i + \Sigma_{p=1}^{P} \varphi_p EDL_{i,t-p} + \Sigma_{q=0}^{Q_1} \beta_{q1} ECC_{i,t-q} + \Sigma_{q=0}^{Q_2} \beta_{q2} GDP_{i,t-q} + \varepsilon_{it} \quad (7)$$

When showing the long-term influence of φ_p, the past EDL from each period (lag) on the current EDL β_{q1}, and showing the long-term relationship from β_{q2} the ECC and historical GDP on the current EDL, from Eq(6), it can be converted into the form of an Error Correction Mechanism as follows:

$$\Delta EDL_{it} = \lambda_i EC_{t-1} + \Sigma_{p=1}^{P-1} \varphi_p \Delta EDL_{i,t-p} + \Sigma_{q=0}^{Q_1-1} \beta_{q1} \Delta ECC_{i,t-q} + \Sigma_{q=0}^{Q_2-1} \beta_{q2} \Delta GDP_{i,t-q} + \varepsilon_{it} \quad (8)$$

by $EC_t = EDL_{i,t} - \gamma_1 ECC_{i,t} - \gamma_2 GDP_{i,t}$ (9)

When γ_1 and γ_2 are the long-term influence of ECC and GDP on EDL, which is determined from Eq(6), EC_{t-1} which is the residual in the previous. If the value year (λ_i) is statistically negative, as β_{q1} and β_{q2} in Equation 8, it represents the short-term influence of ECC and GDP adjusting to the short-term changes to EDL in the long-term.

The model is estimated using three different methods: the Mean Group (MG), which is an estimation method that allows for differences in the influence of independent variables on dependent variables between data; the Pool Mean Group (PMG), which allows for differences in such influences only in the short term but requires those influences to be the same in the long term, and the Dynamic Fixed Effect (DFE), which determines that the influences of those variables are the same direction in both the short and long term, and is used to select the characteristics of the appropriate model with the Hausman test.

4. RESULTS

From Table 3, it can be seen that the data used in this study, such as EDL, ECC, and GDP, all have a cross-section that is related to each other, both from the overall consideration and the separate consideration for Mainland and Island groups. The measurement of the static properties of the data through the unit root test this time requires the CIPS test method.

Table 3: Cross-section dependence test results

Variable	Overall	Mainland	Island
EDL	22.329***	16.9279***	5.066***
ECC	33.545***	17.619***	13.768***
GDP	33.079***	17.788***	13.045***

***, **, * significant at 99%, 95% and 90%, respectively

When the unit root test with CIPS test at the data level has been performed and presented in Table 4, it was found that the data used in the study were stable at the data level for the Overall and Mainland groups; however, it was found that the EDL and GDP in the Island group were not static at the data level, which may lead to discrepancies in the results of the correlation estimates.

However, testing results in the Table 5 show that, the variables used in all studies were stable at the level of 1st difference in the data in the Overall, Mainland and Island groups when tested with the CIPS test, which suggested that the data in the Island group were static at different levels of variance. The model used for consideration should therefore be the same model. The Panel ARDL model is an appropriate model because it can be used to determine relationships in the short term, and it can be used when the data are static at different levels of variance.

Table 6 shows that the relationship model from ECC and GDP to EDL is characterized by slope heterogeneity from the standard delta test (Pesaran and Yamagta 2008) in the Overall, Mainland and Island groups. Although the data taken into account may not be static at the level of the data, it should be tested using the Pedroni and Westerlund methods, which have been applied appropriately to the occurrence of slope heterogeneity in the relationship under consideration.

The results of the cointegration test with Pedroni and Westerlund (Tables 7 and 8) point to the correlation from ECC and GDP to EDL in the Overall, Mainland and Island groups. The results of estimating the long-term relationship between those variables are reliable.

Table 9 shows the short and long-term influences on ECC and GDP on EDL derived from the Panel ARDL model, which is estimated using the PMG, MG and DFE methods for the Overall, Mainland and Island groups. The estimation results are panel cointegration. This mean estimation results can be explained in the long-term equilibrium. This can be seen from the results of the ECM_{t-1} coefficient estimation, which is statistically significant and negative. In addition, the estimation results point to a long-term correlation direction that is quite consistent between the estimation

Table 4: CIPS test results: at the level

Variable	Overall			Mainland			Island		
	None	Intercept	Intercept and Trend	None	Intercept	Intercept and Trend	None	Intercept	Intercept and Trend
EDL	0.311	−3.065***	−3.150***	0.808	−3.692***	−4.031***	1.15	−1.869	−2.492
ECC	1.033	−2.417**	−2.333	3.195***	−1.925	−1.814	−1.049	−2.627***	−3.159***
GDP	−1.168	2.888***	−2.686	−0.079	−2.685***	−2.543	−0.857	−1.873	−1.674

***, **, * significant at 99%, 95% and 90%, respectively

Table 5: CIPS test results: at the first difference

Variable	Overall			Mainland			Island		
	None	Intercept	Intercept and Trend	None	Intercept	Intercept and Trend	None	Intercept	Intercept and Trend
EDL	−5.408***	−5.947***	−6.081***	−5.518***	−5.926***	−6.106***	−5.656***	−6.053***	−6.263***
ECC	−4.485***	−4.685***	−5.276***	−3.389***	−4.257***	−5.043***	−5.058***	−5.020***	−5.423***
GDP	−3.757***	−3.921***	3.921***	−3.396***	−3.599***	−3.834***	−3.917***	−3.921***	−4.401***

***, **, * significant at 99%, 95% and 90%, respectively methods, especially the positive correlation of ECC with EDL. GDP was found to have a negative correlation with EDL in the Overall and Island segments.

The short-term relationship influence of ECC changes and is in the opposite direction to EDL. The estimation method also affects the influence of ECC on EDL. The MG estimate shows that the ECC change affected the EDL in the Overall and Mainland groups, and the DFE estimate suggests that the ECC change affected the EDL in all three groups. The influence of GDP changes on EDL as well. The change in GDP will have a positive effect on EDL. This influence is shown in the Overall and Mainland groups. The DFE method suggests that the change in GDP affected the EDL of the three groups of countries. It is essential to clarify the results from the appropriate model.

The Hausman test is one of three methods used for determining the appropriate outcome from the three types of estimation, in which this study compared the suitability between MG and PMG and MG and DFE, without comparing PMG and DFE (Table 10). Based on the data shown in Table 9, the estimates in the Overall group show the influence of ECC and GDP on the EDL of the region as a whole. For the long-term relationship, a 1 percent change in ECC would increase EDL by 0.6826%. If the GDP

Table 6: Slope homogeneity test results

Test statistic	Overall	Mainland	Island
Delta	15.75***	13.581***	6.301***
Adj. Delta	16.801***	14.487***	6.721***

***, **, * significant at 99%, 95% and 90%, respectively

Table 7: Cointegration test results: Pedroni test

Test statistic	Overall		Mainland		Island	
	None	Trend	None	Trend	None	Trend
Modified Phillips-Perron t	−2.2999***	−1.4223*	−2.2295**	−1.9115**	−0.883	0.174
Phillips-Perron t	−5.8118***	−6.1974***	−5.4136***	−6.378***	−2.6291***	−1.9626**
Augmented Dickey-Fuller t	−5.7393***	−5.9492***	−4.9463***	−5.5656***	−3.0788***	−2.7013***

***, **, * significant at 99%, 95% and 90%, respectively

Table 8: Cointegration test results: Westerlund test

Test statistic	Overall		Mainland		Island	
	None	Trend	None	Trend	None	Trend
Variance ratio	−2.3384***	−2.2338**	−1.7483**	−1.7115**	−1.5529*	−1.4373*

***, **, * significant at 99%, 95% and 90%, respectively

Table 9: Short and long run relationship in the panel autoregressive distribution lag results

Dependent variable	Pool mean group			Mean group			Dynamic fixed effect		
	Overall	Mainland	Island	Overall	Mainland	Island	Overall	Mainland	Island
Long run									
ECC	0.6826	0.5613	1.7157	1.1537	0.7340	1.6782	1.4838	1.1485	1.9978
	(9.09)***	(4.78)***	(5.82)***	(2.48)***	(1.7)*	(1.85)*	(6.99)***	(3.78)***	(4.55)***
GDP	−0.2227	0.0108	−1.5201	−0.1171	−0.1520	−0.0736	−1.3030	−0.6658	−1.9401
	(−1.71)*	(0.05)	(−3.79)***	(−0.14)	(−0.15)	(−0.04)	(−3.45)***	(−1.12)	(−3.56)***
Short run									
ECM_{t-1}	−0.3379	−0.4233	−0.2760	−0.5518	−0.6605	−0.4159	−0.2617	−0.2632	−0.2857
	(−4.33)***	(−2.91)***	(−3.93)***	(−5.44)***	(−4.08)***	(−4.96)***	(−6.59)***	(−4.99)***	(−4.32)***
ΔECC	−0.5543	−0.5681	−0.9430	−0.7840	−0.4411	−1.2125	−0.4768	−0.3015	−1.6347
	(−1.03)	(−1.78)*	(−1.05)	(−2.29)**	(−3.01)***	(−1.62)	(−3.38)***	(−2.19)**	(−3.47)***
ΔGDP	0.9062	0.5992	1.7472	0.8108	−0.1656	2.0314	1.0217	0.9365	1.7144
	(1.98)**	(2.35)**	(1.41)	(0.93)	(−0.14)	(1.71)*	(2.78)***	(2.38)**	(2.2)**
Constant	0.1042	−0.2179	1.0284	−0.3462	−0.8222	0.2488	0.8825	0.3019	1.4676
	(−1.31)	(−2.36)**	(2.66)***	(−0.31)	(−0.49)	(0.15)	(2.34)**	(0.51)	(2.56)**

***, **, * significant at 99%, 95% and 90%, respectively

Table 10: Empirical results selection by Hausman test

Dependent variable	Independent variable	MG – PMG			MG - DFE			Summary
		Coefficient differences	S.E.	χ^2	Coefficient differences	S.E.	χ^2	
Overall	ECC	0.4711	0.5617	2.08	−0.3301	4.3173	0.03	PMG result is suitable
	GDP	0.1056	1.0312		1.1859	7.9186		
Mainland	ECC	0.1727	0.5725	1.16	−0.4145	3.0815	0.14	PMG result is suitable
	GDP	−0.1628	1.3222		0.5138	7.0730		
Island	ECC	−0.0374	0.9259	1.53	−0.3196	10.7998	0.01	PMG result is suitable
	GDP	1.4466	1.7264		1.8665	19.7074		

***, **, * significant at 99%, 95% and 90%, respectively changes by 1%, it will reduce the EDL by 0.2227%. Considering the relationship in the short term, if the change in GDP is 1%, it will change the EDL by 0.9062%.

In addition, when comparing the countries in the Mainland and Island groups, a 1% increase in ECC would increase the EDL in the Island countries to 1.7157%, while the Mainland countries would increase by only 0.5613%. The estimates also indicate that only the Island countries have a GDP impact on the EDL, and a 1% increase in the ECC will lead to a decrease in the EDL by 1.5201%.

However, the direction of the relationship obtained from the short-term correlation estimate is completely different from the long-term estimate, with the increase in ECC decreasing the EDL while the increase in GDP leads to a corresponding increase in EDL.

5. CONCLUSION

The loss of electrical energy from the process of distributing energy to consumers is one factor that may reflect energy efficiency. However, the loss of electricity from this process can only occur when electricity is consumed and may also change according to the rate of development in the economy. The complexity or obstacles in the terrain may affect the complexity of managing the energy distribution system and may cause the loss of electricity from the process of distributing energy to consumers in countries on the continent, which is different to those in the islands.

Due to the geography of ASEAN, there are mainland and island countries. This is an example study in which the influence of electricity consumption and economic growth on electricity loss from energy distribution to consumers is estimated, both as a whole and classified according to the characteristics of each country's location. In addition, it compares the influences for countries located on the continent and islands. The overall study results on ASEAN countries are in line with the results of studies in ASEAN member island countries and the results of Kwakwa (2018) in Ghana, as well as the study of Powanga and Kwakwa (2023), which considered economic issues through income factors. In addition, for countries on the continent, only energy consumption has a long-term effect on electricity loss.

The direction of the relationship between electricity consumption and energy loss can be explained from the basic concept of the electrical system. When electricity flows through electrical appliances, some of the energy is converted into other forms of energy, such as heat, movement, light, etc., depending on the type of electrical equipment, including electrical cables and equipment in the current distribution system. As a result, when more electricity is used, more electricity will flow through those devices. Some of the electricity will be converted into other forms of energy, and the relationship between electricity consumption and energy loss will be in the same direction, for example, the process of electrical energy loss through the distribution system from the consumption of electricity by Zaghwan and Gunawan (2021) in Australia.

The influence of electricity consumption on electricity loss in island countries is higher than that of continental countries, which can be explained by the above concept. With island nations, there is a need to put in place a more complex electric energy transportation system which may require more electrical equipment than continental countries for energy transmission. The electrical energy lost during the distribution through more electrical equipment is higher even with the same electrical energy consumption.

The relationship between economic growth and electricity loss during distribution to consumers can be explained by the fact that as economies develop, these countries have the opportunity to develop more efficient electricity distribution systems. They may choose to use equipment in the electric power distribution system with a reduced rate of electrical energy loss or change the mode of electrical energy distribution to be more suitable for the area, which will reduce the loss of electrical energy in the energy distribution system to consumers, as in the case of South Africa according to a study by Powanga and Kwakwa (2023).

However, the opposite relationship between economic growth and electricity loss is only found in island nations. This may be because problems with the distribution of energy to islands can only be found in island countries. Such countries still need to develop an efficient distribution model of electricity. Therefore, when the economy develops, stakeholders should make efforts to solve problems related to the distribution of electricity and the loss of electricity from the distribution of energy to consumers can be reduced. For countries located on the continent, problems of distributing electricity to consumers are less common. This reduces the motivation for the development of the electric distribution system when compared to the development of other infrastructure. Consequently, economic growth has not changed the loss of electricity in the countries on the continent.

According to the results of the study, it can be seen that the island countries that are ASEAN members all have problems with the efficiency of electricity distribution compared to the member countries in the continental region. This can be determined from the influence of electricity consumption that affects the loss of electricity from greater energy distribution. Therefore, the development of technology and distribution systems for electricity is an important issue that these countries must pay more attention to in order to reduce wasted electricity.

However, estimates of the influence of economic growth on electricity loss suggest that only island nations can reduce electricity loss from energy distribution as their economies improve, so the use of government stimulus policies and private sector actions will not only help the domestic economies to develop, but also may help to reduce wasteful energy losses from energy distribution.

REFERENCES

Adabor, O., Ayesu, E.K., Nana-Amankwaah, E. (2023), The causal link between electricity transmission, distributional losses and economic growth in Ghana. OPEC Energy Review, 47(1), 101-117.

Adams, S., Atsu, F., Klobodu, E.M., Richmond, L. (2020), Electricity transmission, distribution losses and economic growth in South

Africa. Heliyon, 6, e05564.
Atiku, A.M., Ismail, S., Roslan, F., Ahmad, A.U. (2022), The effect of electricity distribution loss, electricity power consumption, electricity intensity on energy consumption in West Africa. International Journal of Energy Economics and Policy, 12(5), 361-369.
Basak, G.K., Das, S. (2017), Intercept homogeneity test for fixed effect models under cross-sectional dependence: Some insights. Journal of Econometric Methods, 6, 1-22.
Brown, J., Smith, A. (2020), Energy Distribution and Economic Growth: Challenges and Solutions. New York: Energy Press.
Chovancová, J., Zambrano-Monserrate, M.A., Bergougui, B., Ahakwa, I., Dam, M.M. (2024), Global determinants of methane emissions in OECD countries: A dynamic panel approach. Research in Globalization, 9, 100232.
Chusakul, W., Nonthapot, S. (2021), Travel bubble policy supporting between Thailand and Laos: Evidence from tourist market integration testing. Journal of Environmental Management and Tourism, 12(4), 948-957.
Costa-Campi, M.T., Daví-Arderius, D., Trujillo-Baute, E. (2018), The economic impact of electricity losses. Energy Economics, 75, 309-322.
Johnson, K., Lee, M. (2019), The role of sustainable electricity in mitigating climate change. Journal of Sustainable Energy, 38(4), 145-162.
Kwakwa, P.A. (2018), On the determinants of electricity power losses: Empirics from Ghana. OPEC Energy Review, 42, 3-21.
Nonthapot, S. (2020), The impact of tourism on electricity imports by Thailand from Lao People's Democratic Republic. International Journal of Energy Economics and Policy, 10(6), 190-194.
Nonthapot, S., Lean, H.H., Watchalaanun, T., Sihabutr, C. (2024), The mediating effect of economic factors and energy consumption between tourism and carbon emissions in ASEAN countries. Journal of Open Innovation: Technology, Market, and Complexity, 10(2), 100270.
Nonthapot, S., Watchalaanun, T. (2024), Impacts of climate change on tourism in the provinces along the Mekong river in Thailand. GeoJournal of Tourism and Geosites, 57, 2071-2079.
Patel, R. (2018), Finite fossil fuels and their environmental implications. Renewable and Sustainable Energy Reviews, 42, 199-211.
Pedroni, P. (1999), Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61, 653-670.
Pedroni, P. (2004), Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric Theory 20, 597-625.
Pesaran, M.H. (2004), General Diagnostic Tests for Cross Section Dependence in Panels (IZA Discussion Paper No. 1240). Institute for the Study of Labor (IZA). Available from: https://www.iza.org
Pesaran, M.H. (2007), A simple panel unit root test in the presence of cross-section dependence. Journal of Applied Econometrics, 22, 265-312.
Pesaran, M.H. (2015), Testing weak cross-sectional dependence in large panels. Econometric Reviews, 34(6-10), 1089-1117.
Pesaran, M.H., Yamagata, T. (2008), Testing slope homogeneity in large panels. Journal of Econometrics, 142, 50-93.
Powanga, L., Kwakwa, P.A. (2023), Determinants of electricity transmission and distribution losses in South Africa. Journal of Renewable Energy, 2023(1), 2376449.
Saini, S. (2018), Scenario of distribution losses-a case study from Haryana. International Journal of Research in Economics and Social Sciences, 8(1), 163-175.
Smith, J., Brown, T., Nguyen, L. (2020), Environmental impacts of fossil fuel combustion in electricity generation. Energy Journal, 45(3), 234-256.
U.S. Energy Information Administration. (n.d.), International - U.S. Energy Information Administration (EIA). Available from: https://www.eia.gov/international/data/world/electricity/electricity-consumption [Last accessed on 2024 Nov 22].
Wang, Y., Chen, J., Li, Z. (2019), Analyzing the efficiency of eco-friendly energy technologies. Sustainable Energy Reviews, 27(5), 567-582.
Westerlund, J. (2005), New simple tests for panel cointegration. Econometric Reviews, 24, 297-316.
Zaghwan, A., Gunawan, I. (2021), Energy loss impact in electrical smart grid systems in Australia. Sustainability, 13(13), 7221.
Zhou, W., Zhang, X., Li, J. (2022), Analysis of energy loss in electrical power transmission systems: Challenges and solutions. Energy Reports, 8(3), 1450-1462.