International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(5), 118-130.

Powering Growth: The Dynamic Impact of Renewable Energy on GDP in ASEAN-5

Mahfuzur Rahman[1]*, Ngu Wang Keat[2], Md Abdul Kaium Masud[3], Mohamed Albaity[1]

[1]Department of Finance and Economics, College of Business Administration, University of Sharjah, Sharjah 27272, United Arab Emirates, [2]Faculty of Business and Economics, University of Malaya, Malaysia, [3]Department of Business Administration, Noakhali Science and Technology University, Noakhali 3814, Bangladesh. *Email: mrahman@sharjah.ac.ae

Received: 12 April 2024 **Accepted:** 13 July 2024 **DOI:** https://doi.org/10.32479/ijeep.16541

ABSTRACT

This study investigates the dynamic relationships between renewable energy consumption, labor force, gross fixed capital (GFC), and GDP across ASEAN-5 nations from 1984 to 2020. Utilizing data from the World Development Indicators (WDI), the Energy Information Agency (EIA), and national labor statistics, we employ unit root tests, ARDL bound testing for cointegration, and Toda-Yamamoto causality procedures. Our findings indicate significant long-term cointegration between the studied variables in Indonesia and the Philippines, suggesting persistent economic relationships, while results for Malaysia show no cointegration and remain inconclusive for Thailand. The economic analysis reveals that GFC robustly drives GDP growth across these countries, whereas the impacts from labor force and renewable energy consumption are more variable. Causality tests further demonstrate that renewable energy consumption significantly fosters GDP growth in Indonesia, Malaysia, and Singapore, aligning with the growth hypothesis. Conversely, findings for the Philippines and Thailand support the neutrality hypothesis, indicating no direct causal impacts. These insights underline the crucial role of tailored renewable energy strategies to enhance economic growth and sustainability in ASEAN-5, providing valuable policy implications for regional energy governance.

Keywords: Renewable Energy, Economic Growth, ASEAN-5, Gross Fixed Capital, Labor Force
JEL Classifications: Q43; Q56; O13; C32

1. INTRODUCTION

The nexus between energy consumption and economic growth has been widely recognized as a pivotal factor in the development trajectories of economies (Munir et al., 2020). This nexus signifies the interconnectedness between the amount of energy a country consumes and its economic performance. As economies grow, they typically require more energy to sustain their development activities such as industrial production, transportation, and infrastructure expansion (Mukhtar et al., 2024). This symbiotic relationship highlights how energy availability and efficiency play a significant role in driving economic growth. Seminal studies by (Adedoyin et al., 2020; Hdom and Fuinhas, 2020; Khan et al., 2021; Xu and Li, 2020) highlight the critical role of energy, alongside capital and labour, as a fundamental driver of economic expansion. Energy is integral not only for supporting primary production activities but also for facilitating various ancillary services. To acknowledge the importance of energy to economic growth, several studies revealed a positive correlation between energy consumption and economic growth. For instance, Vanegas Cantarero (2020) mentioned that energy is a crucial driver of economic development, yet it also poses environmental challenges that can hinder sustainable growth. Al-Shetwi (2022) implied that the relationship between energy consumption and economic growth is complex, with varying impacts depending on the direction of causality. Furthermore, Khan et al. (2021) affirmed that policies restricting energy consumption may negatively affect economic growth, highlighting the need for a balance between energy conservation and economic development. In essence, energy plays a vital role in economic growth, but managing its consumption sustainably is essential to ensure long-term economic growth. Despite its acknowledged importance, the empirical understanding of its impact remains equivocal, with no consensus on the specific nature of its influence on economic growth. Climate change is a major global challenge that has been exacerbated by the energy consumption patterns established during the industrial revolution (Mukhtar et al., 2023). The burning of fossil fuels and deforestation have significantly increased the concentration of greenhouse gases like carbon dioxide in the atmosphere, trapping more heat and warming the planet. Furthermore, the reliance on fossil fuels, crude oil, coal, and natural gas has perpetuated a cycle of greenhouse gas emissions, exacerbated global warming, and associated climatic anomalies (Mukhtar et al., 2023). Addressing climate change requires a global commitment to reduce greenhouse gas emissions and transition to clean, renewable energy sources. This environmental crisis has necessitated a re-evaluation of energy paradigms, steering towards sustainable alternatives. It may imply that by rethinking energy paradigms and embracing sustainable alternatives both society and industries can work toward a more environmentally conscious and sustainable world (Raihan and Tuspekova, 2022). The transition to renewable energy sources, which replenish faster than they are consumed and contribute minimally to greenhouse emissions, has been posited as a viable solution. These sources include solar, wind, hydro, biomass, biogas, and geothermal energy.

The urgency of addressing climate change led to the formation of the Intergovernmental Panel on Climate Change (IPCC) by the United Nations in 1988. The IPPCC's role is to provide governments with regular assessment of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. Subsequent international agreements, notably the Kyoto Protocol and the Paris Agreement, have aimed to consolidate global efforts against climate warming, with a target to cap the rise in global temperatures to below 2°C above pre-industrial levels. The latest IPCC report in 2023 highlights likely global warming of 1.5°C between 2030 and 2052 if current rates persist, emphasizing the critical need for immediate and concerted action to transition towards renewable energy. In Southeast Asia, the Association of Southeast Asian Nations (ASEAN), a coalition of ten countries, has been actively involved in these global initiatives. The region, known for its robust economic growth and increasing energy demands due to population growth, urbanization, and rising incomes, faces unique challenges and opportunities in the energy sector. Among the ASEAN member states, the ASEAN-5 (Malaysia, Thailand, Philippines, Indonesia, and Singapore) represent a significant proportion of the region's economy and energy consumption. These countries exhibit diverse energy consumption patterns and resources, with varying degrees of reliance on both fossil fuels and renewable energy sources. This study focuses on the ASEAN-5 due to their pivotal role in the region's economy and their potential for leadership in the transition to renewable energy. Despite their economic advancements, there is a significant portion of their population without access to electricity and a reliance on biomass as a primary cooking fuel. This context presents a complex landscape for energy policy and underscores the importance of understanding the relationship between renewable energy consumption and economic growth.

The persistent increase in energy consumption in the ASEAN-5, driven by agricultural, manufacturing, and industrial activities, has contributed significantly to their economic growth. However, the dependency on fossil fuels has led to environmental degradation and exacerbated the impacts of climate change. The absence of a consensus in the literature regarding the direction of renewable energy consumption and economic growth, particularly in the ASEAN context, hampers effective policymaking. To address this gap, The primary aim of this study is to explore the causal relationship between renewable energy consumption and economic growth in the ASEAN-5 from 1984 to 2020. Furthermore, the objectives include examining both the long-term and short-term dynamics between renewable energy use, labour force, gross fixed capital formation, and economic growth, and identifying the causal relationships between these variables. This investigation into the dynamics of renewable energy consumption and economic growth in ASEAN-5 is particularly timely and relevant, given the limited availability of time-series data before the 1990s. The study's insights will be critical for policymakers, especially considering the anticipated increases in energy demand and the ongoing challenges in energy access. In addition, this will encourage policymakers to prioritize renewable energy development and integration into the energy mix to support sustainable economic growth. In addition, governments should implement policies to incentivize investment in renewable energy projects to boost the share of renewables in the energy mix. Moreover, to achieve environmental sustainability, governments should phase out fossil fuel subsidies and introduce carbon pricing mechanisms to disincentivize fossil fuel use. Revenues from carbon pricing can be used to fund renewable energy development and energy efficiency programs. Through this study, practitioners should promote energy efficiency measures sustainable production and consumption practices, and the adoption of renewable energy technologies to decouple economic growth from environmental degradation.

The paper is structured as follows: Section two reviews pertinent literature on energy economics, emphasizing the impact of electricity and renewable energy consumption on economic growth. Section three outlines the theoretical model, specifying the variables for analysis and the statistical tests to be utilized. Section four details and discusses the results of the empirical tests. Section five provides conclusions together with the limitations of the study and proposes avenues for future research.

2. LITERATURE REVIEW

The debate on energy consumption and economic growth has been an ongoing issue for some time. Most of the research in this area is based on Kraft and Kraft's pioneering research that empirically tests the connection between energy consumption and economic growth. The study was conducted in the United States from 1947 to 1974 using energy consumption and Gross National Product (GNP) to test for causality. Since then, there has been a boom in the number of literature on the subject. Although it may seem apparent that the increase in energy consumption improves the overall economy (Usman et al., 2021), empirical results have been mixed and inconsistent in terms of the causality of the relationship. There have been many reasons and debates ongoing on the inconsistent results, which include the data used, econometric approach, and characteristics of specific countries or a group (Ozturk, 2010). The country's characteristics can be influenced by many factors such as the economy, political landscape, cultures, policies, maturity of the country (developing/developed), and energy resources (Coldwell et al., 2022).

2.1. Energy Consumption-growth Nexus Hypotheses

Four main hypotheses can be empirically tested to understand the causal relationship between energy consumption and economic growth. They can be categorized as the growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis. These hypotheses have been used extensively in the energy economics world (Alabi et al., 2017; Alper and Oguz, 2016; Aslan, 2016; Bhattacharya et al., 2016; Kyophilavong et al., 2015; Rahman and Velayutham, 2020). Knowing which hypothesis allows policymakers to make informed decisions that have vital energy policy implications.

The "growth hypothesis" suggests that a rise in energy consumption would lead to an increase in economic growth. Energy is a critical input for economic activity and industrial growth. Studies have shown that energy accounts for at least half of industrial growth in modern economies, even though it represents <10% of production costs (Arens et al., 2021; Osman et al., 2023). Increased energy consumption is a strong determinant of economic growth, with both implicit and explicit effects. Thus, energy would be considered to contribute directly or indirectly to the overall economy besides labour and capital. Thus, policymakers would focus on increasing the energy generation and consumption to improve economic growth. On the contrary, limiting energy consumption would hurt economic growth. The "conservation hypothesis" implies that economic growth affects energy consumption unidirectionally. If so, the hypothesis is valid if economic growth causes an increase in energy consumption. Hence, under the conservation hypothesis, energy conservation policies focus on reducing energy consumption such as the reduction in the release of greenhouse gases, more efficient energy controls, and demand have negligible effect on economic growth. The "feedback hypothesis" implies that energy consumption and economic growth have an interdependent relationship and complement one another. The direction of causality runs both ways or is bi-directional. The "neutrality hypothesis" infers that there is no relation between energy consumption and economic growth. Hence, it does not matter which stance the policymaker takes because the rise or fall of energy usage would not affect economic growth and vice versa.

2.2. A Look into the Energy-growth Literature

As mentioned, the growth in energy economics under the energy consumption and economic growth theme has increased tremendously since the research published by Kraft and Kraft. The number of literature on the two variables would be too numerous to cover in this section alone. Hence, only selected literature (bivariate and multivariate) and surveys over the years will be looked upon. This section will investigate some of the studies conducted in ASEAN-5 that involve a single-country analysis of energy and growth first. For instance, Munir et al. (2020) examined the relationship between CO_2 emissions, energy consumption (EC) and economic growth (GDP) for the five main Association of Southeast Asian Nations (ASEAN-5) countries. (Lyazzat et al., 2023) explored the relationship between energy consumption, carbon emissions and economic growth in ASEAN-5 countries. As a result of the causality analysis, it was found that there is a bilateral causality relationship between economic growth and CO_2 emissions in Singapore. Moreover, (Safitri et al., 2022) energy consumption such as fossil fuel energy use, electric power use, and energy import along with economic growth on the ecological environment of ASEAN countries. The findings revealed that fossil fuel energy use, electric power use, energy import, and economic growth have a positive association with carbon (CO_2) emissions and affect the ecological environment of ASEAN countries. Tiba and Omri (2017); and Waheed et al. (2019) have conducted detailed surveys on the energy consumption and growth literature of many authors over various time frames and countries. The survey results conclude that energy consumption on the economic growth causality is mixed. The recommendations for future works include using panel data and multivariate models that include different variables such as carbon dioxide emissions, labour, real gross fixed capital formation, and others.

In Indonesia, Jafari et al., (2012) investigated the Granger causality between three variables which are energy consumption, economic growth, and CO_2 emissions. There is no cointegration among the variables and it is found that energy consumption supports the neutrality hypothesis. For the case of Malaysia, Tang (2008) found no cointegration and that the feedback hypothesis applies where electricity consumption and economic growth cause each other. On the other hand, Azlina (2012) found that the conservation hypothesis applies. Kyophilavong et al. (2015) used multivariate variables that include energy consumption, trade openness, and economic growth for the case of Thailand. It is concluded that the bi-directional causality is running from energy consumption to economic growth. Glasure and Lee (1998) studied the relationship between GDP and energy in South Korea and Singapore independently. The result for the single country of Singapore shows that there is a unidirectional causal relation between energy consumption to economic growth, which suggests the growth hypothesis. Lee (2005) investigated the energy consumption and GDP using panel analysis in 18 developing countries including some of the countries from the ASEAN-5 from the period of 1975 to 2001 and found that causality runs from energy consumption to GDP, implying a growth hypothesis. Yildirim et al., (2014) have selected two methods that are panel data and time series causality to test the connection between energy consumption per capita and GDP per capita for ASEAN-5. Azam et al. (2015) and Heidari et al. (2015) also conducted studies on the region. Energy consumption has a significant effect on economic growth, but the causality of the direction remained mixed in the region. However, the tests show a consistent conservation hypothesis for Malaysia.

Table 1 reports the selected literature and their findings on the relationship between energy consumption and economic growth. From the summary, it can be said that there are no conclusive findings, and the results are mixed regarding the direction of energy consumption towards economic growth. Most of the variables selected are cointegrated, meaning the variables show a long-term relationship with one another.

2.3. Renewable Energy-growth Literature

Taking into consideration the threat of global loss of biodiversity and the need for a sustainable future, there has been a growing interest among researchers in energy economics regarding the capacity of renewable energy in economic development (Khan et al., 2020). As expected with the conventional energy-growth literature in the previous section, renewable energy consumption

Table 1: Selected literature and their findings on the relationship between energy consumption and economic growth

Year	Authors	Period	Countries	Methodology	Findings	Conclusion
1997	Glasure and Lee (1998)	1961c1990	Singapore	Granger Causality Test	Causality running from energy consumption to GDP in Singapore.	EC>GDP
2008	Tang (2008)	1972-2003	Malaysia	ARDL and Granger Test	Energy consumption and energy are not cointegrated. The Granger causality shows the variables cause each other in the short run.	EC<>GDP
2012	Azlina (2012)	1960-2009	Malaysia	VECM Granger Causality	The variables of economy, energy price, capital, labour and consumption are cointegrated. The causality is running from GDP to energy consumption	EC<GDP
2010	Ozturk and Acaravci (2010)	1968-2005	Turkey	ARDL and Granger Test	The variables are cointegrated. The causality tests show neither electricity consumption nor carbon emission causes GDP.	EC--GDP
2012	Jafari et al. (2012)	1971-2007	Indonesia	Toda Yamamoto Test, Granger Causality Test	The tested variables are not cointegrated and the variables do not cause GDP	EC--GDP
2015	Kyophilavong et al. (2015)	1971-2012	Thailand	Bayer and Hanck, VECM Granger Causality	The energy consumption, trade openness and GDP are cointegrated. The GDP causes energy consumption.	EC<GDP
2005	Lee (2005)	1975-2001	18 developing countries	FMOLS	Panel analysis of the data shows the variables are cointegrated. The tests show in the long run and short run energy consumption causes GDP	EC>GDP
2010	Payne (2010)	Various	Various	Survey	There is no clear consensus based on the survey on the direction of energy consumption and growth	Mixed result.
2010	Ozturk (2010)	Various	Various	Survey	There is no clear consensus based on the survey on the direction of energy consumption and growth	Mixed result.
2014	Yildirim et al. (2014)	1971-2009	ASEAN-5	Panel Data and Time Series Causality	The conservation hypothesis is applicable to Malaysia, Thailand, Indonesia, Philippines. The neutrality hypothesis is supported in Singapore.	EC<GDP EC -- GDP
2015	Azam et al. (2015)	1980-2012	ASEAN-5	Granger Causality Test	The cointegration test shows that the variables are cointegrated for all the countries. The neutrality hypothesis is supported for Indonesia. In Malaysia, the conservation hypothesis applies. Other countries do not show the relationships between energy consumption and economic growth.	
2015	Heidari et al., (2015)	1980-2008	ASEAN-5	PSTR	The energy consumption leads to CO_2 increase but does not cause economic growth	EC--GDP
2017	Tiba and Omri (2017)	1978-2014	Various	Survey	There is no clear consensus based on the survey on the direction of energy consumption and growth	Mixed result.
2018	Le and Quah (2018)	1984-2012	14 Selected Countries in Asia and Pacific	FMOLS	The variables CO_2, energy consumption and economic growth are cointegrated. The energy consumption does not affect the GDP	EC--GDP
2019	Waheed et al. (2019)	Various	Various	Survey	There is no clear consensus based on the survey on the direction of energy consumption and growth	Mixed result

EC>GDP-Growth Hypothesis, EC<GDP-Conservative Hypothesis, EC<>GDP-Feedback Hypothesis, EC-GDP-Neutrality Hypothesis has yielded the same mixed results. Some reports support a positive causal relationship which supports renewable energy consumption's contribution to economic growth, while others report that renewable energy consumption has a minimal effect. However, there is a limited number of literature on the ASEAN-5 countries regarding the impact of renewable energy consumption on economic growth (Zeraibi et al., 2021). Many works of literature are taken outside of the ASEAN-5 countries. The reason, as mentioned earlier, is due to a lack of data in the region. The countries in the region did not begin the transition to market-oriented economies until the early 1990s and hence, most of the renewable energy initiatives have not been implemented, and the focus in the regions is on economic transformation.

Renewable energy consumption literature across ASEAN-5 is scarce, whether it is single-country or multiple-country studies. For example, Wang and Wang (2020) explored the relationship between renewable energy and economic growth focusing on the linear relationship, whereas ignoring the non-linear relationship between them. In this study, the nonlinear relationship between renewable energy and economic growth in OECD countries was investigated by developing panel threshold regression models. Similarly, (Chen et al., 2020) examines the causal link between renewable energy use and economic growth by employing a threshold model using a 103-country sample in the 1995 to 2015 period. It found that the relationship between renewable energy consumption and economic growth depends on the amount of renewable energy used. The results demonstrate that the effect of renewable energy consumption on economic growth is positive and significant if and only if developing countries or non-OECD countries surpass a certain threshold of renewable energy consumption. Aslan (2016) investigated the causal relationship in the United States, primarily focusing on biomass energy on economic growth. Taking the data set from 1961 to 2011, the author uses the ARDL for the cointegration test and causality using Toda Yamamoto. The findings concluded that renewable energy (biomass) has a positive impact on the economy, supportive of the growth hypothesis. Shahbaz et al. (2015) examined the relationship between renewable energy consumption and economic growth in Pakistan from 1972 to 2011. The cointegration test was done using ARDL, and the causality shows a feedback hypothesis from the VECM Granger causality test. Boontome et al. (2017) found a neutrality hypothesis for the case in Thailand.

Apergis and Payne (2010) investigated the relationship between 13 countries in Eurasia from 1992 to 2007 and found that renewable energy consumption and the economy affect each other, giving a feedback hypothesis. Alabi et al. (2017) used FMOLS developed by Pedroni to analyze the cointegration and VECM Granger to test causality for OPEC African countries namely Angola, Algeria, and Nigeria. The study provides evidence of a feedback hypothesis where renewable energy consumption enhances the economy bidirectionally. Salim et al. (2014) examined the renewable and non-renewable energy consumption in OECD countries from 1980 to 2011 using panel causality tests. The results show unidirectional causality running from GDP to renewable energy consumption. In a similar study, Inglesi-Lotz (2016) and Salim et al. (2014) investigated the OECD countries from 1990 to 2011. Both findings concluded that causality is running from REC to GDP. Alper and Oguz (2016) employed the VECM Granger causality to test the relationship between renewable energy consumption and the economy for 8 new European Union (EU) countries over the period 1990 to 2009 and found a positive impact on the economic growth for all. The causality test shows growth, neutrality, and conservation hypotheses for the investigated countries. Bhattacharya et al. (2016) selected the top 38 countries in renewable energy consumption in their studies from 1991 to 2012. Using heterogeneous panel estimation techniques, the authors found that 57% of the countries show a positive implication of renewable energy on the economic output.

Tuna and Tuna (2019) analyzed the causality for the ASEAN-5 countries with renewable and non-renewable energy and found the results to be mixed. Using Hacker and Hatemi-J tests, the results show a neutrality hypothesis for Malaysia, Singapore, Indonesia, and Thailand and a conservation hypothesis for the Philippines. This would mean that a more renewable energy-oriented policy would not affect the economy of these countries. Rahman and Velayutham (2020) use the Dumitrescu-Hurlin causality test to determine the causal linkage between the variables in South Asia that covers Bangladesh, India, Nepal, Pakistan, and Sri Lanka from 1990 to 2014. At the same time, Pedroni and Kao tests are used to determine the cointegration. From the tests, the conservation hypothesis is supported, which means the causality is running from economic growth to renewable energy consumption.

Table 2 shows the selected literature and their findings on the relationship between renewable energy consumption and economic growth. Like the previous section on energy consumption and economic growth, it can be said there are no conclusive findings, and the results are regarding the direction of renewable energy consumption towards economic growth. Many of the selected literature shows a feedback hypothesis which implies that renewable energy consumption and economic growth have an interdependent relationship and complement one another. The literature also revealed that the variables GDP, REC, RGFC and LF that will be used in this study are cointegrated.

3. MATERIALS AND METHODS

3.1. Data

Secondary data on macroeconomic indicators for the ASEan-5 countries-Indonesia, Malaysia, the Philippines, Singapore, and Thailand-were collected from sources available online, including the World Development Indicators (WDI) published by the World Bank, the Energy Information Agency (EIA), and national labour statistics. GDP, representing the total annual market value of all goods and services produced within a country, and Gross Fixed Capital (GFC), reflecting investment in land, plants, machinery, and buildings, were sourced from the WDI. Labor force (LF) data, covering individuals aged 15 and older who are employed or actively seeking employment, were obtained from national labor statistics and the WDI. Renewable Energy Consumption (REC), measured in kilowatt-hours (kWh) generated from renewable sources, was sourced from the EIA (Bhattacharya et al., 2016). The data were collected across the ASEAN-5, ranging from

Table 2: Selected literature and their findings on the relationship between renewable energy and economic growth

Year	Authors	Period	Countries	Methodology	Findings	Conclusion
2014	Lin and Moubarak (2014)	1977-2011	China	ARDL and Granger Causality	There is a bi-directional causality between renewable energy consumption and GDP	REC<>GDP
2015	Shahbaz et al. (2015)	1975-2011	Pakistan	ARDL and Granger Causality	The variables renewable energy consumption, capital and labour are cointegrated and the causality test shows a feedback hypothesis	REC<>GDP
2016	Aslan (2016)	1961-2011	USA	ARDL and Toda-Yamamoto causality test	The long run and short run show that energy consumption from biomass sources has positive implications for economic growth	REC>GDP
2017	Boontome et al. (2017)	1971-2013	Thailand	Granger Causality Test	The variables are cointegrated. The evidence only shows a unidirectional from non-renewable consumption to CO2.	REC--GDP
2010	Apergis and Payne (2010)	1992-2007	13 Eurasian Countries	Pedroni heterogeneous panel cointegration test and VECM Granger Causality Test	Panel test shows cointegration between REC, RGFC and LF. The result indicates a feedback hypothesis between REC and GDP	REC<>GDP
2012	Tugcu et al. (2012)	1980-2009	G7 countries	ARDL and Hatemi J Causality test	There is no clear consensus among the G7 countries on the direction of renewable energy consumption and growth	Mixed Result
2014	Salim et al. (2014)	1980-2011	OECD countries	Panel Cointegration Test and Panel Causality Test	Bidirectional causality between the industrial output and both renewable and non-renewable energy consumption	REC<>GDP
2016	Alper and Oguz (2016)	1990-2009	EU developing countries	ARDL and Hatemi J Causality test	Growth hypothesis for Bulgaria, Estonia, Poland and Slovenia. Neutrality for Cyprus, Estonia, Hungary, Poland and Slovenia. The conservation hypothesis holds for the Czech Republic	Mixed Result
2016	Kahia et al. (2016)	1980-2012	MENA Net Oil Exporting Countries	Panel cointegration test and VECM Granger Causality Test	GDP, REC, RGFC and LF are cointegrated. In the short run, causality is running from GDP to REC.	REC<GDP
2016	Inglesi-Lotz (2016)	1990-2010	OECD countries	Panel cointegration test and VECM Granger Causality Test	Renewable energy consumption has a positive impact on the economic growth	REC>GDP
2016	Bhattacharya et al. (2016)	1991-2012	Top 38 countries	Panel cointegration test and VECM Granger Causality Test	Long-run equilibrium relationship between variables	
2017	Alabi et al. (2017)	1971-2011	Angola, Algeria, Nigeria	Panel cointegration test and VECM Granger Causality Test	Renewable energy consumption and economic growth both cause each other in the long and short run	REC<>GDP
2019	Tuna and Tuna (2019)	1980-2015	ASEAN-5	Hatemi J Causality test	Renewable energy consumption does not much influence on economic growth as the neutrality hypothesis is supported for all ASEAN 5 countries except for the Philippines which supports conservation hypothesis	REC--GDP
2020	Rahman and Velayutham (2020)	1990-2014	Bangladesh, India, Pakistan, Nepal, Sri Lanka	Dumitrescue-Hurlin panel causality test	Panel data tests show causality running from GDP to renewable energy consumption	REC<GDP

REC>GDP-Growth Hypothesis, REC<GDP-Conservation Hypothesis, REC<>GDP-Feedback Hypothesis, REC-GDP-Neutrality Hypothesis

1984 to 2020. The data availability varies by country, with an average of 30 years of annual data collected. The time series data collected span the years 1984 to 2020 and encompass variables from the ASEAN-5 countries. Time series data are preferred in economic analysis for their simplicity and the availability of analytical tools. Panel data offers several advantages, particularly for developing countries with limited time series data. Panel data analysis allows for the study of multiple data series simultaneously, accommodating heterogeneity and increasing the overall number of observations, which enhances variability and reduces noise in regression models (Westerlund et al., 2015). Hence, panel data can be used for the robustness of the analysis.

3.2. Model Specification and Variables Selection

To investigate the link between renewable energy consumption and economic growth, this study adopted the model and selected variables based on the Cobb-Douglas production function, with the inclusion of renewable energy consumption (Alper and Oguz, 2016; Inglesi-Lotz, 2016; Lin and Moubarak, 2014; Rahman and Velayutham, 2020; Salim et al., 2014; Shahbaz et al., 2015; Westerlund et al. 2015). The Cobb-Douglas production function was transformed into a natural logarithm because of the nature of the data. Keeping the efficiency factor constant, the following model was constructed for this study:

$$lnGDP_t=\beta_0+\beta_1\ lnREC_t+\beta_2\ lnGFC_t+\beta_3\ lnLF_t+\mu_t \quad (3.1)$$

Where the GDP is the real GDP in constant 2010 US dollar, REC is the renewable energy consumption, LF is the labour force and GFC is real gross fixed capital formation in constant 2010 US dollar.

This study employs the following model to determine the stationarity of the data:

$$y_t=\mu+\rho y_{t-1}+\epsilon_t$$

The analysis includes unit root tests (Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF), and Phillips-Perron (PP)), a cointegration test, the autoregressive distributed lag (ARDL) model, and Granger Causality tests. Unit root tests are essential for assessing the non-stationarity of time series data, and employing multiple tests ensures the robustness of results. Cointegration tests evaluate the presence of a long-term equilibrium among non-stationary series, which is critical as it implies a common stochastic trend among the variables.

Pesaran et al., (2001) established that ARDL could effectively test for cointegration, even if variables are integrated at different orders:

$$\Delta \ln GDP = \beta_0 + \sum_{i=1}^{q} \beta_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta \ln GFC_{t-i} + \sum_{i=1}^{q} \beta_{3i} \Delta \ln LF_{t-i} + \sum_{i=1}^{q} \beta_{4i} \Delta \ln REC_{t-i} + \delta_1 \ln GDP_{t-1} + \delta_2 \ln GFC_{t-1} + \delta_3 \ln LF_{t-1} + \delta_4 \ln REC_{t-1} + \mu_t \quad (3.2)$$

Upon confirming a long-run relationship, the ARDL framework transitions into an Error Correction Model (ECM) to capture the short-run dynamics and adjustments towards long-term equilibrium:

$$\Delta \ln GDP = \beta_0 + \sum_{i=1}^{q} \beta_{1i} \Delta \ln GDP_{t-i} + \sum_{i=0}^{q} \beta_{2i} \Delta \ln GFC_{t-i} + \sum_{i=0}^{q} \beta_{3i} \Delta \ln LF_{t-i} + \sum_{i=0}^{q} \beta_{4i} \Delta \ln REC_{t-i} + \omega EC_{t-1} + \mu_t \quad (3.3)$$

Granger causality, proposed by Granger (1969), investigates the predictive relationship between time series. This study uses the Toda and Yamamoto (1995) procedure with a Vector Autoregressive (VAR) model to test causality, which allows analysis irrespective of the integration order or cointegration status of the model:

$$y_t = a_1 + \sum_{i=1}^{n} \beta_i x_{t-i} + \sum_{j=1}^{m} \gamma_j y_{t-k} + e_{1t} \quad (3.4)$$

$$x_t = a_2 + \sum_{i=1}^{n} \theta_i x_{t-i} + \sum_{j=1}^{m} \delta_j y_{t-k} + e_{2t} \quad (3.5)$$

4. RESULTS AND DISCUSSIONS

This section presents the results and discussions of the analysis. Table 3 reports the descriptive statistics of the data for different variables at different levels. The values are in natural logarithms and the mean, median, maximum, and minimum do not provide much information. From the skewness, a negative number implies a left-skewed distribution and a positive number implies a right-skewed distribution. From the Jarque-Bera test, LNGDP and LNGFC failed to reject the null hypothesis, meaning that the variables are normally distributed. However, LNLF and LNREC reject the null hypothesis, meaning that the variables are non-normally distributed. Kurtosis measures the combined weights of the tails relative to the rest of the distribution.

Macroeconomic data such as GDP, GFC, LF, and REC are typically non-stationary or I(1) series, as suggested by visual inspections of graphs (Figures 1-5), which indicate an upward trend and apparent non-stationarity. Structural breaks in GDP and GFC for Indonesia, Malaysia, and Thailand, denoted by vertical lines in the graphs, correlate with the onset of the Asian Financial Crisis-1997 for Indonesia and Malaysia, and 1996 for Thailand. The subsequent section verifies these visual observations through unit root tests to confirm the stationarity status of these series.

Table 4 reports the findings based on the unit test results. For Indonesia, Malaysia, and Thailand, the order of cointegration of the variables consists of I (0) and I (1) after the inclusion of the structural break in the unit root test. In the Philippines, all the variables are I (1) or non-stationary at the level. For Singapore, I (2) variables are found for the GFC and LF.

Table 3: Summary statistics for LN_GDP, LN_GFC, LN_LF and LN_REC

	LN_GDP	LN_GFC	LN_LF	LN_REC
Mean	26.10096	24.77203	16.75592	1.802093
Median	26.06285	24.66597	17.23021	2.098754
Maximum	27.57147	26.44354	18.63010	3.286086
Minimum	24.95417	23.58486	14.22696	−1.771957
Standard Deviation	0.601262	0.674311	1.310912	1.184631
Skewness	0.414874	0.487335	−0.493111	−1.076264
Kurtosis	2.589648	2.593134	2.116281	3.132235
Jarque-Bera	4.462865	5.810006	9.133301	24.22323
Probability	0.107375	0.054749	0.010393	0.000005
Sum	3262.620	3096.503	2094.490	225.2616
Sum Sq. Dev.	44.82798	56.38218	213.0928	174.0156
Observations	125	125	125	125

Figure 1: The time series graphs at a level for Indonesia

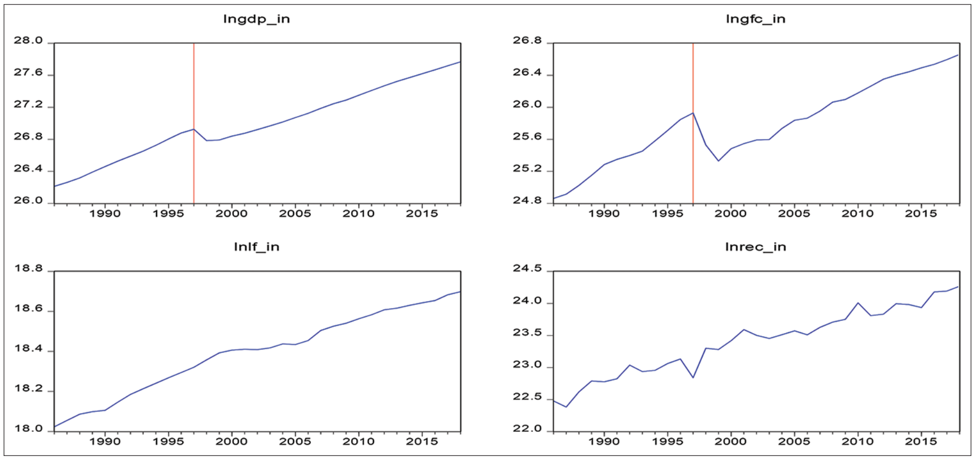


Figure 2: The time series graphs at the level of Malaysia

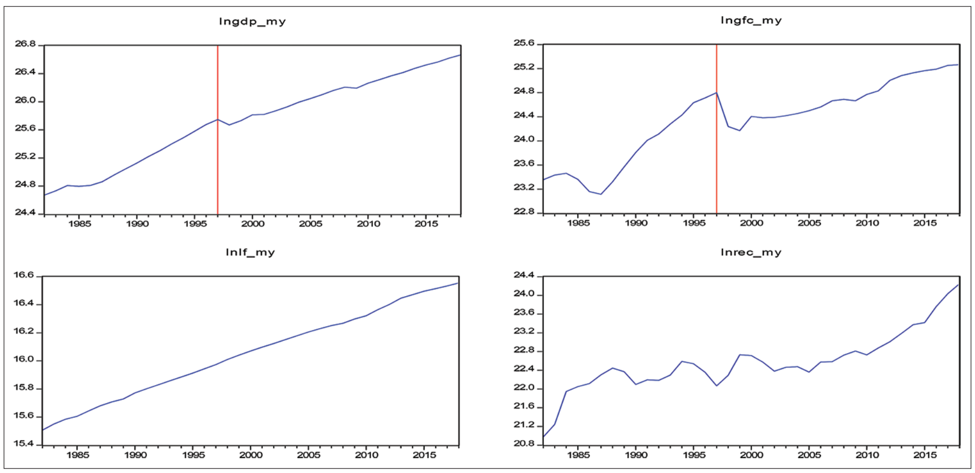
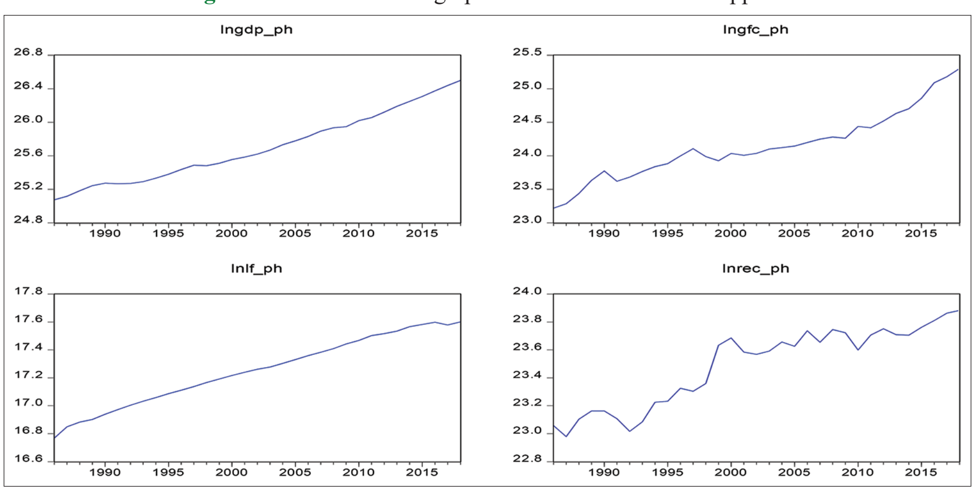


Figure 3: The time series graphs at the level for the Philippines



Based on the results in the previous section, it is found that the variables for Indonesia, Malaysia, the Philippines, and Thailand consist of either I (0), I(1), or a mixture of both. Therefore, ARDL is the preferred method for cointegration analysis. Singapore will be excluded because the unit root test shows that some of the variables are I (2).

There are five Data Generating Process (DGP) trend specifications, namely Case 1 to Case 5, to choose from. The time series shows that an upward trend is apparent, and the values of the series are not centered around zero. An important assumption is made that the upward trend will continue in the future. Hence, the selection of the DGP is Case 4, which is the unrestricted constant and trend. As with the unit root test previously, a structural break is included for Indonesia, Malaysia, and Thailand using a dummy variable to represent the structural break. The variable assumes a value of 1 for the year

Figure 4: The time series graphs at the level of Singapore

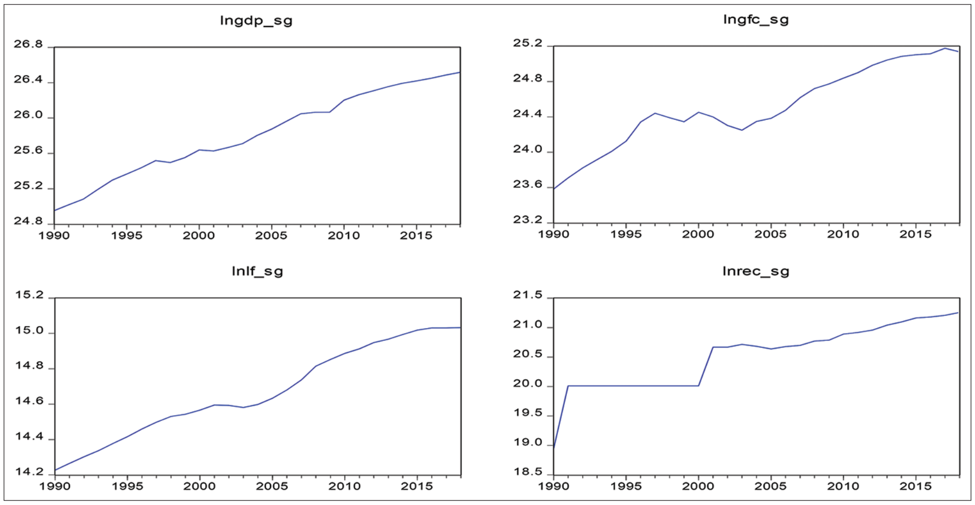


Figure 5: The time series graph at the level of Thailand

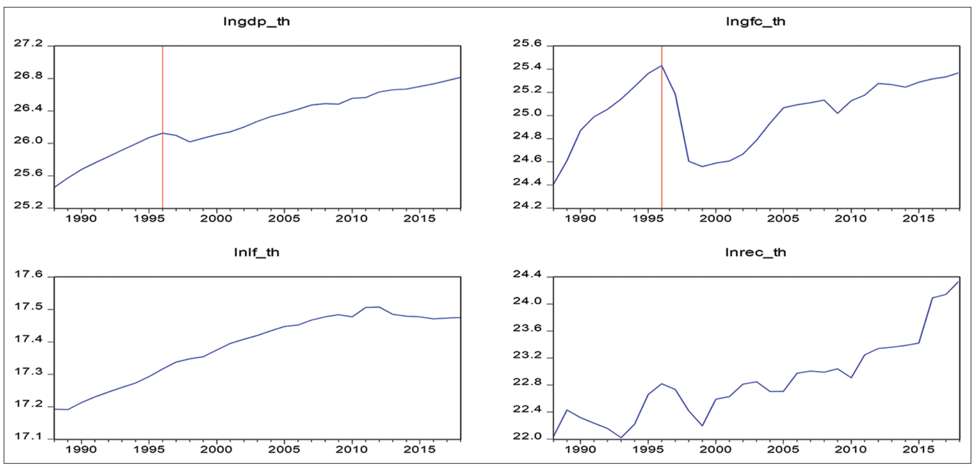


Table 4: Unit root test results

Country	GDP	lnGFC	lnLF	lnREC
Indonesia	I (0)***	I (0)***	I (1)**	I (0)***
Malaysia	I (1)***	I (0)***	I (1)***	I (1)**
Philippines	I (1)**	I (1)***	I (1)***	I (1)**
Singapore	I (1)***	I (2)***	I (2)***	I (0)***
Thailand	I (1)**	I (0)***	I (1)***	I (1)**

***, ** and * represent significant level at 1%, 5% and 10% respectively

Table 5: Bound test result summary

Country	F-statistic	Critical bound values	Conclusion
Indonesia	8.881543	2.97-5.23	Cointegrated***
Malaysia	2.240266	2.97-5.23	Not Cointegrated
Philippines	4.483214	2.97-5.23	Cointegrated**
Singapore	-	-	Not tested
Thailand	3.340367	2.97-5.23	Inconclusive

***, ** and * represent significant levels at 1%, 5% and 10% respectively

starting 1997 for Indonesia and Malaysia and 1996 for Thailand. The lag length is selected using the Schwarz Bayesian Criterion (SIC) with a maximum lag of 2.

Table 5 shows the bound test results summary of the ARDL model for each country except for Singapore. The bound test shows that the variables are cointegrated for Indonesia and the Philippines but not for Malaysia. In the case of Thailand, an inconclusive inference is made.

Table 6 presents the long-run estimation output of the cointegrated countries, with Thailand included in the estimation. An examination of each country and the selected variables on GDP shows that in Indonesia, the GFC contributes to GDP in the long run. A 1% increase in the GFC will increase the GDP by 0.39%.

Table 6: Long-run estimation output

Countries	Selected Model	lnGFC	lnLF	lnREC
Indonesia	(2,1,0,1)	0.397312***	0.274337	0.032749
		(11.22309)	(1.421125)	(0.700150)
Philippines	(1,1,0,0)	−0.146102	−3.048473**	0.057170
		(−0.784560)	(−2.316416)	(0.279512)
Thailand	(2,1,1,0)	0.131581	3.571061	0.565739
		(0.533088)	(0.711313)	(0.564708)

***, ** and * represent significant levels at 1%, 5% and 10% respectively. The coefficient is outside of the parenthesis. t-statistic is in parenthesis

In the Philippines, LF contributes negatively to GDP in the long run. A 1% increase in the LF reduces the GDP by 3%. There are no significant variables for Thailand. Although most of the variables are not significant to GDP, this does not invalidate the results. The

Table 7: ECM regression results summary

Country	Error correction term	D (lnGDP(-1))	D (lnGFC)	D (lnREC)
Indonesia	−0.564299***	−0.233008***	0.334671***	−0.027302**
	(−24.70766)	(−5.249967)	(20.04221)	(−2.550092)
Country	Error Correction Term	D (lnGFC)	D (lnGFC(−1))	
Malaysia	−0.131644***	0.237337***	−0.076988***	
	(−3.595082)	(12.80559)	(−3.868546)	
Country	Error Correction Term	D (lnGFC)		
Philippines	−0.141692***	0.167272***		
	(−5.099278)	(6.959405)		
Country	Error Correction Term	D (lnGDP(−1))	D (lnGFC)	D (lnLF)
Thailand	−0.062713***	−0.268087***	0.243205***	−0.525617**
	(−4.496444)	(−4.162582)	(16.46794)	(−2.392108)

***, ** and * represent significant levels at 1%, 5% and 10% respectively. The coefficient is outside of the parenthesis. t-statistic is in parenthesis

Table 8: Diagnostic test

Country	Test	F-statistic	P-value
Indonesia	Heteroskedasticity	0.752377	0.6592
	Serial Correlation LM test	0.955987	0.4022
Malaysia	Heteroskedasticity	1.143377	0.3688
	Serial Correlation LM test	0.777908	0.4706
Philippines	Heteroskedasticity	0.749283	0.6157
	Serial Correlation LM test	0.494703	0.6161
Thailand	Heteroskedasticity	0.278869	0.9727
	Serial Correlation LM test	3.056183	0.0735

Table 9: Max order of I (d) and the optimal lag length

Country	Max order of I (d), m	Optimal lag length, P
Indonesia	1	2
Malaysia	1	2
Philippines	1	1
Singapore	2	2
Thailand	1	2

combination of GDP with GFC, LF, and REC is cointegrated, as shown by the bound test. Some of the relationships are not captured in the long run but in the short run.

The results of the short-run summary are reported in Table 7, which is the Error Correction Model (ECM) of the ARDL. The variables show that in Indonesia, GFC, REC, and the lagged value of GDP are significant in the short run. In Malaysia and the Philippines, only GFC is significant. In Thailand, GDP is influenced by GFC, LF, and the lagged value of GDP. If the variables exhibit both long-run and short-run components, it can be said that they have a stronger relationship than if the variables are only significant in the short run. The Error Correction Term (ECT) is negative and significant for Indonesia, Malaysia, the Philippines, and Thailand, meaning that there is convergence in the model to the long-run equilibrium. For Indonesia, this implies that about 56% of any movements into disequilibrium are corrected within a year. In Malaysia, the Philippines, and Thailand, the corrections to equilibrium are 13%, 14%, and 6% respectively.

Table 8 shows the diagnostic test conducted in each country except for Singapore. There is no heteroskedasticity and serial correlation because the null hypothesis failed to be rejected.

This section covers the long-run and short-run relationships of each country using the ARDL bound test. The results show that

Table 10: Result of the Granger causality test

Dependent variable	lnGDP	lnGFC	lnLF	lnREC	Remarks
Indonesia					
lnGDP	-	1.035108	0.044447	5.667821*	REC >GDP
lnREC	0.385806	0.739395	1.922787	-	
Malaysia					
lnGDP	-	1.519458	0.503610	0.097844*	REC >GDP
lnREC	0.7748	0.9496	0.5942	-	
Philippines					
lnGDP		0.714073	0.230826	0.588628	
lnREC	0.833401	0.268776	1.179965		
Singapore					
lnGDP		8.819999**	6.862922**	9.350925**	REC >GDP
lnREC	1.687397	9.663204**		0.826949	
Thailand					
lnGDP	-	1.472597	2.184316	1.986106	
lnREC	0.339304	2.793555	4.736709	-	

***, ** and * represent significant levels at 1%, 5% and 10% respectively. Values shown are Chi-square values

Table 11: Long-run relationship

Dependent variable	lnGFC	lnLF	lnREC
lnGDP	0.472213***	−0.700018**	0.127168**
	(17.59970)	(−2.569242)	(2.456753)

**, ** and * represent significant levels at 1%, 5% and 10% respectively. The coefficient is outside of the parenthesis. t-statistic is in parenthesis

in the long run, GFC is significant to GDP in Indonesia, and LF is significant to GDP in the Philippines. There are no significant variables to GDP in Thailand. In the short run, GFC, REC, and the lagged value of GDP are significant to GDP in Indonesia. In Malaysia and the Philippines, only GFC is significant. In Thailand, GDP is influenced by GFC and LF and the lagged value of GDP. Hence, GFC has a strong relationship with GDP in all the ASEAN-5 countries. REC presents a relationship in Indonesia but not in Malaysia, the Philippines, and Thailand.

The causality test will be based on the Toda-Yamamoto procedure. The main interest in this section is to examine the causality between renewable energy and GDP so that a hypothesis can be formed. Granger causality is not the "real cause" of a variable. It does not establish a definitive cause-and-effect relationship. Using a statistical concept, it measures whether one thing happens before another and nothing else. The results from the cointegration do not affect the causality test. The first step is to determine the maximum order of integration, m, and optimal lag length, p, for each country, as presented in Table 9. An augmented VAR is generated using this information, and the Granger causality test/Wald test is conducted.

Table 10 reports the Granger causality test for the dependent and independent variables. The causality test in this section will focus on REC and GDP only. The table shows that REC Granger causes GDP for Indonesia, Malaysia, and the Philippines, implying a growth hypothesis. For the Philippines and Singapore, there is no causality in either direction, hence implying a neutrality hypothesis.

4.1. Robustness Check (Panel Data Analysis)

To evaluate the limitations of solely analyzing time series data, an additional robustness check was performed using panel data. Table 11 details the PMG outcomes for long-run relationships, highlighting the significant impacts of GFC, LF, and REC on GDP. A 1% increase in GFC increases GDP by 0.47%, whereas a 1% increase in LF reduces GDP by 0.7%, and a 1% increase in REC boosts GDP by 0.12%.

In the short-run, as shown in Table 12, GFC significantly influences GDP across combined countries, with the error correction term indicating a 19% adjustment speed to long-run equilibrium.

Moreover, Table 13 explores short-run relationships individually across countries, revealing significant impacts of GFC, LF, and REC in various nations, except for Singapore where lagged GDP values did not exhibit significant effects. The error correction terms across these countries suggest varying speeds of adjustment towards long-run equilibrium.

Table 14 reveals that the variables are a mix of I (0) and I (1), with none at I (2). Specifically, GDP, GFC, and LF are integrated at I (1), while REC is at I (0). Previous unit root tests confirmed this integration mix. Due to the integration mix, traditional panel cointegration tests like Pedroni, Kao, and Fisher are not applicable, prompting the use of a pooled mean group (PMG) approach. This approach, introduced by Pesaran et al. (1999), is akin to the ARDL model and provides a single long-run coefficient across groups, alongside country-specific short-run dynamics.

In sum, the panel data analysis, through the PMG approach, confirms significant long-run and short-run impacts of GFC, LF, and REC on GDP across the ASEAN-5. This robustness check not only corroborates the long-run relationships identified in time series analysis but also enhances understanding through the nuanced insights of short-run dynamics at the country level.

Table 12: Short-run relationship-combined

Dependent variable	Coint	D (lnGDP(-1))	D (lnGFC)	D (lnLF)	D (lnREC)
lnGDP	−0.194227**	−0.130912	0.193567***	−0.165247	−0.019963
	(−2.122034)	(−1.564861)	(9.278612)	(−1.141845)	(−1.386639)

***, ** and * represents significant levels at 1%, 5% and 10% respectively. The coefficient is outside of the parenthesis. t-statistic is in parenthesis

Table 13: Short-run relationship-individual

Countries	Cointeq1	D (lnGDP(-1))	D (lnGFC)	D (lnLF)	D (lnREC)
Indonesia	−0.509011***	−0.336628***	0.148735***	0.229460***	−0.049210***
Malaysia	−0.079136***	−0.205719***	0.187936***	−0.469279*	−0.004524***
Philippines	−0.045468***	0.154605***	0.148174***	−0.078422	0.013219***
Singapore	−0.294832***	−0.060871	0.239533***	0.017436	−0.059337***
Thailand	−0.042687***	−0.205948***	0.243458***	−0.525429***	0.0000382

**, ** and * represent significant levels at 1%, 5% and 10% respectively. The coefficient is outside of the parenthesis

Table 14: Panel unit root test result

Intercept and trend	Variables	Level		First Difference		Conclusion
Test Procedure		t-Statistic	P-value	t-Statistic	P-value	
Levin, Lin and Chu	lnGDP	−0.11493	0.4543	−7.28225	0.0000	I (1)***
	lnGFC	−0.55479	0.2895	−6.46836	0.0000	I (1)***
	lnLF	0.04082	0.5163	−1.63635	0.0509	I (1)*
	lnREC	−2.53894	0.0056	-	-	I (0)***
Im, Pesaran and Shin W-stat	lnGDP	−2.07740	0.0189	−5.49116	0.0000	I (1)***
	lnGFC	−0.85593	0.1960	−5.20840	0.0000	I (1)***
	lnLF	0.08182	0.5326	−2.95413	0.0016	I (1)***
	lnREC	−2.70192	0.0034	-	-	I (0)***
ADF-Fisher Chi Square	lnGDP	23.7994	0.0082	44.2831	0.0000	I (1)***
	lnGFC	16.7265	0.0806	42.6021	0.0000	I (1)***
	lnLF	19.1696	0.0382	28.4174	0.0015	I (1)***
	lnREC	34.7049	0.0001	-	-	I (0)***
PP-Fisher Chi Square	lnGDP	11.5775	0.3143	50.6963	0.0000	I (1)***
	lnGFC	4.81197	0.9034	38.5699	0.0000	I (1)***
	lnLF	4.25851	0.9349	34.1820	0.0002	I (1)***
	lnREC	31.6437	0.0005	-	-	I (0)***

Lag length is selected using Schwarz Info Criterion automatic selection. ***, ** and * represents significant level at 1%, 5% and 10% respectively

5. CONCLUSION

This study examines the impact of renewable energy consumption on GDP in the ASEAN-5 (Malaysia, Singapore, Thailand, Philippines, and Indonesia) from 1982 to 2018, utilizing a modified Cobb-Douglas production function that incorporates renewable energy alongside traditional economic factors like GFC and LF. The study employs both time series and panel data methodologies to provide a comprehensive analysis of the dynamics between renewable energy consumption and GDP. The time series analysis reveals cointegration in Indonesia and the Philippines, suggesting a long-term equilibrium relationship between renewable energy consumption and economic growth, but not in Malaysia, and yields inconclusive results in Thailand. GFC exerts a significant long-run influence on GDP in Indonesia, whereas LF negatively impacts GDP in the Philippines. The short-run analysis underscores the significance of GFC across all countries and highlights significant effects from REC specifically in Indonesia. The panel data analysis further supports the long-run relevance of GFC, LF, and REC, emphasizing the sustainable impact of renewable energy on economic development.

Granger causality tests indicate that REC Granger causes GDP in Indonesia, Malaysia, and Singapore, supporting a growth hypothesis in these regions, while indicating neutrality for the Philippines and Thailand. These findings suggest that renewable energy not only enhances GDP but also supports sustainable energy development, and job creation, and reduces global warming impacts. The study highlights renewable energy's potential as a driver of economic growth, especially in regions grappling with the dual challenges of development and environmental sustainability.

However, the research faces limitations due to the relatively short timeframe of data, which may impact the robustness of long-run analyses. Future research could extend the timeframe, incorporate more structural breaks, include different variables, or expand the focus beyond the ASEAN-5 to provide a more comprehensive understanding of renewable energy's economic impact. By demonstrating that renewable energy investments can positively impact GDP, this thesis provides a compelling argument for policymakers to prioritize renewable technologies and reduce reliance on fossil fuels, both economically and environmentally unsustainable in the long run. The paper aims to enrich the discourse on renewable energy's role in the ASEAN-5, offering valuable insights for policymakers committed to fostering sustainable economic development through renewable energy investments.

REFERENCES

Adedoyin, F.F., Bekun, F.V., Driha, O.M., Balsalobre-Lorente, D. (2020), The effects of air transportation, energy, ICT and FDI on economic growth in the industry 4.0 era: Evidence from the United States. Technological Forecasting and Social Change, 160, 120297.

Alabi, O., Ackah, I., Lartey, A. (2017), Re-visiting the renewable energy-economic growth nexus: Empirical evidence from African OPEC countries. International Journal of Energy Sector Management, 11(3), 387-403.

Alper, A., Oguz, O. (2016), The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. Renewable and Sustainable Energy Reviews, 60, 953-959.

Al-Shetwi, A.Q. (2022), Sustainable development of renewable energy integrated power sector: Trends, environmental impacts, and recent challenges. Science of the Total Environment, 822, 153645.

Apergis, N., Payne, J.E. (2010), Renewable energy consumption and growth in Eurasia. Energy Economics, 32(6), 1392-1397.

Arens, M., Åhman, M., Vogl, V. (2021), Which countries are prepared to green their coal-based steel industry with electricity?-Reviewing climate and energy policy as well as the implementation of renewable electricity. Renewable and Sustainable Energy Reviews, 143, 110938.

Aslan, A. (2016), The causal relationship between biomass energy use and economic growth in the United States. Renewable and Sustainable Energy Reviews, 57, 362-366.

Azam, M., Khan, A.Q., Bakhtyar, B., Emirullah, C. (2015), The causal relationship between energy consumption and economic growth in the ASEAN-5 countries. Renewable and Sustainable Energy Reviews, 47, 732-745.

Azlina, A.A. (2012), Energy consumption and economic development in Malaysia : A multivariate cointegration analysis. Procedia-Social and Behavioral Sciences, 65, 674-681.

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.

Boontome, P., Therdyothin, A., Chontanawat, J. (2017), Investigating the causal relationship between non-renewable and renewable energy consumption, CO_2emissions and economic growth in Thailand. Energy Procedia, 138, 925-930.

Chen, C., Pinar, M., Stengos, T. (2020), Renewable energy consumption and economic growth nexus: Evidence from a threshold model. Energy Policy, 139, 111295.

Coldwell, D., Venter, R., Joosub, T., Duh, H. (2022), The tension between smes' growth and sustainability in emerging and developed countries. Internationalization: Towards a conceptual model. Sustainability, 14(8), 14084418.

Glasure, Y.U., Lee, A.R. (1998), Cointegration, error-correction, and the relationship between GDP and energy: The case of South Korea and Singapore. Resource and Energy Economics, 20(1), 17-25.

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica 37, 424-438.

Hdom, H.A.D., Fuinhas, J.A. (2020), Energy production and trade openness: Assessing economic growth, CO_2 emissions and the applicability of the cointegration analysis. Energy Strategy Reviews, 30, 100488.

Heidari, H., Turan Katircioğlu, S., Saeidpour, L. (2015), Economic growth, CO_2 emissions, and energy consumption in the five ASEAN countries. International Journal of Electrical Power and Energy Systems, 64, 785-791.

Inglesi-Lotz, R. (2016), The impact of renewable energy consumption to economic growth: A panel data application. Energy Economics, 53, 58-63.

Jafari, Y., Othman, J., Nor, A.H.S.M. (2012), Energy consumption, economic growth and environmental pollutants in Indonesia. Journal of Policy Modeling, 34(6), 879-889.

Kahia, M., Ben Aïssa, M.S., Charfeddine, L. (2016), Impact of renewable and non-renewable energy consumption on economic growth: New evidence from the MENA Net Oil Exporting Countries (NOECs). Energy, 116, 102-115.

Khan, I., Hou, F., Irfan, M., Zakari, A., Le, H.P. (2021), Does energy trilemma a driver of economic growth? The roles of energy use, population growth, and financial development. Renewable and Sustainable Energy Reviews, 146, 111157.

Khan, I., Hou, F., Zakari, A., Tawiah, V.K. (2021), The dynamic links among energy transitions, energy consumption, and sustainable economic growth: A novel framework for IEA countries. Energy, 222, 119935.

Khan, M.K., Khan, M.I., Rehan, M. (2020), The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financial Innovation, 6(1), 1-13.

Kyophilavong, P., Shahbaz, M., Anwar, S., Masood, S. (2015), The energy-growth nexus in Thailand: Does trade openness boost up energy consumption? Renewable and Sustainable Energy Reviews, 46, 265-274.

Le, T.H., Quah, E. (2018), Income level and the emissions, energy, and growth nexus: Evidence from Asia and the Pacific. International Economics, 156, 193-205.

Lee, C. (2005), Energy consumption and GDP in developing countries : A cointegrated panel analysis. Energy Economics, 27, 415-427.

Lin, B., Moubarak, M. (2014), Renewable energy consumption-economic growth nexus for China. Renewable and Sustainable Energy Reviews, 40, 111-117.

Lyazzat, K., Abubakirova, A., Igilikovna, O.A., Zhanargul, T., Suleimenovna, S.B. (2023), The relationship between energy consumption, carbon emissions and economic growth in ASEAN-5 countries. International Journal of Energy Economics and Policy, 13(2), 265-271.

Mukhtar, B., Shad, M.K., Lai, F., Waqas, A. (2023), Empirical analysis of ESG-driven green innovation : The moderating role of innovation orientation. Management and Sustainability: An Arab Review. https://doi.org/10.1108/MSAR-08-2023-0043

Mukhtar, B., Shad, M.K., Lai, F.W. (2024), Fostering sustainability performance in the Malaysian manufacturing companies: The role of green technology innovation and innovation capabilities. Benchmarking An International Journal. https://doi.org/10.1108/BIJ-07-2023-0468

Mukhtar, B., Shad, M.K., Woon, L.F., Waqas, A., Mukhtar, Z. (2023), Role of green technology innovation to promote sustainability performance in Malaysian manufacturing solar PV industry. Platform: A Journal of Management and Humanities, 6, 36-46.

Munir, Q., Lean, H.H., Smyth, R. (2020), CO_2 emissions, energy consumption and economic growth in the ASEAN-5 countries: A cross-sectional dependence approach. Energy Economics, 85, 104571.

Osman, A.I., Chen, L., Yang, M., Msigwa, G., Farghali, M., Fawzy, S., Rooney, D.W., Yap, P.S. (2023), Cost, environmental impact, and resilience of renewable energy under a changing climate: A review. Environmental Chemistry Letters, 21(2), 741-764.

Ozturk, I. (2010), A literature survey on energy-growth nexus. Energy Policy, 38(1), 340-349.

Ozturk, I., Acaravci, A. (2010), CO_2 emissions, energy consumption and economic growth in Turkey. Renewable and Sustainable Energy Reviews, 14(9), 3220-3225.

Payne, J.E. (2010), Survey of the international evidence on the causal relationship between energy consumption and growth. Journal of Economic Studies, 37(1), 53-95.

Pesaran, Shin and Smith, (2001), Bounds Testing Approaches to the Analysis of Level Relationships Journal of Applied Econometrics, 16, 289326.

Rahman, M.M., Velayutham, E. (2020), Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia. Renewable Energy, 147, 399-408.

Raihan, A., Tuspekova, A. (2022), Role of economic growth, renewable energy, and technological innovation to achieve environmental sustainability in Kazakhstan. Current Research in Environmental Sustainability, 4, 100165.

Safitri, D., Fahrurrozi, F., Marini, A., Husen, A., Purwanto, A., Arum, W.S.A., Nafiah, M. (2022), The role of energy consumption and economic growth on the ecological environment in ASEAN countries. Environmental Science and Pollution Research, 29(51), 77671-77684.

Salim, R.A., Hassan, K., Shafiei, S. (2014), Renewable and non-renewable energy consumption and economic activities: Further evidence from OECD countries. Energy Economics, 44, 350-360.

Shahbaz, M., Loganathan, N., Zeshan, M., Zaman, K. (2015), Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. Renewable and Sustainable Energy Reviews, 44, 576-585.

Tang, C.F. (2008), A re-examination of the relationship between electricity consumption and economic growth in Malaysia. Energy Policy, 36(8), 3077-3085.

Tiba, S., Omri, A. (2017), Literature survey on the relationships between energy, environment and economic growth. Renewable and Sustainable Energy Reviews, 69, 1129-1146.

Toda, H.Y., Yamamoto, T. (1995), Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometrics, 66(1-2), 225-250.

Tugcu, C.T., Ozturk, I., Aslan, A. (2012), Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. Energy Economics, 34(6), 1942-1950.

Tuna, G., Tuna, V.E. (2019), The asymmetric causal relationship between renewable and Non-Renewable energy consumption and economic growth in the ASEAN-5 countries. Resources Policy, 62, 114-124.

Usman, A., Ozturk, I., Hassan, A., Maria Zafar, S., Ullah, S. (2021), The effect of ICT on energy consumption and economic growth in South Asian economies: An empirical analysis. Telematics and Informatics, 58, 101537.

Vanegas Cantarero, M.M. (2020), Of renewable energy, energy democracy, and sustainable development: A roadmap to accelerate the energy transition in developing countries. Energy Research and Social Science, 70, 101716.

Waheed, R., Sarwar, S., Wei, C. (2019), The survey of economic growth, energy consumption and carbon emission. Energy Reports, 5, 1103-1115.

Wang, Q., Wang, L. (2020), Renewable energy consumption and economic growth in OECD countries: A nonlinear panel data analysis. Energy, 207, 118200.

Xu, Y., Li, A. (2020), The relationship between innovative human capital and interprovincial economic growth based on panel data model and spatial econometrics. Journal of Computational and Applied Mathematics, 365, 112381.

Yildirim, E., Aslan, A., Ozturk, I. (2014), Energy consumption and GDP in Asean countries: Bootstrap-corrected panel and time series causality tests. Singapore Economic Review, 59(2), 1450010.

Zeraibi, A., Balsalobre-Lorente, D., Murshed, M. (2021), The influences of renewable electricity generation, technological innovation, financial development, and economic growth on ecological footprints in ASEAN-5 countries. Environmental Science and Pollution Research, 28(37), 51003-51021.