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An Empirical Analysis of Factors Affecting Renewable Energy Consumption in Association of Southeast Asian Nations-4 Countries

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ABSTRACT

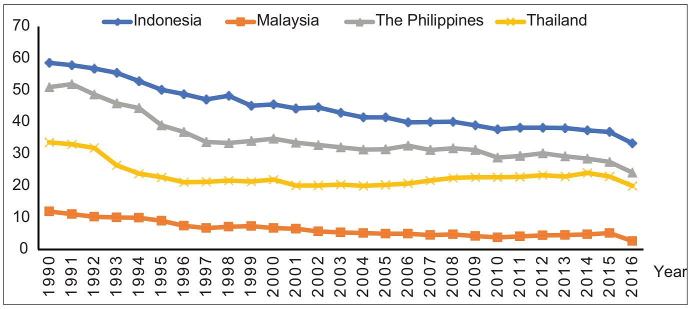
This study aimed to explore the determinants of renewable energy consumption in selected Association of Southeast Asian Nations (ASEAN) countries by emphasizing the significant role played by the quality of governance. This paper is classified according to the coverage of three dimensions approach (economic, environment, and governance) for sustainability. This study employed panel data analysis to examine the relationship between GDP, CO_2 emissions, foreign direct investment, trade openness, urbanization, and quality of governance on renewable energy consumption in selected ASEAN countries from 1990 to 2016. The results revealed that urbanisation has a significant positive impact on renewable energy based on FMOLS and DOLS analyses while the quality of governance has a significant positive impact on renewable energy based on pooled mean group analysis in the long run. However, GDP and trade openness have a significant negative impact on renewal energy. The elasticity analysis in the short run revealed that none of the factors applied in this study affected renewable energy consumption. Hence, several policies are recommended as an excellent approach to meet the energy demand of private investors and future generations.

Keywords: Renewable Energy, Association of Southeast Asian Nations, Quality of Governance, Panel Estimation
JEL Classifications: F64, Q42, P28

1. INTRODUCTION

The consumption of renewable energy such as solar, biomass, wind, hydroelectricity, and many others has been emphasis to meet the global warming challenge. Global warming is widely recognised as a serious threat to the future well-being of humanity. Despite the aim for higher use of renewable energy, the decreasing trend of renewable energy consumption by four-original members of Association of Southeast Asian Nations (ASEAN) countries namely Indonesia, Malaysia, Philippines, and Thailand might disrupt the association's agenda to use cleaner energy to prevent environmental pollution. Thus, the ASEAN has set an ambitious target of securing 23% of its primary energy from the renewable sources by 2025 due to the high energy demand in the region which is expected to grow by 50%. This target is very important in reducing the environmental pollution such as higher release of carbon emissions that can lead to global warming. Based on World Bank (2017), Malaysia has the lowest renewable energy consumption among Indonesia, Philippines, and Thailand. In addition, Figure 1, shows the trend of consumption for renewable energy as per centage of GDP for ASEAN-4 countries. According to the latest data for the renewable energy in World Bank (2017), the renewable energy consumption for 2016 in Indonesia is 33.29% of GDP, followed by 24.19% of GDP in the Philippines,

Figure 1: The trend of renewable energy consumption as % of GDP for ASEAN-4 countries



Source: World Development Indicator, 2018

and 19.97% of GDP in Thailand. It is known that Malaysia has the lowest renewable energy consumption among the four selected countries, which is 2.70% of GDP. This trend indicated that the ASEAN-4 countries still depending heavily on non-renewable sources energy which generated from coal and fossil fuel to generate energy. One of the reasons of heavy reliance on non-renewable energy is because of cheaper costs as compared to renewable energy. Therefore, these four countries were selected in this study among the ten countries in Southeast Asia, which is known as ASEAN-4 countries.

Renewable energy is the unlimited energy in which the supplies can continually be renewed through natural processes such as solar energy, wind energy, hydroelectric energy, biomass, and Biogas (Shukla et al., 2017). Renewable energy consumption becomes an important source of alternative energies and reduces energy costs (Omri et al., 2015). There are several examples of government policies implemented by the selected four ASEAN countries to improve renewable energy. For example, Indonesia implemented the National Energy Policy to increase their renewable energy to 31% in 2030. Malaysia has targeted that their renewable energy consumption to reach 2080 Megawatt by 2020, which can contribute 7.8% of total installed capacity in National Renewable Energy Policy, Action Plan 2011, and 11th Malaysia Plan 2016-2020. The action plans in the three policies show the efforts in Malaysia to improve renewable energy consumption. Next, the Philippines targeted to increase their renewable energy to 15.3 Gigawatt in 2030 and some additional target before 2030 in National Renewable Energy Program Roadmap 2010-2030. The final example is Thailand, which targeted 30% of renewable energy consumption in Thailand's total energy consumption by 2036 in the form of 20.11% of electricity, 36.67% of heat production, and 25.04% of biofuels in the transportation sector (IRENA, 2018). Overall, it is believed that the policies that develop renewable energy will motivate renewable energy consumption. However, the increase in energy shortage, climate change, and global warming in Southeast Asia has encouraged some of the countries' government to implement policies to increase the use of renewable energy consumption.

Among the profound macroeconomic indicators that could possibly influence the level of renewable energy consumption in ASEAN-4 group are economic growth (GDP), urban population (UPOP) and level of governance (GOV). The indicators are choosen based on their current issue. For instance, the Great Recession from 2008 to 2009 shows the negative effect on Economic Growth (GDP) of a country. According to Murphy (2018), it is expected that technical recession will occur in early 2020. Thus, it has a negative impact on renewable energy consumption in the UK due to the poor economy implications (Brock, 2010). This has been supported by Anbumozhi and Banuer (2010) who conducted research in Southeast Asia. The economic slowdown has reduced the demand for energy which led to the reduction of renewable energy consumption. This action makes them rely on traditional source of energy highly. For example, the Great Recession in 2008 to 2009 has huge implications for Malaysia and the Philippines. Before the recession, the GDP growth in Malaysia in 2007 was 9.43%, and it is reduced sharply to 3.31% and −2.53% during the recession from 2008 to 2009. The renewable energy consumption dropped from 4.73% to 4.23% in 2009 and continued decreasing to 3.82% in 2010 (World Bank, 2017). Next, the impressive growth rate of urban cities has caused several challenges for environmental sustainability in the Philippines. World Bank (2017) mentioned that although the Philippines is one of the fastest urbanising countries in ASEAN, poor urban management and inadequate investments in urban facilities are the major issues faced by the Philippines. Poor living condition in urban areas can result in lower income level, poor sanitation, and inefficiency of city development that can lead to deteriorating the consumption of renewable energy. Therefore, it is important to investigate whether the urban development process in ASEAN is one of the main engines for renewable energy consumption based on the prospects of sustainable development goals (SDG). The other potential indicator that might influence the level of renewable energy consumption in ASEAN-4 countries is level of governance. The public authorities in these countries lack transparency, and the anti-corruption authorities fail to reach their full potential as they lack the potential and operational independence with limited capacities (Transparency International, 2015). According to Transparency International (2015), one of the risks of corruption is several government projects especially renewable energy project will provide the opportunity for certain party to use the funds for illegal purposes. Besides that, there are a lot of projects without financial viability from the bank and government support (Koh, 2017) that can cause the projects to be obstructed by corruption. It is encouraged to promote the adoption of renewable energy for sustainable use in the future.

The combination of macroeconomic and environmental variables is to establish potential variables that can influence the consumption of renewable energy. Therefore, this study aimed to examine the factors affecting renewable energy consumption in the original member of ASEAN countries consists of Malaysia, Indonesia, Philippines and Thailand (ASEAN-4) as most macroeconomic variables are visible in these countries. It also intended to investigate the effects of quality of governance as the crucial factor in affecting renewable energy consumption.

The rest of this paper has been structured as follows. Section 2 discusses past empirical analyses of demand for renewable energy. Section 3 describes the methodologies for model development and the sources of data. The empirical findings are presented in Section 4. Finally, Section 5 emphasized the conclusions and policy implications drawn from the results of the study.

2. LITERATURE REVIEW

Currently, renewable energy plays an important role as more policymakers are encouraging people to use renewable energy rather than non-renewable energy. According to Alper and Oguz (2016), the most important features of renewable energy sources are reducing CO_2 emissions, assisting to protect the environment, reducing dependence on foreign sources for domestic sources of energy, and contributing to the increase in employment. Other than that, there is also a strong relationship between economic growth and renewable energy consumption. According to Danish et al. (2017), energy plays a significant role to boost the economy of any country and the developed nations switch from conventional energy consumption to renewable energy sources to tackle the future consequences of energy. According to Chen (2018), the changes in GDP have a significant and positive impact on renewable energy consumption. Zhao and Luo (2016) suggested that renewable energy consumption is improving along with the increase in GDP per capita for a long term using the ARDL model and error correction model. Disposable income can be used to develop green technology that can help to increase renewable energy consumption (Omri and Nguyen, 2014). On the other hand, Akar (2016) found that GDP has a negatively significant impact on renewable energy consumption from 1998 to 2011 in Balkan countries using IPS panel unit root test and system-GMM estimation. Cadoret and Padovano (2016) stated that GDP has a negative impact on renewable energy consumption. It is believed that the countries have reached the target of renewable energy sources. Thus, the market force is insufficient, and it is hard to stimulate the investment and consumption of renewable energy. According to Omri and Nguyen (2014), the relationship between GDP and renewable energy consumption is insignificant in low-income countries and global countries because GDP is not important for renewable energy consumption.

Omri and Nguyen (2014) investigated the determinants of renewable energy consumption for 64 countries from 1990 to 2011. It was found that trade openness has a statistically significant impact on renewable energy consumption in other income groups except for high-income level. Higher trade openness with a positive impact on technology transfers can help the countries to adopt modern renewable energy technologies. Besides that, trade openness has a significant impact on renewable energy consumption by increasing domestic production and economic activities. In a study by Akar (2016) that applied dynamic panel data method, trade openness has a positive effect on renewable energy consumption in the Balkans from 1998 to 2011. Meanwhile, Chen (2018) found that import and export trade are important factors that will affect energy consumption in China. Exports can lead to more renewable energy production because the increase in export volume will stimulate renewable energy consumption. Subsequently, it will promote more production and transportation of energy and renewable energy to foreign countries.

Previous studies concentrated more on the monetary impacts of foreign direct investment (FDI) and the environmental effects of FDI. Doytch and Narayan (2016) examined the environmental effects of FDI inflows. Doytch and Narayan (2016) affirmed that FDI is an essential driver of the expansion in sustainable power source utilisation for the upper-middle-income countries (UMICs), whereas the impact on lower centre salary nations (LMICs) is lower for the impacts of sectoral FDI. Lee (2013), on the other hand, stated there is no evidence for the statistically significant relationship between total net FDI inflow and increased renewable energy consumption. Recently, there are several studies that explored the relationship between urbanisation and renewable energy consumption. According to Chen (2018), changes in urbanisation have a significant and positive impact on renewable energy consumption, especially for regions with a high level of urbanisation population. He used a dynamic system-GMM panel model from 1996 to 2013 in 30 selected provinces of China. Meanwhile, Kammen and Sunter (2016) stated that the use of renewable energy in urban areas will be challenging and it is expected that the increase of urbanisation will continue in the next 30 years. The installation of renewable energy generation facilities in urban areas is challenging due to limited available land. Renewable energy is less likely to be consumed with the insufficient supply of renewable energy. A study by Salim and Shafiei (2014) used a STIRPAT model for investigating the impacts of urbanisation on renewable and non-renewable energy consumption in OECD countries from 1980 to 2011. The study revealed that urbanisation has a positive effect on non-renewable energy consumption, but it did not generate obvious effects on renewable energy consumption.

Other than that, past studies revealed that there was a relationship between CO_2 emissions and renewable energy consumption (Bhattacharya et al., 2016; Al-mulali et al., 2015; Dogan and Ozturk, 2017; Sharif et al., 2019). Omri and Nguyen (2014) conducted studies in 64 countries from 1990 to 2011 using system-GMM estimator. It was found that CO_2 emissions have significant positive effects on renewable energy consumption in high-income countries. Based on the study, renewable energy consumption has a significant negative impact on CO_2 emissions in both long run and short run dynamics in Pakistan (Danish et al., 2017). According to Cadoret and Padovano (2016), corruption is the measurement of quality of governance by reducing the government's responsiveness towards the policies and the income level is raised to protect the policies. Cadoret and Padovano (2016) revealed that the quality of governance is positive and there is a significant relationship for renewable energy consumption at 26 European countries from 2004 to 2011. When the quality of governance in a country is higher, the consumption of renewable energy will be higher. According to Ghimire and Kim (2018), corruption is the barrier to renewable energy development. The corruption activities will misuse the public fund and delay the public fund release process.

3. METHODOLOGY

The econometric model that were constructed based on the objective of this research paper can be seen as follows:

$$RE = f(GDP, FDI, TO, UPOP, CO_2, GOV) \quad (1)$$

Where

- RE_t represents renewable energy consumption,
- GDP_t represents economic growth,

- FDI_t represents foreign direct investment inflows,
- TO_t represents trade openness,
- $UPOP_t$ represents urban population,
- CO_2 represents carbon emersions,
- *GOV* represents quality of governance.

GDP is expected to have a positive sign with RE in ASEAN-4 group. With rapid growth, the ASEAN-4 group will seek for cleaner energy by promoting the use of renewable energy such as solar and wind energy. FDI is expected to have a positive sign given that most of the foreign investors that poured in their investment into ASEAN-4 group are come from developed countries such as Japan and South Korea that have owned and advanced in cleaner technology. TO is also expected to have a positive sign where cleaner products are imported from the country's trading partners. Higher CO_2 might lead towards the higher demand of renewable energy in ASEAN-4 group. The governments of ASEAN-4 group would take a preventive measurement by using more renewable energy when there is a rising issues of global warming due to high concentration of carbon emission release from the country. Lastly, GOV which is measure by corruption perception index is expected to have a mix sign. The positive sign indicated that higher governance (lower corruption) lead to higher consumption of RE, while negative sign indicated that lower governance (higher corruption) lead to a lower consumption of RE.

All of the variables were transformed into log-linear forms (LN). This transformation was to convert the results into short-run and long-run elasticities and to reduce the sharpness of the time series data so that there was a consistent and reliable estimation (Shahbaz and Rahman, 2010). The new transformation of the model in log form is as follows:

$$LNRE_{it} = \alpha_0 + \beta_1 LNGDP_{it} + \beta_2 LNFDI_{it} + \beta_3 LNTO_{it} + \beta_4 LNUPOP_{it} + \beta_5 LNCO_{2it} + \beta_6 LNGOV_{it} + \varepsilon_{it} \quad (2)$$

3.1. Statistical Techniques and Tools

The study will decide the exact model on the basis of data nature according to the previous studies. The data of this study will be analysed using statistical techniques such as descriptive statistics, correlation, FMOLS, and DOLS models. The study will conduct Pedroni tests and Philips Pearson tests for co-integration, whereas stationarity will be checked via Panel unit test (IPS), Fisher-ADF, and Fisher-PP panel unit root tests whether the variables are classified as I(1). If all the variables are stationary on the first difference, the study will proceed with panel cointegration tests.

3.1.1. Unit root test

Stationary is checked through panel unit test (IPS), Fisher-ADF and Fisher-PP panel unit root tests whether the variables are classified as l(1). If all the variables are stationary on the first difference, the study will proceed with panel cointegration tests.

3.1.2. Panel cointegration tests

When two non-stationary series are separated as individual non-stationary, their linear combination can be stationary. "Economically speaking, two variables will be cointegrated if they have a long-term or equilibrium relationship between them" (Gujarati, 2003). After presenting the methodology, the study will proceed with the analysis using panel unit root tests, which is the usual way of starting cointegration analysis to identify whether the series is stationary or non-stationary. A non-stationary series is not a mean-reverting series in which a shock (innovation) in the series does not die away. It is formulated as "non-stationary series has long memory" (Harris and Sollis, 2005). The linear combinations of non-stationary series might lead to the estimation of spurious regressions in which the estimated coefficients can be biased (Gujarati, 2003). In this regard, the identification of the existence of non-stationarity (unit root) and its order is important in two respects:

- First, it is important to know the order of unit root in the series to conduct panel cointegration tests. Panel cointegration tests can only be conducted among series which have the same order of integration.
- Second, the order of unit root in the series is also important to get rid of spurious regression risk when the existence of panel cointegration is not verified. For this case, the results of unit root test are useful in converting the series into stationary form by taking the first or second differences. Otherwise, the use of non-stationary series which is not cointegrated will lead to the estimation of biased coefficients.

In order to examine the long run relationship, this study conducted three tests to explore the long run relationship called Padroni test, Kao test, and Fisher test.
H_0: No cointegration
H_1: Cointegration exists.

If the above tests indicate that there is a cointegration among the variables, this study will apply panel FMOLS model.

3.1.3. Panel full modified OLS, panel dynamic OLS, and panel mean group

After finding the existence of long run relations among the panel series, there is the need to estimate the size and sign of these relations. In other words, cointegration analysis has only verified the existence of long run relations among the variables of eight models. The quantitative values are needed to make interpretations and comparisons. In panel estimation literature, panel OLS (fixed effect estimator) and dynamic OLS methods are in the class of parametric approaches, whereas fully modified (FM) OLS is a nonparametric approach. In the panel unit root and cointegration tests, there is no consensus among scholars on which estimation method performs better in estimating less biased and more robust coefficients. For example, Kao and Chiang (2000) found that FMOLS may be more biased than DOLS (Harris and Sollis, 2005). Banerjee (1999) claimed that FMOLS or DOLS are asymptotically equivalent for more than 60 observations. To overcome this shortcoming, panel fully modified ordinary least squares (FMOLS) and panel dynamic ordinary least squares (DOLS) methods developed by Pedroni (2000; 2001) will be used in this study. FMOLS and DOLS estimators were developed after deviated results were seen in the estimation of series that have long term relationship via least squares method. FMOLS method corrects the autocorrelation and endogeneity problem using a non-parametric approach, whereas autocorrelation is eliminated in

DOLS method and the estimation is made by taking the variables with their lag values.

Pooled mean group (PMG) is also known as Panel ARDL, which is the combination of pooling and averaging the coefficients, whereas MG estimator is based on estimating N time-series regressions and averaging the coefficients (Pesaran et al., 1999). PMG estimation derives the long run parameter for average long run parameter from ARDL model for individual country (Pesaran et al., 1999). For example, ARDL is as follows:

$$\alpha_i(K)y_{it} = b_i(K)x_{it} + c_{iyit} + \varepsilon_{it} \quad (3)$$

For country i, for $i = 1,\ldots, N$, long run parameter is as follows:

$$\varepsilon_i = \frac{b_i(1)}{c_i(1)} \quad (4)$$

and MG estimator for the overall panel is as follows:

$$\varepsilon = \frac{1}{N}\sum_{i=1}^{N}\varepsilon_i \quad (5)$$

MG estimation with high sequence of lag will have a consistent estimator for long run average parameter. MG estimation allows both slope and intercept to be different among the countries. For fixed-effect method, the slope is fixed, and the intercept is allowed to be different among the countries. In PMG estimation, the long run coefficient is fixed to be the same for all countries, whereas short run coefficient is allowed to be different. In other words, PMG estimator yields efficient and consistent estimates when homogeneity restriction is true. When N is rather small, PMG estimator is less sensitive to outlier's problem as well as simultaneously correct the serial autocorrelation problem and the problem of endogenous regressors by choosing appropriate lag structure for both dependent and independent variables. This study will apply PMG that requires appropriate lag selection. The lag is selected by Schwarz Information Criterion (SIC). The lag length can be determined by taking maximum lags and choosing the model where the value of SIC is minimum. It is relevant to use PMG estimation to capture the short run elasticities outcomes for the model which are not found in panel FMOLS and panel DOLS. This study used Eviews 9.5 to conduct empirical analysis. The basic ARDL with lag order of p, q, r, s, w, y, z, equation system for the period of time $t = 1, 2,\ldots, 26$ and country $i = 1, 2,\ldots, 4$ for dependent variable y is as follows:

$$\begin{aligned}\Delta LNRE_{it} &= \alpha_{0i} + \sum_{j=1}^{p}\partial_{ij}\Delta LNRE_{i,t-j} + \sum_{j=0}^{q}\vartheta'_{ij}\Delta LNGDP_{i,t-j} + \\ &\sum_{j=0}^{r}\vartheta'_{ij}\Delta LNFDI_{i,t-j} + \sum_{j=0}^{s}\vartheta'_{ij}\Delta LNTO_{i,t-j} + \\ &\sum_{j=0}^{w}\vartheta'_{ij}\Delta LNUPOP_{t-i} + \sum_{j=0}^{y}\vartheta'_{ij}\Delta LNCO_{2i,t-j} \\ &+\sum_{j=0}^{z}\vartheta'_{ij}\Delta LNGOV_{i,t-j} + \varepsilon_{it} \quad (6)\end{aligned}$$

PMG allows the long run coefficient to be equal over the cross-section that is $\alpha i' = \alpha'$ for all I; thus, the specific model for PMG is given as below:

$$\begin{aligned}\Delta LNRE_{it} &= \alpha_{0i} + \theta_i(LNRE_{i,t-1} - \alpha' LNGDP_{i,t-1} - \alpha' LNFDI_{i,t-1} \\ &-\alpha' LNTO_{i,t-1} - \alpha' LNUPOP_{i,t-1} - \alpha' LNCO_{2i,t-1} \\ &+\alpha' LNGOV_{i,t-1}) + \sum_{j=1}^{p-1}\partial_{ij}\Delta LNRE_{i,t-j} \\ &+\sum_{j=0}^{q-1}\vartheta'_{ij}\Delta LNGDP_{i,t-j} + \sum_{j=0}^{r-1}\vartheta'_{ij}\Delta LNFDI_{i,t-j} + \\ &\sum_{j=0}^{s-1}\vartheta'_{ij}\Delta LNTO_{i,t-j} + \sum_{j=0}^{w-1}\vartheta'_{ij}\Delta LNUPOP_{t-i} + \\ &\sum_{j=0}^{y-1}\vartheta'_{ij}\Delta LNCO_{2i,t-j} + \sum_{j=0}^{z-1}\vartheta'_{ij}\Delta LNGOV_{i,t-j} + \varepsilon_{it} \quad (7)\end{aligned}$$

This study has used annual data ranging from 1990 up to 2016 (27 years) as a sample period. A summary of the data and its sources is displayed in Table 1.

4. ANALYSIS AND DISCUSSION

Table 2 shows the panel unit root tests that consist of five different tests suggested by Levin et al. (2002), Breitung (2000), Im et al. (2003), Maddala and Wu (1999), and Hadri (1999). The panel unit root tests are tested both at level and at first difference to detect the trend of stationarity more clearly. The outcomes provide crucial information to the researcher in selecting suitable long run estimation. The outcomes of the first four-unit root tests show mix stationarity of the tested variables at level and at first difference. For example, Levin et al. (2002) found that LNRE, LNFDI, LNUPOP, and $LNCO_2$ are the most significant at 1% level and these variables seem to be stationary at first difference except LNUPOP. A more powerful unit root test namely Hadri test (1999) was performed and the mix stationarity is detected for the variables. Thus, it can be concluded that panel ARDL analysis is suitable to derive its short run and long run elasticities besides panel FMOLS and DOLS. However, there is the need to confirm the existence of long run cointegration for the estimate model using Pedroni and Kao Panel Cointegration test which is disclosed in Table 3 to reach the level of this analysis.

The Pedroni Residual cointegration test consists of seven tests which are divided into two groups: within dimension and between

Table 1: Sources of data

Variable	Description	Source
RE	RE (% total final energy consumption)	WDI
GDP	GDP per capita (constant, 2010)	WDI
FDI	Foreign direct investment, net inflows (% of GDP)	WDI
TO	Trade (% of GDP)	WDI
UPOP	Urban population growth (annual %)	WDI
CO_2	Carbon emissions (metric tonnes per capita)	WDI
GOV	Corruption perception index	ICRG

WDI stands for World Development Indicators (2018) and ICRG stands for International Country Risk Guide (2017)

Table 2: Panel unit root test

Method test	Level		First difference	
	Individual intercept	Individual intercept and trend	Individual intercept	Individual intercept and trend
Null: Panel data has unit root (assumes common unit root process)				
Levin et al. (2002) t*-statistics				
1. LNRE	−1.825 (5)**	−0.741 (1)	−1.826 (0)**	0.399 (4)
2. LNGDP	1.821 (0)	−0.265 (5)	−5.828 (1)***	−4.034 (5)***
3. LNFDI	−3.182 (1)***	−2.380 (1)***	−7.184 (5)***	1.093 (5)
4. LNTO	−0.371 (0)	−1.795 (3)**	−9.097 (0)***	−4.648 (5)***
5. LNUPOP	−2.499 (1)***	−3.462 (2)***	−1.174 (1)	0.955 (0)
6. $LNCO_2$	−3.519 (0)***	−1.134 (5)	−7.040 (4)***	−5.621 (5)***
7. LNGOV	−1.194 (0)	0.114 (1)	−8.597 (0)***	−7.071 (2)***
Breitung (2000) t*-statistics				
1. LNRE	-	1.468 (1)	-	1.604 (4)
2. LNGDP	-	1.449 (5)	-	−3.465 (5)***
3. LNFDI	-	−2.734 (1)***	-	−1.282 (5)*
4. LNTO	-	2.339 (3)	-	−3.948 (0)***
5. LNUPOP	-	1.697 (2)	-	0.606 (0)
6. $LNCO_2$	-	−0.990 (5)	-	−1.737 (5)***
7. LNGOV	-	−1.065 (1)	-	−3.082 (2)***
Null: Panel data has unit root (assumes individual unit root process)				
Im et al. (2003) W-statistic				
1. LNRE	−0.898 (5)	−0.895 (1)	−4.831 (1)***	−4.088 (4)***
2. LNGDP	3.701 (0)	−1.860 (5)	−4.670 (4)***	−3.531 (5)***
3. LNFDI	−3.811 (1)***	−2.704 (1)***	−7.906 (5)***	−3.932 (5)***
4. LNTO	0.229 (0)	0.875 (3)	−8004 (0)***	−4.979 (5)***
5. LNUPOP	0.665 (1)	−1.393 (2)*	−1.043(1)	1.010 (0)
6. $LNCO_2$	−1.760 (0)**	−3.586 (5)***	−6.871 (4)***	−6.212 (5)***
7. LNGOV	−1.276 (0)	−0.051 (1)	−8.285 (0)***	−7.048 (2)***
Maddala and Wu (1999) and Choi (2001)				
ADF-Fisher Chi-square				
1. LNRE	11.116 (5)	9.689 (1)	36.994 (0)***	29.793 (4)***
2. LNGDP	2.810 (0)	17.322 (5)	35.276 (1)***	25.603 (5)***
3. LNFDI	29.133 (1)***	20.828 (1)***	64.680 (5)***	29.599 (5)***
4. LNTO	6.837 (0)	5.768 (3)	63.146 (0)***	36.845 (5)***
5. LNUPOP	7.331 (1)	12.828 (2)	13.673 (1)*	10.142 (0)
6. $LNCO_2$	14.437 (0)*	26.239 (5)***	55.489 (4)***	46.408 (5)***
7. LNGOV	14.106 (0)*	9.412 (1)	65.755 (0)***	51.702 (2)***
PP-Fisher Chi-square				
1. LNRE	6.730 (5)	7.681 (1)	33.695 (0)***	22.101 (4)***
2. LNGDP	2.927 (0)	7.583 (5)	37.625 (1)***	34.891 (5)***
3. LNFDI	28.108 (1)***	20.174 (1)***	102.341 (5)***	335.038 (5)***
4. LNTO	7.638 (0)	4.565 (3)	67.403 (0)***	122.853 (5)***
5. LNUPOP	33.049 (1)***	6.807 (2)	13.123 (1)	10.702 (0)
6. $LNCO_2$	13.771 (0)*	14.984 (5)*	71.940 (4)***	61.191 (5)***
7. LNGOV	14.187 (0)*	8.043 (1)	67.111 (0)***	52.849 (2)***
Null: Panel data has no unit root (assumes individual unit root process)				
Hadri (1999)				
1. LNRE	7.388***	4.655***	−0.273	1.901**
2. LNGDP	8.089***	3.198***	0.677	1.045
3. LNFDI	0.546	2.566***	−0.623	1.959**
4. LNTO	3.236***	5.958***	3.755***	6.848***
5. LNUPOP	7.776***	3.146***	1.970**	3.175***
6. $LNCO_2$	7.642***	2.084**	1.073	2.565***
7. LNGOV	2.210**	1.802**	0.066	2.663***

*,**,*** Indicate significant at 10%, 5% and 1% significance level respectively

dimensions. The analysis is repeated for the following three different cases: (I) Individual intercept; (II) individual intercept and trend; and (III) no intercept and no trend. Among these three tests, this study refers to the first category as it is the only case that generates the outcomes of Kao Residual cointegration test. This study displayed all outcomes in the same table to increase the robustness of the analysis. The outcomes confirmed the existence of long run cointegration relationship for the variables in the model in which 6 out of 12 tests cover both statistic and weighted statistic are significant either at 10%, 5%, or 1% level. Furthermore, some of the tests are significant for the second and third cases. This evidence allowed us to proceed in testifying the long run elasticities that focused on examining the relationship of each independent variable on the dependent variable.

Table 3: Pedroni and Kao panel cointegration

Method test	Deterministic trend specification					
	Individual intercept		Individual intercept and trend		No intercept no trend	
	Statistic	Weighted statistic	Statistic	Weighted statistic	Statistic	Weighted statistic
Pedroni residual cointegration test						
Within-dimension						
Panel v-statistic	2.437***	1.515*	1.565*	1.191	2.352***	1.237
Panel rho-statistic	0.770	1.064	1.341	1.658	−0.453	0.482
Panel PP-statistic	−0.868	−0.254	−0.749	−0.413	−1.837**	−0.271
Panel ADF-statistic	−2.039**	−2.528***	−1.678**	−2.892***	−2.002**	−0.573
Between-dimension						
Group rho-statistic	1.793		2.352		1.119	
Group PP-statistic	0.033		−2.767**		−0.284	
Group ADF-statistic	−3.210***		−3.157***		−1.883	
Kao residual cointegration test						
ADF	−4.013***					

*,**,*** Indicate significant at 10%, 5% and 1% significance level respectively

Table 4 shows the results of long run elasticities which were derived from FMOLS, DOLS, and PMG. It was proven in all three tests that economic growth of ASEAN (LNGDP) has a negative relationship with the consumption of renewable energy (LNRE). Higher economic growth experienced in these countries can lead towards the reduction of renewable energy consumption as the countries are still heavily depended on pollutive types of energy such as coal and fossil fuel. They are not ready to invest in alternative energy on a large scale. For instance, 1% increase in LNGDP can reduce the country's demand on renewable energy by 0.64% (FMOLS), 0.54% (DOLS), and 0.69% (PMG).

Table 4: Results of long run elasticities

Regressor	FMOLS	DOLS	PMG (1,1,1,1,1,1,1)
LNGDP	−0.635***	−0.541*	−0.687***
LNFDI	0.018	0.126	0.011
LNTO	−0.305***	−0.385**	0.162
LNUPOP	0.792***	0.900***	0.282
$LNCO_2$	−0.174	−0.263	0.104
LNGOV	−0.001	0.033	0.217*
R square	0.989	0.999	-
Adjusted R square	0.988	0.995	-

*,**,*** Indicate significant at 10%, 5% and 1% significance level respectively

Next, the outcomes of trade openness (LNTO) exhibit similar expected sign like LNGDP where it has a negative relationship with renewable energy consumption (LNRE) as proven by FMOLS and DOLS estimation. Higher degree of openness to trade in selected ASEAN countries can reduce the demand for renewable energy as the dependency on pollutive energy is high due to the huge demand by their local industries to generate productivity. Technically, 1% increase in LNTO reduces LNRE by 0.31% (FMOLS) and 0.39% (DOLS). Next, it is found that the increase in urban population (LNUPOP) for selected ASEAN countries can lead to higher demand for renewable energy (LNRE). Technically, 1% increase in urban population increases the demand for renewable energy by 0.79% (FMOLS) and 0.90% (DOLS). Urban area usually focuses on energy efficiency technology such as the use of solar panel for housing projects and also offices. Lastly, governance, proxied by level of corruption perception has a positive relationship with renewable energy consumption for selected ASEAN countries which is proven by PMG estimation. This result is a good sign for the nation as higher level of governance can help the country to be involved in more high-prolific projects without the fear of corruption issues as there are more transparent procedures in selecting the developers. This strategy can enhance the success rate of projects related to renewable energy. For instance, 1% increase in LNGOV can increase LNRE by 0.22%.

This study extends the analysis by running the short run elasticities as well as checking the speed of adjustment (ECT) for selected ASEAN countries as a group and individual. The analysis is performed using PMG method and Table 5 shows the outcomes. In the short run, there is no single indicator in the model that can influence LNRE for the selected ASEAN countries. In Indonesia, it is found that LNGDP and $LNCO_2$ have a significant and negative relationship with LNRE, while the rest of the variables are not significant except for LNUPOP that is significant and can positively influence LNRE. For Malaysia, LNGDP, LNTO, and LNGOV have a significant and negative relationship with LNRE. For the Philippines, LNGDP, LNTO, and LNGOV have a significant and negative relationship with LNRE while LNFDI and $LNCO_2$ have a positive and significant relationship with LNRE. For Thailand, $LNCO_2$ has a negative and significant relationship with LNRE while LNFDI, LNTO, and LNGOV have a positive and significant relationship with LNRE. From the outcomes of the four selected ASEAN countries, the improvement in governance can increase the consumption of renewable energy for Indonesia and Thailand, as well as reducing the consumption of renewable energy for Malaysia and the Philippines.

Table 5 shows the estimated lagged ECT in PMG regression for the four countries which are negative and statistically significant. Based on the ECT value, the highest speed of adjustment was obtained by Malaysia (−0.63), followed by Indonesia (−0.18), Thailand (−0.14), and the Philippines (−0.07). More than 63%, 18%, 14%, and 0.7% of the adjustments were completed within less than a year for all the selected ASEAN countries.

Table 5: Short run elasticities for selected ASEAN countries

Variables	ASEAN-4	Indonesia	Malaysia	Philippines	Thailand
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
D(LNGDP)	0.127	−0.447***	−0.625***	−0.488**	0.154
D(LNFDI)	−0.007	0.033***	1.290	0.016***	0.010***
D(LNTO)	0.149	0.027***	−0.091***	−0.238***	0.112***
D(LNUPOP)	−0.756	−0.415	0.4732	−4.200	1.117
D(LNCO$_2$)	−0.117	−0.013***	0.027	0.102**	−0.586***
D(LNGOV)	−0.104	0.018***	−0.564**	−0.049***	0.179***
C	2.237**	3.779	3.859	0.407*	0.903
ECT$_{t-1}$	−0.252**	−0.184***	−0.625***	−0.065***	−0.136***

*,**,*** Indicate significant at 10%, 5% and 1% significance level respectively

5. CONCLUSION AND POLICY RECOMMENDATION

This study was conducted based on the factors affecting renewable energy. It examined the relationship between GDP, CO_2 emissions, FDI, trade openness, urbanisation, and the quality of governance on renewable energy consumption in the selected ASEAN countries. The findings in the long run elasticities concluded that urbanisation has a significant positive impact on renewable energy based on FMOLS and DOLS analyses, whereas the quality of governance has a significant positive impact on renewable energy based on PMG analysis. The long run elasticities results revealed that GDP and trade openness have a significant negative impact on renewal energy, whereas FDI and the quality of governance are not significant on renewal energy. The outcomes for ASEAN-4 groups in the short run elasticities analyses revealed that none of the factors affected renewable energy consumption. On the other hand, the individual ASEAN-4 members showed mixed evidence for the short run elasticities.

Although there are various initiatives to develop the policies on renewable energy consumption, the implementation is still at an infant stage. Many challenges especially in financing the renewable energy project still remain unresolved as it involves a huge amount of fund. A study by Mat Rahim and Mohamad (2018) suggested green sukuk to finance renewable projects while Lam and Law (2018) suggested debt, equity, and grants. However, the return of this investment is questionable. The financier would need to monitor that their investment is used to finance the renewable project and not for other business operation purposes. Therefore, there is the need to have a comprehensive policy on renewable energy project agreement. It was found that urbanisation has a significant impact on renewable energy consumption in the long run. According to Worldometer (2018), the urban population in ASEAN in 2018 is 49.25% and it is expected to increase to 63.7% in 2050. Hence, it is recommended to include renewal energy policies in the development such as promoting smart cities, solar infrastructures, and water consumption. This policy is in line with one of the SDG which emphasized on the access to affordable, reliable, and modern energy. This study concludes that better quality of governance can increase renewable energy consumption. Hence, leaders should be aware of the importance of renewable energy consumption. They will able to implement the policies when they are equipped with knowledge in this area. Knowledgeable and experienced leaders can lead to quality governance in which they can manage the resources. This study can be used as a guide for the strategies to develop policies on renewable energy consumption especially on GDP and trade openness. Both aspects can contribute to renewable energy consumption.

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