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Factors Influencing the Consumption of Renewable Energy in Selected ASEAN Countries: A Dynamic Panel Data Analysis

Umme Humayara Manni,[a] Kasim Hj Mansur[b] and Munshi Naser Ibne Afzal[c]

Abstract: *Governments and policymakers have discussed energy security due to the instability of the global energy market and the risks greenhouse gas (GHG) emissions cause to the environment. Renewable energy generation and consumption reduce carbon dioxide (CO_2) emissions most effectively. Thus, this paper highlights factors that, if aggressive environment policies are implemented, might enhance or even avoid energy security degradation. The study uses a balanced panel data set for Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam that covers the 1990 to 2020 period. Pooled panel dynamic least squares are employed in this study. Renewable energy consumption is favourably influenced by gross domestic product (GDP) per capita, energy intensity per capita, and installed renewable energy capacity. Utilisation of renewable energy is inversely related to per capita consumption of electricity, CO_2 emissions, and use of fossil fuels. Given the lack of research identifying the factors influencing energy security in the Association of Southeast Asian Nations (ASEAN), this study focuses on the drivers that influence energy security, which is explained by the proportion of renewable energy in final energy consumption. Without identifying energy demand and supply sources, especially renewable energy-based power generation, policymakers cannot fulfil their goals.*

Keywords: Energy security; Panel DOLS; FMOLS; PMG-ARDL; Renewable energy consumption
JEL Classification: F64, Q43, Q56

[a] Corresponding author. Faculty of Business, Economics and Accountancy, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia. *Email: umme_humayara_db20@iluv.ums.edu.my*. ORCID ID: 0000-0002-0187-8937

[b] Faculty of Business, Economics and Accountancy, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia. *Email: kmansur@ums.edu.my*

[c] Department of Economics, Shahjalal University of Science and Technology, Sylhet, Bangladesh. *Email: munshinaser-eco@sust.edu*. ORCID ID: 0000-0002-6351-4856

1. Introduction

The major goal of this study is to use dynamic panel data analysis to empirically analyse the factors impacting the use of renewable energy in a selected number of Southeast Asian Nations (ASEAN). The study shows that a panel dynamic model enables us to estimate the time-varying relationships between the dependent and independent variables over a longer period of time while controlling for cross-sectional variance across countries or regions (Garca-lvarez et al., 2016). This is crucial to comprehending both renewable and non-renewable energy generation and consumption. It also takes into consideration unobserved regional or national differences in resource endowments or institutional traits that influence energy production and consumption. Additionally, it can assess the long-term effects of renewable energy efforts. The complex interactions between energy production, consumption, and policy actions can be better understood by policymakers and researchers with the aid of panel dynamic models (Xu et al., 2019). Renewable energy deployment worldwide combats climate change and provides power to billions of impoverished people. The quest for renewable energy is turning into a serious issue since renewable energy sources may meet up to half of the world's energy requirements by 2050 (Krewitt et al., 2007).

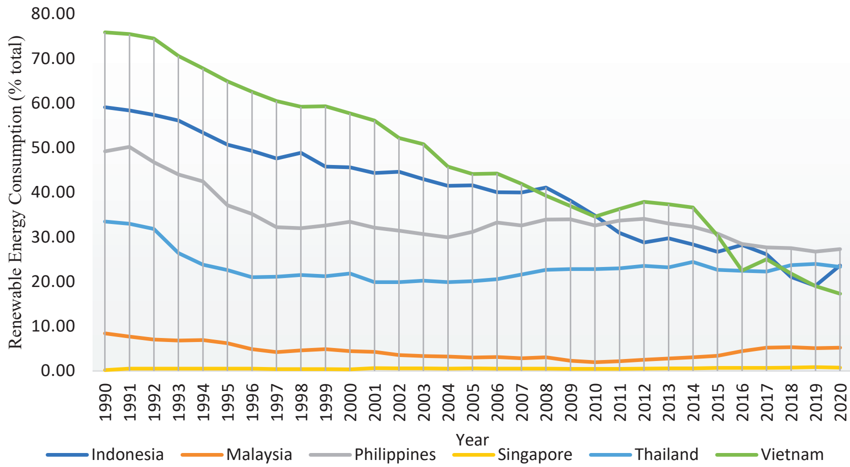
Even the International Renewable Energy Agency (IRENA, 2018) believes that by 2050, two-thirds of the world's energy supply must come from renewable sources. The replacement of fossil fuels with new, renewable sources is necessary for a potential future transition to a low-carbon economy (Foxon et al., 2008; Grubb et al., 2008; Jiang et al., 2018). Developing nations must compromise the environment in order to achieve their economic objectives (Acheampong et al., 2019; Akintande et al., 2020; Asongu & Odhiambo, 2021). In the upcoming decades, Southeast Asia's economy will expand quickly, and energy consumption is expected to rise sharply. Fossil fuels, which account for more than 85% of all primary energy in the world today, dominate the energy supply (IRENA, 2022).

ASEAN-6 (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) has emerged as a growing economy, with a 3% increase in gross domestic product (GDP) per capita from 2000 to 2020 (World Bank, 2022). This expansion raises the issue of how ASEAN will meet its rising energy demands and what is driving most of this increase. It can continue to rely on fossil fuels, the bulk of which come from non-indigenous sources (ACE, 2020), increasing pollution, and exposing the region to volatile and unaffordable world commodity markets. The area could lower energy prices, emissions, and economic growth by using its abundant, affordable, locally available renewable energy resources. ASEAN can provide local, affordable fossil fuel alternatives with its vast green energy potential and ambitious near-term goals.

The average renewable energy consumption for the ASEAN-6 nations was 16.25% in 2020, which is lower than Sub-Saharan Africa countries (Oluoch et al., 2021), and also lower than the average figure for the ASEAN-6 countries in 1990, which was 37.72%. (Figure 1). Singapore has the lowest value in the group, and Vietnam has the greatest. For each of the six ASEAN nations, the trend is deteriorating. Malaysia and Thailand have seen minor rising trends in recent years; however, these trends are negligible when compared to the value in the 1990s. IRENA's most recent *World Energy Transitions Outlook*, produced in early 2022, suggested that a significant reduction in greenhouse gas (GHG) emissions was required to accomplish the Paris Agreement goal of keeping the temperature rise worldwide well below 2°C and limited to 1.5°C. When compared to the 1990s value of 3.53%, the ASEAN-6 nations' share of global GHG emissions in 2020 was about 4.66% (World Bank, 2022) (Figure 2). The Philippines has the lowest carbon dioxide (CO_2) emissions in terms of value, with Vietnam coming in second. Singapore has the highest CO_2 emissions among the six nations, regularly above 8% since 2010.

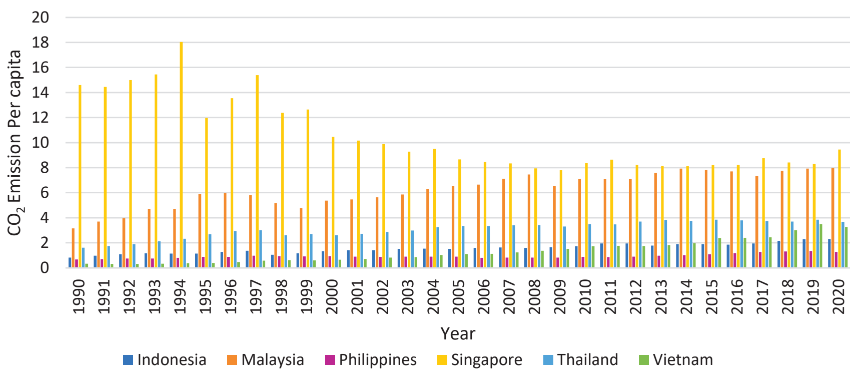
Even though numerous studies have looked at historical energy transitions (Fouquet, 2008; Fouquet & Pearson, 1998; Gales et al., 2007), giving a rich understanding of their nature and implications, very few studies have empirically examined the factors influencing the consumption of renewable energy (Lin & Omoju, 2017; Liu et al., 2019; Marques et al., 2019). To the best of our knowledge, only two studies have investigated the factors that influence the percentage of renewable energy that is utilised in ASEAN countries. Huang et al. (2022) analyse the ASEAN-5 nations to evaluate how trade, environmental pollution, and government impact the consumption of renewable energy, while Kumaran (2020) primarily looks at the ASEAN-5 nations. However, no research has looked at the ASEAN-6 nations. Nearly all literature studies have used panels of regions to explain renewable energy usage. This panel data study is the first to examine the long-term connection between renewable energy usage and other independent factors in ASEAN-6. In order to understand the current pattern and its potential long-term drivers, this paper examines ASEAN renewable energy consumption variables. The panel data analysis of the study is based on ASEAN-6.

Figure 1: Renewable Energy Consumption for ASEAN-6, 1990 - 2020



Source: World Development Indicators 2022.

Figure 2: CO_2 Emission Per Capita for ASEAN-6, 1990 - 2020



Source: World Development Indicators 2022.

The study aims to assess the research question, 'Which factors are influencing renewable energy consumption in the selected ASEAN region?' As these ASEAN economies will play a pivotal role in determining the future trajectory of global energy demand, it is of the utmost importance to identify the common drivers, challenges, and risks they face, as well as the most effective means of responding to these challenges to ensure regional and, by extension, global energy security.

2. Literature Review

Liddle and Sadorsky (2017) utilise a large panel data set of 93 nations and a new panel estimate approach to examine how much non-fossil fuel power production reduces carbon dioxide emissions. Eberhardt and Teal's heterogeneous Pesaran common correlated effects mean group (CMG) and augmented mean group (AMG) estimators are used in the second-generation panel unit root test. Olarewaju et al. (2019) uses yearly data from 1990 to 2015 to analyse panel data from Africa's five most populous and influential economies: Nigeria (West), Egypt (North), Ethiopia (East), the Democratic Republic of the Congo (Central), and South Africa. Le and Park (2021) performed the first analysis on energy insecurity sources for 139 countries between 1996 and 2016. Kartal (2022) examined energy security and growth in 74 nations using Kónya's (2006) bootstrap panel Granger causality technique. A total of 20 and 14 countries had a one-way causal association between GDP and energy security risk level, whereas 22 had a bidirectional relationship. From 1990 to 2016, Ozcan and Ozturk (2019) performed a bootstrap panel causality test to analyse renewable energy consumption and economic development in emerging nations. Except for Poland, all markets are developing, and conserving energy does not hurt growth in the 16 rising nations evaluated.

Wang and Wang (2020) study renewable energy consumption and economic development using a nonlinear panel threshold model. This model examines renewable energy's internal mechanism for economic development, utilising threshold factors including urbanisation, non-renewable energy intensity, and income per capita. Long-term estimations show that renewable energy boosts economic development in Brazil, the United Kingdom and France, whereas non-renewable energy boosts growth in eight of the 10 nations (Fareed & Pata, 2022). The study by Oluoch et al. (2021) of panel autoregressive distributed lags (ARDL) panel models found that renewable energy consumption is significant and positively correlates with the independent variables' GDP per capita and education index over time. Renewable energy investment will pay off for OECD countries that use more at a certain level (Wang & Wang, 2020). The RE sector affects economic growth, but solely due to natural resource issues (Xu et al., 2019). The authors' oil dependence-real estate development connection is noteworthy since it considerably minimises economic growth downsides. Bhattacharya et al. (2016) examine how renewable energy consumption impacts the world's largest renewable energy users' economies. The authors observed cross-sectional dependence and heterogeneity across countries using panel estimation.

Significant amounts of renewable energy are used, and their use is inversely correlated with CO_2 emissions per person (Chen et al., 2019; Oluoch et al., 2021). Consumption of non-renewable energy was seen to have a positive impact on CO_2 emissions, although this differed across the three regions, with the central region benefiting the most, followed by the western and eastern regions (Chen et al., 2019). Nguyen and Kakinaka (2019) examine how the relationship between the use of renewable energy and carbon emissions is connected to the stage of development by employing a panel cointegration study of 107 countries between 1990 and 2013. In low-income countries, renewable energy use increases carbon emissions, but in high-income countries, it decreases output. Every 1% increase in the percentage of non-fossil fuel energy generation reduces the number of CO_2 emissions per person from electricity generation by approximately 0.82% (Liddle & Sadorsky, 2017). The authors' findings imply that increasing the use of non-fossil fuels only reduces carbon emissions slightly. The major energy producers in Sub-Saharan Africa emit less CO_2 because of trade liberalisation (Inglesi-Lotz & Dogan, 2018). Conversely, FDI has minimal effects, whereas trade openness has a negative impact on all metrics of energy insecurity (Le & Park, 2021).

Inglesi-Lotz and Dogan (2018) separate the significance of renewable and non-renewable energy from CO_2 emissions while also examining the causative linkages between CO_2 emissions, energy consumption, and economic growth in Sub-Saharan Africa. To test the environmental Kuznets curve (EKC) theory for Africa's Big 10 energy providers, panel estimating methods that consider panel heterogeneity and cross-sectional dependence are used. The authors claim that non-renewable energy usage increases pollution and slows environmental degradation. Chen et al. (2019) evaluate the EKC concept at the regional level in China, looking at the influence of economic development, renewable energy consumption, and non-renewable energy consumption on CO_2 emissions. The total degree of energy insecurity is decreased by increased income and good governance (Le & Park, 2021).

There are few studies in ASEAN that use panel model analysis in the context of renewable energy consumption. This study focuses on the variables that influence renewable energy usage, as measured by the proportion of renewable energy in total energy consumption. The goal is to investigate major variables influencing renewable energy usage in selected ASEAN countries to develop a comprehensive energy plan for Sustainable Development Goal (SDG) 7. Switching to renewable energy will offer each country long-term, low-cost energy. Policymakers cannot meet their renewable energy targets unless they identify energy demand and supply sources, particularly renewable energy-based power production. This research gap will be filled by examining the impact of economic (GDP per capita, foreign direct investment, average crude oil price), energy (renewable electricity capacity, energy intensity, electricity consumption), and environmental (CO_2 emissions) variables on renewable energy consumption in ASEAN6 from 1990 to 2020.

3. Methodology

The relationship between renewable and non-renewable energy consumption, GDP, foreign direct investment (FDI), energy intensity, and the market price of oil is dynamic and complex. A dynamic panel estimation model can be applied to this issue, as it permits the analysis of time series data and the estimation of fundamental economic relationships over time. The mathematical derivation of the model-based theory of using a dynamic panel model is as follows:

$$y_{it} = \alpha + \beta x_{it} + \delta y_{i,t-1} + \varepsilon_{it} \tag{1}$$

In this model, y_{it} is the dependent variable for the i-th cross-sectional unit at time t, x_{it} is the explanatory variable for the i-th cross-sectional unit at time t, $y_{i,t\text{-}1}$ is the lagged dependent variable for the i-th cross-sectional unit at time t-1, and ε_{it} is the error term. The model-based theory suggests that the lagged dependent variable $y_{i,t-1}$ should be included in the model to capture the dynamics of the data over time. This can be done by defining the first difference of the dependent variable as follows:

$$\Delta y_{it} = y_{it} - y_{i,t-1} \tag{2}$$

The first difference in the dependent variable represents the change in the dependent variable between time t and t-1. The original model can be rewritten using the first difference of the dependent variable as follows:

$$\Delta y_{it} = \beta x_{it} + \varepsilon_{it} \tag{3}$$

However, unobserved heterogeneity or omitted variables may be associated with both the dependent and explanatory variables. To control for this potential bias, we can include lagged values of the explanatory variable as additional explanatory variables:

$$\Delta y_{it} = \beta x_{it} + \gamma x_{i,t-1} + \varepsilon_{it} \tag{4}$$

where γ is the autoregressive coefficient that captures the effect of the lagged explanatory variable on the change in the dependent variable.

The fully modified ordinary least squares (FMOLS) estimator, another non-parametric dynamic model for β_i, is derived by considering the long-run covariance matrix of the residuals and regressors to correct for endogeneity.

3.1 Panel methods

This study aims to determine which model best suits the given circumstances. Unit root tests, cointegration tests, and the estimation of long-run (and short-run) relationships are the typical components of panel data analysis. To prevent any erroneous findings, the panel analysis starts with panel unit root testing. Testing for panel cointegration follows if the series are non-stationary, which brings the analysis to an end. The unit root Levin, Lin, and Chu (LLC) (Levin et al., 2002), test and the Im, Pesaran, and Shin (IPS) test (Im et al., 2003), Fisher-type tests using augmented Dickey–Fuller (ADF) and Phillips-Perron (PP) tests (Choi, 2001; Maddala & Wu, 1999) are used in this study after the panel.

Next, the study assessed panel cointegration tests based on Kao (1999) and Johansen-Fisher, established by Maddala and Wu (1999). Three estimation techniques, pooled panel FMOLS, pooled panel dynamic least squares (DOLS), and pooled mean group-autoregressive distributed lag (PMG-ARDL), are used to estimate the long-term relationship in general. FMOLS and DOLS only provide long-term predictions, so PMG-ARDL is used for short-term estimation. Researchers have extended the DOLS estimator by Saikkonen (1992) and Stock and Watson (1993) (Kao & Chiang, 2000; Pedroni, 2001), as well as the FMOLS estimator by Phillips and Hansen (1990) (Kao & Chiang, 2000; Pedroni, 2000; Phillips & Moon, 1999), to panel data. The standard ARDL model's cointegration form is modified for a panel setting by the PMG-ARDL (Pesaran et al., 1999) by allowing the intercepts, short-run coefficients, and cointegration terms to vary across cross-sections. The following is an illustration of the econometric model developed in accordance with the objectives of this thesis:

$$Y\,(REENC) = f(GDPPC, REICAP, ENIPC, ECPC, FDI, CO2EPC, AOP)$$

All the variables were transformed into log-linear forms (*LN*) so as to reduce the sharpness of the time series data so that there was a consistent and reliable estimation (Shahbaz & Rahman, 2010). The following model was employed to understand the long-term factors that affect the utilisation of renewable energy.

$$LNREENC_{it} = \alpha_i + \beta_{1i}LNGDPPC_{it} + \beta_{2i}LNREICAP_{it} + \beta_{3i}LNENIPC_{it} + \beta_{4i}LNECPC_{it} + \beta_{5i}LNFDI_{it} + \beta_{6i}LNCO2EPC_{it} + \beta_{7i}LNAOP_{it} + \varepsilon_{it}$$

Where, $LNREENC_{it}$ represents renewable energy consumption at time t, $LNGDPPC_{it}$ represents GDP per capita constant 2015 USD at time t, $LNREICAP_{it}$ represents renewable electricity installed capacity at time t, $LNFDI_{it}$ represents foreign direct investment at time t, $LNENIPC_{it}$ represents energy intensity per capita at time t, $LNECPC_{it}$ represents electricity consumption per capita at time t, $LNCO_2EPC_{it}$ represents CO_2 emission per capita at time t, $LNAOP_{it}$ represents average crude oil price at time t, ε_{it} is the error term while i and t denote country and time, respectively.

3.2 Estimation procedures

Due to the availability of data for Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam, the study used a balanced panel data set that spans 30 years (1990–2020). DOLS, FMOLS and PMG-ARDL were employed in this study.

Except for renewable electricity capacity and average crude oil price, the data was primarily taken from the World Development Indicators (WDI). Data on renewable electricity capacity was gathered from the GlobalEconomy website and the average price of crude oil from the World Bank commodity price dataset. We normalised our variables by obtaining their natural logarithmic representations to reduce heteroscedasticity. Following that, the specification was subjected to unit root testing, cointegration tests, and model estimation using the DOLS, FMOLS, and PMG-ARDL techniques. The estimation techniques were carried out using the statistical analysis tool EViews 11.

3.3 Descriptive statistics

The descriptive data for ASEAN-6 is listed in Table 1. Vietnam has the lowest GDP per capita while using the most renewable energy. Singapore, however, has the greatest GDP per capita and the lowest renewable energy use. Malaysia trails Thailand and Singapore in GDP per capita. Thailand ranks third in mean and maximum values, followed by Malaysia, second after Singapore. Vietnam leads in renewable power capacity (mean = 8.63, maximum = 38.38), while Singapore comes in worst (mean = 0.14, minimum = 0). Vietnam emits the least CO_2 per capita (the Philippines emits the least overall in terms of mean value), whereas Singapore emits the highest, as expected given renewable energy usage figures.

Table 1: Descriptive Statistics for ASEAN-6

Variable	Country	Mean	Std. dev.	Min	Max
REENC	Indonesia	40.13	11.48	19.09	59.10
	Malaysia	4.38	1.71	1.96	8.40
	Philippines	34.14	6.12	26.73	50.20
	Singapore	0.53	0.13	0.20	0.84
	Thailand	23.24	3.52	19.89	33.50
	Vietnam	47.06	17.41	17.29	75.90
GDPPC	Indonesia	2452.35	735.58	1483.64	3892.42
	Malaysia	7474.41	1921.87	4260.27	11114.54
	Philippines	2276.54	593.99	1655.84	3589.62
	Singapore	41918.82	12082.55	23273.12	61373.65
	Thailand	4458.91	1138.15	2608.17	6456.24
	Vietnam	1722.03	811.61	673.39	3352.06
REICAP	Indonesia	6.28	2.21	3.15	9.63
	Malaysia	3.60	2.29	1.45	8.05
	Philippines	4.42	2.04	1.45	7.40
	Singapore	0.14	0.13	0.00	0.47
	Thailand	5.35	3.08	2.46	12.26
	Vietnam	8.63	8.60	0.68	38.38
FDI	Indonesia	1.25	1.37	-2.76	2.92
	Malaysia	3.99	1.94	0.06	8.76
	Philippines	1.63	0.75	0.38	3.12
	Singapore	17.22	6.75	4.23	29.76
	Thailand	2.56	1.50	-0.99	6.43
	Vietnam	5.52	2.24	2.78	11.94
ENIPC	Indonesia	4.44	0.82	3.16	5.44
	Malaysia	5.25	0.45	4.25	5.85
	Philippines	3.89	0.92	2.68	5.15
	Singapore	3.65	1.19	2.05	6.28
	Thailand	4.99	0.24	4.50	5.56
	Vietnam	5.52	0.81	4.38	7.55
ECPC	Indonesia	554.10	290.09	162.52	1089.00
	Malaysia	3249.16	1223.88	1157.36	5100.00
	Philippines	576.07	162.97	335.27	900.00
	Singapore	7770.71	1392.76	4983.05	9500.00
	Thailand	1885.44	670.11	709.55	2900.00
	Vietnam	816.18	721.13	95.25	2450.23

Variable	Country	Mean	Std. dev.	Min	Max
CO_2EPC	Indonesia	1.55	0.39	0.82	2.30
	Malaysia	6.26	1.35	3.14	7.98
	Philippines	0.93	0.18	0.67	1.35
	Singapore	10.54	2.91	7.79	18.04
	Thailand	3.08	0.65	1.60	3.84
	Vietnam	1.31	0.92	0.31	3.49
AOP	Indonesia	49.51	26.78	15.90	95.31
	Malaysia	49.51	26.78	15.90	95.31
	Philippines	49.51	26.78	15.90	95.31
	Singapore	49.51	26.78	15.90	95.31
	Thailand	49.51	26.78	15.90	95.31
	Vietnam	49.51	26.78	15.90	95.31

3.4 Unit root tests

The first step in the study was to perform unit root tests to determine stationarity. The tests used were the LLC test (assuming slopes are the same) (Levin et al., 2002), the IPS test (assuming slopes are different) (Im et al., 2003), the ADF test, and the PP test (Kumaran et al., 2020). The null hypothesis for all tests was that the panels contained a unit root. Most variables had unit roots according to the test results (see Table 2). The first difference between the variables met the panel requirement for stationarity and showed evidence of stationarity. The first difference also made all variables stationary, allowing for the rejection of unit roots at a 1% level.

Table 2: LLC, IPS, ADF, and PP Panel Unit Root Test Results

Variable	Levels				First difference			
	LLC	IPS	ADF	PP	LLC	IPS	ADF	PP
LNREENC	-0.68	-0.78	30.41***	25.23*	-8.79***	-9.89***	96.46***	79.89***
LNGDPPC	-2.04**	1.17	7.4	8.23	-1.92**	-5.12***	48.66***	52.73***
LNREICAP	1.01	3.45	2.14	2.69	-8.06***	-8.28***	83.23***	83.45***
LNFDI	-7.43***	-7.49***	73.67***	73.17***	-13.19***	-14.19***	135.53***	119.53***
LNENIPC	0.06	0.89	9.84	14.09	-9.31***	-9.34***	93.50***	99.21***
LNECPC	-5.12***	-3.27***	39.09***	37.44***	-4.52***	-5.64***	53.28***	57.43***
$LNCO_2EPC$	-2.66***	-0.96	20.02	19.49	-9.05***	-10.33***	107.51***	128.67***
LNAOP	-0.36	0.92	4.96	4.98	-9.00***	-8.07***	78.55***	76.04***

Note: *p*-values in squared parentheses.

3.5 Cointegration tests

The study included a cointegration test using the Kao (1999) residual cointegration test and the Johansen-Fisher cointegration test (see Tables 3 and 4). The Engle and Granger (1987) two-step paradigm was the basis for the Kao test, which gave results for both homogeneous coefficients and cross-section-specific intercepts. The null hypothesis was that there was no cointegration across all units in the panel, and both Kao test statistics and the Johansen-cointegration Fisher's test were used to support this (Kao, 1999; Maddala & Wu, 1999). The results of the cointegration test rejected the null hypothesis, indicating the existence of a long-run cointegration connection between variables.

Table 3: Kao Residual Cointegration Test

Variable	Coefficient	Std. error	*t*-Statistic	Probability
RESID(-1)	-0.139	0.0385	-3.615	0
D(RESID(-1))	0.209	0.0682	3.067	0.002
R^2	0.0961	Mean dependent variable		-0.0051
Adjusted R^2	0.0905	SD dependent variable		0.0751

Table 4: Johansen Fisher Panel Cointegration Test

Hypothesised No. of CE(s)	Fisher statistic*		Fisher statistic *	
	(From trace test)	Probability	(From max eigen test)	Probability
None	332.3	0	102.1	0
At most 1	202.7	0	89.29	0
At most 2	137	0	63.56	0
At most 3	83.79	0	42.87	0
At most 4	49.02	0	42.83	0
At most 5	49.84	0	33.02	0.001
At most 6	41.57	0	27.69	0.0061
At most 7	37.04	0.0002	37.04	0.0002

3.6 Model estimation

At this level, the results for the unit root at first show that they are not stationary, but after the first difference, they become stationary. This is one of the preliminary conditions for the DOLS model and the FMOLS model. The cointegration test is then performed, and most tests show that there is cointegration between the variables. These two procedures led us to the conclusion that the panel DOLS model should be used since it necessitates first-order stationarity and co-integration. The panel DOLS model is the most suitable one in this situation. The DOLS technique (Table 5) solves the issues of significant endogeneity and correlation. It is therefore better than other regression models in this case.

Table 5: Results of Panel DOLS, FMOLS and PMG/ARDL

Dependent variable: Renewable energy consumption						
	DOLS		FMOLS		PMG/ARDL	
Variable	**Coefficient**	***t*-Statistic**	**Coefficient**	***t*-Statistic**	**Coefficient**	***t*-Statistic**
LNGDP	0.0662	-0.2729	0.1892	0.6263	1.4700	6.8996***
LNREICAP	0.5874	3.2843***	0.4987	3.6293***	0.6784	6.0657***
LNFDI	0.2180	2.9832**	0.2428	-2.1401**	0.1554	2.7051***
LNENIPC	0.8700	2.0467***	0.7800	2.3384***	-0.1108	-0.3343
LNECPC	0.1560	0.7945	0.2686	0.6611	-1.1827	-5.1141***
LNC02EPC	-1.4331	-6.3740***	-1.5622	-5.9505***	-1.0024	-7.8612***
LNAOP	-0.0193	-0.4800	-0.2489	-1.1025	-0.2971	-7.0768***
R^2	0.9926		0.9239			
Adjusted R^2	0.9630		0.9211			

This study has found a positive correlation between consumption of renewable energy and GDP per capita in all three tests. As a country's economic ability grows, the correlation between higher consumption of renewable energy and higher GDP per capita can be attributed to a country's rising economic ability to adopt and invest in renewable energy. The effect is statistically insignificant for DOLS and FMOLS, but statistically significant for PMG-ARDL at a 1% significance level. This observation is supported by several studies, e.g., Zaekhan and Nachrowi (2012). According to Tudor and Sova (2021), GDP per capita stimulates renewable resource utilisation over USD5,000, owing mostly to high-income countries' research and development. According to the authors' study, the International Energy Agency discovered that renewable energy supply grows with GDP per capita. Wang et al. (2022) discovered a U-shaped relationship between renewable energy utilisation and long-term economic growth in Pakistan. The authors advocate for a shift to renewable energy sources since using fossil fuels may boost economic growth in the early phases of manufacturing but not later.

The correlation between renewable energy consumption and energy intensity is an essential indicator of an economy's energy security. The coefficients are 0.870002 for DOLS and 0.780444 for FMOLS, indicating that a statistically significant correlation exists between an increase in LNENIPC and an increase in renewable energy consumption. The PMG model yields different results in comparison to the DOLS and FMOLS models. LNENIPC is negatively correlated with LNREENC and statistically insignificant. Developing countries with high energy consumption relative to GDP typically have a high energy intensity, and these nations may also be pressing for renewable energy consumption (Ishaq et al., 2022). Moreover, during the transition from fossil fuels to renewable energy, there may be times when both forms of energy are extensively utilised. This could cause a short-term increase in energy intensity. Nations with good prospects for developing renewable energy can attract a lot of capital, which can help them develop large-scale renewable energy at a lower cost, while making their energy use more efficient and lowering their energy intensity (Tugcu & Tiwari, 2016; Yu et al., 2019; Rafiq et al., 2016).

In countries with little renewable energy development, a lack of technical and financial resources leads to higher costs of energy production and higher energy intensity (Lima et al., 2018). It indicates that a one percent increase in LNENIPC is associated with an increase in renewable energy consumption of approximately 0.87 percent (DOLS) and 0.78 percent (FMOLS). At 1%, both are statistically significant. It is not enough to have a mitigating factor effect on energy intensity because the selected ASEAN countries have much lower levels of renewable energy production and mostly use non-renewable energy.

This study also found that the consumption of renewable energy and the installed capacity to make electricity from renewable sources are linked in a positive way. The coefficients for renewable installed capacity are positive for all three of the tests, implying that an increase in LNREICAP is associated with an increase in renewable energy consumption. Statistically, the effect is significant. Increasing installed capacity is frequently accompanied by improvements in infrastructure, such as improved grid connectivity and storage solutions, as well as policies designed to promote the use of renewable energy (Kim & Park, 2016). These innovations and policies can increase the supply and demand for renewable energy.

A positive relationship between renewable energy consumption and electricity consumption per capita in our panel DOLS and FMOLS results may be due to the fact that as per capita electricity consumption rises, the need for diverse and sustainable energy sources increases. Renewable energy technologies, such as solar, wind, and hydroelectric power, have become more efficient and cost-effective due to technological advancements (Chang et al., 2003; Zhong et al., 2021). Therefore, countries with higher per capita electricity consumption may find renewable energy sources increasingly viable to satisfy their energy needs.

The consumption of renewable energy is positively impacted by foreign direct investment (FDI). The DOLS, FMOLS, and PMG-ARDL estimations yielded coefficient values of 0.22, 0.24, and 0.16, respectively. Both the DOLS and FMOLS estimates of these coefficient values are determined to be statistically significant at a 5% level of significance. Foreign direct investment enables the transfer of cutting-edge technology and know-how while also providing the renewable energy industry of the host nation with more financial resources. By using these technologies, renewable energy generation might become more effective and productive while also becoming more economically feasible and attractive to domestic consumers and enterprises (Huang et al., 2022).

The study's final outcome is that renewable energy utilisation negatively affects CO_2 emissions per person. The carbon emission coefficient is negative and substantial in all three models: -1.43, -1.56, and -1 in DOLS, FMOLS, and PMG-ARDL, respectively. According to the DOLS model, a one-unit increase in LNC02EPC decreases renewable energy consumption by 1.433181 units. It shows that non-renewable energy is extensively utilised, increasing CO_2 emissions (Huang et al., 2022). During economic growth, energy consumption grows. If renewable energy cannot match this demand, cheaper fossil fuels may be employed, increasing CO_2 emissions (Kumaran et al., 2020; Tudor & Sova, 2021). Thus, renewable energy degrades the environment. This analysis found an inverse link between CO_2 emissions and renewable energy use, supporting Hasnisah et al. (2019) and Ito (2017). This contradicts Begum et al. (2015), who showed that in Malaysia, per capita CO_2 emissions fell with growing GDP from 1970 to 1980 and then grew from 1980 to 2009.

Renewable energy lowers nuclear power generation rather than fossil fuels in industrialised nations; hence CO_2 emissions are suppressed less. According to the Paris Agreement, ASEAN states have released their second nationally determined contribution (NDC), raising their greenhouse gas emission reduction objective. At the end of 2022, Singapore altered its NDC. It raised its emissions peak and cut its absolute emissions limit from 65 $MtCO_2e$ in 2030 to 60 $MtCO_2e$ (NCCS, 2022). In the case of oil prices, all tests imply negative values, indicating that renewable energy consumption will decrease for each unit increase in oil prices. Oil prices may increase due to geopolitical factors, whereas renewable energy consumption may be influenced by government policies, technological advances, and consumer preferences, among other variables (Adom, 2015; Aguirre & Ibikunle, 2014; da Silva et al., 2018). Thus, the relationship between oil prices and the consumption of renewable energy may not be robust.

The short-run estimate (Table 6) also indicated a negative link between renewable energy use, GDP, FDI, energy intensity, and CO_2. Positive association with renewable installed capacity and a negligible coefficient for electricity usage per capita. The average oil price boosts renewable energy use in the near term but not in the long term. In conclusion, our model implies that only average oil price fluctuations affect renewable energy consumption statistically in the near term. The coefficient of -0.138102 suggests that one period corrects 13.81% of renewable energy consumption disequilibrium. The p-value of 0.1402 is not statistically significant at usual levels.

Table 6: Short-run Estimation

	PMG/ARDL short-run estimation		
Variables	**Coefficient**	**Std. error**	**t-Statistic**
COINTEQ01	-0.1381	0.0930	-1.4848
D(LNGDP)	-0.8082	0.7002	-1.1543
D(LNREICAP)	0.0329	0.0840	0.3913
D(LNFDI)	-0.0046	0.0157	-0.2955
D(LNENIPC)	-0.0544	0.2290	-0.2377
D(LNECPC)	0.3356	0.5378	0.6239
D(LNC02EPC)	-0.2094	0.2321	-0.9021
D(LNAOP)	0.1301	0.0400	3.2543**

4. Conclusion and Policy Implications

In recent years, academics and governments across the globe have shown a growing interest in renewable energy-generating factors. Increasing academic research and government initiatives reflect these goals. Despite these efforts, the literature on renewable energy consumption determinants is still lacking.

This study examined the primary factors influencing the consumption of renewable energy in ASEAN-6. It evaluated the impact of per capita GDP, renewable installed capacity, foreign direct investment, energy intensity, electricity consumption, CO_2 emissions, and the global oil price on renewable energy consumption in ASEAN-6. According to FMOLS and DOLS, renewable installed capacity and energy intensity have a positive effect on renewable energy, while PMG analysis indicates that the GDP has a positive effect on renewable energy consumption. These results are 1% significant. The results show that the GDP influences the consumption of renewable energy. Except for Malaysia and Indonesia, the majority of selected countries import energy. This study demonstrates a negative long-term and short-term correlation between renewable energy consumption and CO_2 emissions, whereas the oil price has a negative long-term correlation with renewable energy consumption but a positive short-term correlation. PMG concluded that variables other than oil prices had no effect on the consumption of renewable energy.

ASEAN countries are facing challenges in the transition towards renewable energy. These challenges include, but are not limited to, legislation, governance, and management-related issues. To increase the capacity of renewable electricity, ASEAN countries should work towards overcoming the abovementioned barriers. For example, the implementation of legislation to encourage the use of renewable energy is still in its infancy. Furthermore, priority should be given to key transition technologies, like increasing solar PV, as well as widespread initiatives aimed at enhancing energy efficiency, materials efficiency, and the circular economy, as well as scaling up sustainable bioenergy, hydropower, and geothermal energy sources (IRENA, 2022). In the long run, it is important to promote and enhance regional power system integration to fully use the increase in renewable energy (Obi & Bass, 2016). The ASEAN Plan of Action for Energy Cooperation (APAEC): Phase II (2021-2025) outlines updated regional goals to mitigate GHG emissions through energy transition in ASEAN, and the organisation has already welcomed the launch of the Laos, Thailand, Malaysia, and Singapore Power Integration Project (LTMS-PIP) to enhance green and renewable energy in the region (NEA, 2022). To prevent stranded assets, the phase-out of coal power plants should be accelerated soon, and the growth of infrastructure based on fossil fuels should be avoided whenever feasible. For example, the electricity industry in Indonesia accounts for 43% of total emissions, whereas Malaysia accounts for 49.6%, Singapore 40%, and Thailand 36% (Climate Transparency, 2022).

Governments should make significant efforts to replace fossil fuel-based energy sources with renewable energy sources such as hydropower, wind power, and solar energy. For instance, Germany’s adoption of renewable energy has resulted in the creation of new employment and industries while reducing its reliance on imported fossil fuels (IEA, 2020). In addition, the positive correlation between foreign direct investment and consumption of renewable energy suggests that policies should be devised to encourage investment to fund renewable energy development. Local manufacturing would be more efficient and attract FDI and multinationals with sustainable energy. Finally, promote renewable energy and sustainable practices across all industries by raising public awareness of their benefits. ASEAN governments may accomplish economic development and environmental sustainability with these strategies. This research will help policymakers and development practitioners identify the main drivers of renewable energy use in ASEAN nations, emphasising the constraints of widespread renewable energy usage and how to overcome them.

5. Limitations

The study does have some limitations. Firstly, due to certain data being unavailable, the research did not include all of the nations in ASEAN. Second, we excluded institutional variables while measuring renewable energy consumption drivers. Some research considered the institutional variable independent (Huang et al., 2022; Kumaran, 2020). Future research may consider these limitations.

References

Acheampong, A. O., Adams, S. & Boateng, E. (2019), Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? *Science of The Total Environment*, *677*, 436–446. https://doi.org/10.1016/j.scitotenv.2019.04.353

Akintande, O. J., Olubusoye, O. E., Adenikinju, A. F. & Olanrewaju, B. T. (2020). Modeling the determinants of renewable energy consumption: Evidence from the five most populous nations in Africa. *Energy*, *206*, 117992. https://doi.org/10.1016/j.energy.2020.117992

Ala, A., Isiksal, A., & Tursoy, T. (2020). Renewable energy consumption, financial development, environmental pollution, and innovations in the ASEAN +3 group: Evidence from (P-ARDL) model. *Renewable Energy*, *165*(1), 689–700. https://doi.org/10.1016/j.renene.2020.11.052

Aldieri, L., Gatto, A., & Vinci, C. P. (2021). Evaluation of energy resilience and adaptation policies: An energy efficiency analysis. *Energy Policy*, *157*, 112505. https://doi.org/10.1016/j.enpol.2021.112505

ASEAN Centre for Energy (ACE) & Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) (2020). *The 6th ASEAN energy outlook*. ACE. https://aseanenergy.org/the-6th-asean-energy-outlook/

Asongu, S. A., & Odhiambo, N. M. (2021). Inequality, finance and renewable energy consumption in Sub-Saharan Africa. *Renewable Energy*, *165*, 678–688. https://doi.org/10.1016/j.renene.2020.11.062

Begum, R. A., Sohag, K., Syed Abdullah, S. M., & Jaafar, M. (2015). CO_2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, *41*, 594–601. https://doi.org/10.1016/j.rser.2014.07.205

Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied Energy*, *162*, 733–741. https://doi.org/10.1016/j.apenergy.2015.10.104

Chang, J., Leung, D.Y., Wu, C.Z., & Yuan, Z. H. (2003). A review on the energy production, consumption, and prospect of renewable energy in China. *Renewable and Sustainable Energy Reviews*, *7*(5), 453–468. https://doi.org/10.1016/S1364-0321(03)00065-0

Chen, Y., Zhao, J., Lai, Z., Wang, Z., & Xia, H. (2019). Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China's CO_2 emissions: Evidence from a regional panel analysis. *Renewable Energy*, *140*, 341–353. https://doi.org/10.1016/j.renene.2019.03.058

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance*, *20*(2), 249–272. https://doi.org/10.1016/S0261-5606(00)00048-6

Chontanawat, J. (2020). Dynamic modelling of causal relationship between energy consumption, CO_2 emission, and economic growth in SE Asian countries. *Energies*, *13*(24), 6664. https://doi.org/10.3390/en13246664

Climate Transparency (2022). *Climate Transparency Report 2022*. https://climate-transparency.org/g20-climate-performance/g20report2022

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica*, *55*(2), 251–276. https://doi.org/10.2307/1913236

Fareed, Z., & Pata, U. K. (2022). Renewable, non-renewable energy consumption and income in top ten renewable energy-consuming countries: Advanced Fourier based panel data approaches. *Renewable Energy*, *194*, 805–821. https://doi.org/10.1016/j.renene.2022.05.156.

Fouquet, R. (2008). *Heat, power and light: Revolutions in energy services*. Edward Elgar Publishing.

Fouquet, R., & Pearson, P. J. (1998). A thousand years of energy use in the United Kingdom. *The Energy Journal*, *19*(4), 1–41. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol19-No4-1

Foxon, T., Köhler, J., & Oughton, C. (2008). *Innovation for a low carbon economy: Economic, institutional and management approaches*. Edward Elgar Publishing.

Gales, B., Kander, A., Malanima, P., & Rubio, M. (2007). North versus South: Energy transition and energy intensity in Europe over 200 years. *European Review of Economic History*, *11*(2), 219–253. https://doi.org/10.1017/s1361491607001967

García-Álvarez, M. T., Moreno, B., & Soares, I. (2016). Analyzing the environmental and resource pressures from European energy activity: A comparative study of EU member states. *Energy*, *115*, 1375–1384. https://doi.org/10.1016/j.energy.2016.01.035

Grubb, M., Haj-Hasan, N., & Newbery, D. (2008). Accelerating innovation and strategic deployment in UK electricity: Applications to renewable energy. In M. Grubb, T. Jamasb, M. G. Pollitt (Eds.), *Delivering a low-carbon electricity system: Technologies, economics and policy* (pp. 333–360). Cambridge University Press.

Gulagi, A. (2023). South Asia's energy [r]evolution—Transition towards defossilised power systems by 2050 with special focus on India [Doctoral dissertation]. Lappeenranta-Lahti University of Technology. https://lutpub.lut.fi/handle/10024/165144

Hartwick, J. M. (1977). Intergenerational equity and the investing of rents from exhaustible resources. *American Economic Review*, *67*(5), 972–974. http://www.jstor.org/stable/1828079

Hasnisah, A., Azlina, A. A., & Taib, C. M. I. C. (2019). The impact of renewable energy consumption on carbon dioxide emissions: Empirical evidence from developing countries in Asia. *International Journal of Energy Economics and Policy*, *9*(3), 135. https://www.econjournals.com/index.php/ijeep/article/view/7535

Huang, Y., Ahmad, M., & Ali, S. (2022). The impact of trade, environmental degradation and governance on renewable energy consumption: Evidence from selected ASEAN countries. *Renewable Energy*, *197*, 1144–1150. https://doi.org/10.1016/j.renene.2022.07.042

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

Inglesi-Lotz, R., & Dogan, E. (2018). The role of renewable versus non-renewable energy to the level of CO_2 emissions a panel analysis of sub-Saharan Africa's Big 10 electricity generators. *Renewable Energy*, *123*, 36–43. https://doi.org/10.1016/j.renene.2018.02.041

International Renewable Energy Agency (IRENA) (2018). *Global energy transformation: A roadmap to 2050*. IRENA. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf

International Renewable Energy Agency (IRENA) (2022). *Renewable energy outlook for ASEAN: Towards a regional energy transition*. https://www.irena.org/publications/2022/Sep/Renewable-Energy-Outlook-for-ASEAN-2nd-edition

Ito, K. (2017). CO_2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics*, *151*, 1–6. https://doi.org/10.1016/j.inteco.2017.02.001

Jiang, Z., Li, R., Li, A., & Ji, C. (2018). Runoff forecast uncertainty considered load adjustment model of cascade hydropower stations and its application, *Energy*, *158*, 693–708. https://doi.org/10.1016/j.energy.2018.06.083

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics*, *90*(1), 1–44. https://doi.org/10.1016/S0304-4076(98)00023-2

Kao, C., & Chiang, M. H. (2000). On the estimation and inference of a cointegrated regression in panel data. In B. H. Baltagi, T. B. Fomby, & R. Carter Hill (Eds.), *Nonstationary panels, panel cointegration, and dynamic panels* (pp. 179–222). Emerald. https://doi.org/10.1016/S0731-9053(00)15007-8

Kartal, G. (2022). The relationship between energy security and economic growth: A bootstrap panel granger causality analysis. *Politická Ekonomie*, *70*(4), 477–499.

Kónya, L. (2006). Exports and growth: Granger causality analysis on OECD countries with a panel data approach. *Economic Modelling*, *23*(6), 978–992. https://doi.org/10.1016/j.econmod.2006.04.008

Krewitt, W., Simon, S., Graus, W., Teske, S., Zervos, A., & Schäfer, O. (2007). The 2°C scenario—A sustainable world energy perspective. *Energy Policy*, *35*(10), 4969–4980. https://doi.org/10.1016/j.enpol.2007.04.034

Kresnawan, M. R., & Suryadi, B. (2022). *ASEAN energy in 2022: Outlook report*. ACE. https://aseanenergy.org/asean-energy-in-2022/

Kumaran, V. V., Ridzuan, A. R., Khan, F. U., Abdullah, H., & Mohamad, Z. Z. (2020). An empirical analysis of factors affecting renewable energy consumption in association of Southeast Asian nations—4 countries. *International Journal of Energy Economics and Policy*, *10*(2), 48–56. https://doi.org/https://doi.org/10.32479/ijeep.8142

Le, T. H., & Park, D. (2021). What drives energy insecurity across the world? A panel data analysis. *Energy Research and Social Science*, *77*, 102093. https://doi.org/10.1016/j.erss.2021.102093

Law, C., & Sek, S. K. (2021). Panel evidence of the dynamics between energy consumption and trade openness in ASEAN and East Asia, *Energy and Environment*, *33*(3), 958305X2110075. https://doi.org/10.1177/0958305x211007596

Levin, A., Lin, C. F., & James Chu, C. S. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7.

Liddle, B., & Sadorsky, P. (2017). How much does increasing non-fossil fuels in electricity generation reduce carbon dioxide emissions? *Applied Energy*, *197*, 212–221. https://doi.org/10.1016/j.apenergy.2017.04.025

Lin, B., & Omoju, O. E. (2017). Focusing on the right targets: Economic factors driving non-hydro renewable energy transition. *Renewable Energy*, *113*, 52–63. https://doi.org/10.1016/j.renene.2017.05.067

Liu, W., Zhang, X., & Feng, S. (2019). Does renewable energy policy work? Evidence from a panel data analysis. *Renewable Energy*, *135*, 635–642. https://doi.org/10.1016/j.renene.2018.12.037

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, *61*(1), 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Marques, A. C., Fuinhas, J. A., & Pereira, D. S. (2019). The dynamics of the short and long-run effects of public policies supporting renewable energy: A comparative study of installed capacity and electricity generation. *Economic Analysis and Policy*, *63*, 188–206. https://doi.org/10.1016/j.eap.2019.06.004

National Climate Change Secretariat Singapore (NCCS) (2022). Singapore and international efforts. *NCCS*. https://www.nccs.gov.sg/singapores-climate-action/singapore-and-international-efforts/

National Environment Agency Singapore (NEA) (2022). Singapore's fifth national communication and fifth biennial update report. *NEA*. https://unfccc.int/sites/default/files/resource/Singapore%20-%20NC5BUR5.pdf

Nguyen, K. H., & Kakinaka, M. (2019). Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis. *Renewable Energy*, *132*, 1049–1057. https://doi.org/10.1016/j.renene.2018.08.069.

Olanrewaju, B. T., Olubusoye, O. E., Adenikinju, A., & Akintande, O. J. (2019). A panel data analysis of renewable energy consumption in Africa. *Renewable Energy*, *140*, 668–679. https://doi.org/10.1016/j.renene.2019.02.061.

Oluoch, S., Lal, P., & Susaeta, A. (2021). Investigating factors affecting renewable energy consumption: A panel data analysis in Sub-Saharan Africa. *Environmental Challenges*, *4*. https://doi.org/10.1016/j.envc.2021.100092

Ozcan, B., & Ozturk, I. (2019). Renewable energy consumption-economic growth nexus in emerging countries: A bootstrap panel causality test. *Renewable and Sustainable Energy Reviews*, *104*, 30–37. https://doi.org/10.1016/j.rser.2019.01.020.

Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels, in H. Baltagi, B., B. Fomby, T. and Carter Hill, R. (Eds.). *Nonstationary Panels, Panel Cointegration, and Dynamic Panels* (93-130), Vol. 15, Emerald Group Publishing Limited, https://doi.org/10.1016/S0731-9053(00)15004-2.

Pedroni, P. (2001). Purchasing power parity tests in cointegrated panels. *The Review of Economics and Statistics*, *83*(4), 727–731. https://doi.org/10.1162/003465301753237803.

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, *94*(446), 621–634. https://doi.org/10.1080/01621459.1999.10474156.

Phillips, P. C. B., & Moon, H. R. (1999). Linear regression limit theory for nonstationary panel data. *Econometrica*, *67*(5), 1057–1111. https://doi.org/10.1111/1468-0262.00070.

Radovanović, M., Filipović, S., & Pavlović, D. (2017). Energy prices and energy security in the European Union: Panel data analysis. *Energy Sources, Part B: Economics, Planning, and Policy*, *12*(5), 415–419. https://doi.org/10.1080/15567249.2016.1157649.

Saikkonen, P. (1992). Estimation and testing of cointegrated systems by an autoregressive approximation. *Econometric Theory*, *8*(1), 1–27. https://doi.org/10.1017/S0266466600010720.

Shafiullah, M., Rahman, S., Imteyaz, B., Aroua, M. K., Hossain, M. I., & Rahman, S. M. (2023). Review of smart city energy modeling in Southeast Asia. *Smart Cities*, *6*(1), 72–99. https://doi.org/10.3390/smartcities6010005

Shahbaz, M., & Rahman, M. M. (2010). Foreign capital inflows-growth nexus and role of domestic financial sector: An ARDL co-integration approach for Pakistan. *Journal of Economic Research*, *15*(3), 207–231.

da Silva, P. P., Cerqueira, P. A., & Ogbe, W. (2018). Determinants of renewable energy growth in Sub-Saharan Africa: Evidence from panel ARDL. *Energy*, *156*, 45–54. https://doi.org/10.1016/j.energy.2018.05.068

Stock, J. H., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica*, *61*(4), 783–820. https://doi.org/10.2307/2951763

Tugcu, C. T., & Tiwari, A. K. (2016). Does renewable and/or non-renewable energy consumption matter for total factor productivity (TFP) growth? Evidence from the BRICS. *Renewable and Sustainable Energy Reviews*, *65*, 610–616. https://doi.org/10.1016/j.rser.2016.07.016

Tudor, C., & Sova, R. (2021). On the impact of GDP per capita, carbon intensity and innovation for renewable energy consumption: worldwide evidence. *Energies*, *14*(19), 6254. https://doi.org/10.3390/en14196254

UN News. (2014, April 10). UN launches decade-long sustainable energy for all initiative. *Our World*. https://ourworld.unu.edu/en/un-launches-decade-long-sustainable-energy-for-all-initiative

Vakulchuk, R., Overland, I., & Suryadi, B. (2023). ASEAN's energy transition: How to attract more investment in renewable energy. *Energy, Ecology and Environment*, *8*(1), 1–16. https://doi.org/10.1007/s40974-022-00261-6

Wang, Q., & Wang, L. (2020). Effect of renewable energy consumption on economic growth in OECD countries from non-renewable energy intensity, urbanization level and per capita incomes. *Energy*, *207*, 118200. https://doi.org/10.1016/j.energy.2020.118200

Wang, J., Hassan, M. S., Alharthi, M., Arshed, N., Hanif, I., & Saeed, M. I. (2022). Inspecting non-linear behavior of aggregated and disaggregated renewable and non-renewable energy consumption on GDP per capita in Pakistan. *Energy Strategy Reviews*, *39*, 100772. https://doi.org/10.1016/j.esr.2021.100772

World Bank. *World Development Indicators*. https://data.worldbank.org/indicator

Xu, X., Wei, Z., Ji, Q., Wang, C., & Gao, G. (2019). Global renewable energy development: Influencing factors, trend predictions and countermeasures. *Resources Policy*, *63*, 101470. https://doi.org/10.1016/j.resourpol.2019.101470

Xu, X., Yu, J., Zhang, D., & Ji, Q. (2021). Energy insecurity, economic growth, and the role of renewable energy: A cross-country panel analysis. *Singapore Economic Review*, *66*(2), 323–343. https://doi.org/10.1142/S021759081943001X

York, R., & McGee, J. A. (2017). Does renewable energy development decouple economic growth from CO_2 emissions? *Socius*, *3*, 1–6. https://doi.org/10.1177/ 2378023116689098

Yu, S., Zheng, Y., & Li, L. (2019). A comprehensive evaluation of the development and utilization of China's regional renewable energy. *Energy Policy*, *127*, 73–86. https://doi.org/10.1016/j.enpol.2018.11.056

Zaekhan, & Nachrowi, N. D. (2012). The impact of renewable energy and GDP per capita on carbon dioxide emission in the G20 countries. *Economics and Finance in Indonesia*, *60*, 145–174. https://www.lpem.org/repec/lpe/efijnl/201202.pdf

Zhong, J., Bollen, M., & Rönnberg, S. (2021). Towards a 100% renewable energy electricity generation system in Sweden. *Renewable Energy*, *171*, 812–824. https://doi.org/10.1016/j.renene.2021.02.153