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Effect of Renewable Energy Consumption on Environmental Degradation in ASEAN Countries

Norashida Othman[1*], Rishan Sampath Hewage[2], Jaafar Pyeman[1], Farah Raihana Ismail[3]
** Corresponding Author*

[1] Department of Economics and Financial Studies Faculty of Business and Management,
Universiti Teknologi MARA (UiTM), Selangor, Malaysia
[2] Department of Accountancy and Finance, Faculty of Management Studies
Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka
[3] Academic Department, Faculty of Business, YPC International College, Kuala Lumpur, Malaysia

shidaothman@uitm.edu.my; hewagesampath@mgt.sab.ac.lk; jaaf@uitm.edu.my; raihana@ypccollege.edu.my
Tel: +60102451335

Abstract
This study focused on estimating the long-run and short-run relationship of dross domestic savings, development of the industrial sector, and renewable energy consumption towards the environmental degradation in Association of Southeast Asian (ASEAN) countries. We conducted the Pooled Mean Group (PMG) estimation techniques developed by Pesaran et al.(1999). The results highlighted that all the variables present significant environmental degradation while using renewable energy has abolished environmental pollution in ASEAN countries. Therefore, policymakers must take action to design sustainable economic development mechanisms and convert industrial investments to environmentally friendly projects to improve green technology.

Keywords: Domestic Savings, Renewable Energy Consumption, Environmental Degradation, Pooled Mean Group

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1.0 Introduction

Having a green environment is one of the sustainable goals of any country while achieving the highest utilization of resources. Hence, many countries have taken many steps to reduce environmental degradation and introduce policies promoting a low-carbon economy (Tao et al., 2022). Globalization and industrialization are the primary drivers of increased energy consumption and efficiency in energy utilization, reducing environmental deterioration and lowering energy costs. The surge in energy use is attributed to a significant increase in carbon emissions, especially the consumption of non-renewable energy, which degrades environmental standards. As a result, governments gave special emphasis to developing alternative energy sources to replace non-renewable energy. Renewable energy sources such as biomass, hydro, wind, solar, and geothermal emit no carbon dioxide (CO2) during electricity generation (Rahman et al., 2022). Unlike non-renewable energy that releases CO_2 when burning coal, oil, or natural gas, renewables generate electricity without any direct emissions, thereby reducing overall CO_2 emissions.

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In order to build an innovative and specifically agenda for sustainable development, the United Nations set 17 Sustainable Development Goals (SDGs) in 2015, with the goal of achieving them by 2030 (UN, 2015). Among these, Goal 13 calls for the adoption of immediate steps to combat climate change and its repercussions (UN, 2015). Climate change is the most serious concern confronting all governments in the new millennium. Reducing global CO_2 output is a global environmental threat that necessitates a global response to create a real solution; otherwise, the continual rise in CO_2 emissions will become even more challenging.

Developing countries need help to formulate policies that meet sustainable development goals based on awareness of the environment, and ASEAN is no exception. The significant decline in total energy consumption across the ASEAN Region in 2020 demonstrates the economic impact of the COVID-19 pandemic. With the coronavirus under control, the economy will likely increase with energy demand. During the pandemic, energy consumption from numerous industries fell, owing primarily to mobility restrictions imposed by the governments.

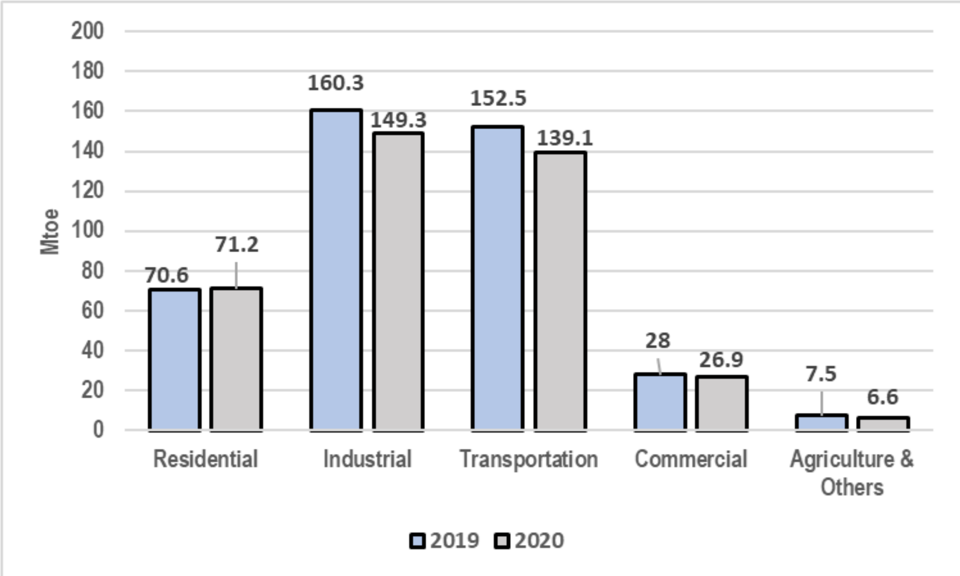

Fig 1. ASEAN Energy Consumption by Sector
(Source: ASEAN Centre for Energy, 2022)

ASEAN has over 661 million people and is one of the world's fastest-growing economic regions (Handayani, 2022). Nonetheless, ASEAN's average power usage per capita remains at 1,560 kW-hours (kWh), less than half the global average of 3,300 kWh in 2018. The International Energy Agency (IEA) forecasted an increase in ASEAN energy-related CO2 emissions to 2.4 Gt in 2040, 71% higher than in 2018. Southeast Asia, on the other hand, is one of the most sensitive regions to climate change (Overland, 2021). Therefore, it makes sense to view the ASEAN low-carbon pathway not just as a luxury imposed by the Paris Agreement but also as a necessity, given the region's unique vulnerability to the effects of climate change.

To date, the impact of renewable energy consumption towards environmental degradation is empirically ambiguous and under exploration, particularly in the ASEAN region. Thus, the aim of this study is to investigate the long run & short run effect of renewable energy consumption towards environmental degradation in ASEAN countries. This study used 7 Association of Southeast Asian (ASEAN) countries: Cambodia; Indonesia; Malaysia; Philippines; Singapore; Thailand, and Vietnam, to examine the cointegration between variables. The annual data were gathered for the period of 20 years within the time spanning from 2000 to 2020. The rest of the paper is organised as follows: Section 2 offers a quick assessment of the literature on the connection between renewable energy consumption on environmental effects, while the methodology is described in Section 3. Section 4 discusses the finding from the empirical data, and Section 5 concludes the paper.

2.0 Literature review

Since environmental degradation has drawn so much attention, controlling it has moved up every nation's priority. The literature of renewable energy documents various mechanisms through which renewable energy helps improve the environment's quality. Since renewable energy does not release any harmful substances, the environment's quality is not harmed. Jebli and Youssef (2017) and Al-Mulali et al. (2016) claim that renewable energy might harm the environment since waste and combustible renewable energy sources are not clean, thus leading to emissions. Al-Mulali et al. (2016) utilized a sample of 58 countries using annual data from 1980 to 2009 to conclude that using renewable energy worsens the environment by increasing the inefficiency of the used amount of water and land. This finding is also supported by Farhani & Shahbaz's (2014) study in 10 MENA, covering the period from 1980 to 2009.

Contrarily, Bilgili et al. (2016) argue that fossil fuels should be replaced by renewable energy, reducing the potential emissions of fossil fuels. They conducted a study on a panel of OECD countries from 1977 to 2010, and the results indicate the negative effect of renewable energy on carbon emissions. The finding was also supported by Balsalobre-Lorente et al. (2018) for Germany, France, Italy, the United Kingdom, and Spain for the period 1985-2016. Their results demonstrated how using renewable energy sources, innovation, and a wealth of natural resources improves the environment. Majeed and Luni (2019) explore the links of renewable energy, water withdrawal, and economic growth with environmental degradation by utilizing Pooled OLS, Random Effects, and Fixed Effects estimations for 166 countries from 1990-2017. Their results confirm the negative effect of renewable energy on environmental degradation. Sulaiman et al. (2013), Belaid & Zrelli (2019) and Dogan & Ozturk (2017), for the case of Malaysia, Mediterranean countries and the USA, respectively, also have the same conclusions. More recent study empirical findings from Amin (2022) founds that renewable energy lowered CO_2 emissions by 0.46% for the case of ASEAN nations from 1991 to 2018.

In contradiction with renewable energy consumption, industrialization is also considered the factor that leads to environmental degradation and has become a major concern in developed countries. Depending on the source of energy used, the production can either enhance or worsen the environment. For example, when renewable energy sources, including wind, solar, hydropower, biomass and biogas energy, are used, the environment is improved and vice versa. Additionally, most previous studies suggest a positive link between industrialization and CO2 emissions. Industrialization also increased economic activity and energy consumption patterns, thus increasing CO_2 emissions (Ahmad et al., 2019 & Dong et al., 2019). In analyzing how domestic savings and technological improvements affect environmental degradation in ASEAN nations, Othman et al. (2022) found a negative correlation between domestic savings and environmental degradation. They contend that whereas domestic savings and technological advancements in ASEAN countries reduce greenhouse gas emissions temporarily, they have the reverse effect over the long term. This study shows that large domestic savings and technological advances aid in transitioning to renewable energy and ecologically friendly technologies.

The positive effect of non-renewable energy consumption on emissions is extensively documented in the literature. However, the effect of renewable energy on the environment is relatively less explored. Moreover, the available evidence on renewable energy and the environment must be more conclusive. This study contributes to the existing literature in various ways. Carbon dioxide (CO2) emissions are used as proxy variables for environmental degradation (Majeed & Luni, 2019), and the influence of explanatory variables such as Gross Fixed Capital Formation (GFC) and Gross Domestic Savings (GDS) on environmental degradation is measured. However, adopting these explanatory variables to measure environmental degradation is rare in the case of ASEAN. This study also adds significantly to the existing literature by comparing the effects of domestic savings and industrial development on environmental degradation.

3.0 Methodology

3.1 Model Specification

The following econometric model examines the effect of renewable energy consumption (REN), Carbon dioxide (Co2) emissions.

$$\mathrm{Co2EMI}_{it} = \theta_0 + \theta_1 REN_{it} + \theta_2 GFC_{it} + \theta_3 GDS_{it} + \varepsilon_t \tag{1}$$

Where; $Co2EMI$ designates Carbon dioxide (CO_2) emissions (Majeed & Luni, 2019) while REN represent the renewable energy consumption (Islam et al., 2022). Control variables of GFC, and GDS are represent gross fixed capital formation (Mitić et al., 2020), and gross domestic savings (Othman et al., 2022), respectively, while ε shows the error term. The data was collected via world bank database. Since the study used panel data analysis with unrestricted specification, 'i' denotes the cross-sections and 't' represents the respective time. Here, i represents the cross-sections (1, … 7), t represents the time series (2000, …, 2020), θ represents the respective elasticities of REN, GFC, and GDS, and ε represents the error term.

3.2 Data Sources and Description of Variables

For this study, we used annual times series data spanning from 2000 to 2020 for seven selected ASEAN countries, i.e. Cambodia; Indonesia; Malaysia; Philippines; Singapore; Thailand, and Vietnam. Data availability for all required variables determines the selection of countries and the length of the study period. All variables are obtained from the World Development Indicator (WDI) via World Bank Online Database (2023). Table 1 shows the selected variables and the proxies used to measure each variable. Table 1 summarizes the variables used for the model specified in Equation 1:

Table 1. Key Variables

Variable Name	Proxy and the calculation mechanism
CO_2 Emissions	CO_2 emissions (metric tons per capita)
Renewable energy (REN)	Renewable energy consumption (as % of total energy consumption)

Gross Fixed Capital Formation (GFC)	Gross fixed capital formation (% of GDP)
Gross Domestic savings (GDS)	Gross domestic savings (% of GDP)

(Source. World Development Indicators, 2023)

3.3 Model Construction

The Pooled Mean Group (PMG) allows for heterogeneity in short-run coefficients and error variances while imposing homogeneity in long-run coefficients across countries. Since the countries in this study have a lower degree of heterogeneity, PMG is a better option (e.g., Othman et al., 2018). This study also conducted a Mean group (Pesaran & Smith, 1995), and Dynamic Fixed Effect (Pesaran et al., 1999) was used for comparison purposes only. The primary analysis tools to look at the relationship between explanatory and regressor variables over the short- and long-run.

3.4 Cross-sectional Dependency

The study used the Breush-Pagan (1980) LM test, Pesaran (2004) scaled LM test, Baltagi, Feng, and Kao (2012) bias-corrected scaled LM test, and Pesaran (2004) as its key methodologies because the choice of data analysis method depends on whether the data set contains cross-sectional dependencies.

3.5 Panel unit root test

Since this study uses macro panel data, which consists of large T (times) and small N (groups), it is necessary to perform a panel unit root test to determine the order of integration among the variables before proceeding to the PMG estimation analysis (Othman et al., 2018). The analysis results are more reliable when the best unit root test is chosen among the first and second generations. The data set contains a cross-sectional dependency. Hence panel unit roots test with second-generation cross-sectional dependency was applied. The two main tests were the Cross-sectional Augment Dickey-Fuller test (CADF) and the Cross-sectional IPS test (CIPS).

3.6 Hausman Test

The study occupied the Hausman test to confirm the slope homogeneity and finalize the best-fitted model among PMG, MG, and DFE. The study selects PMG as the most appropriate technique to present the relationship between explanatory and regressor variables If the P-value > 0.05.

4.0 Results

4.1 Descriptive Statistics

The attributes of chosen variables are presented in Table 1. According to table statistics, all the variables demonstrate the symmetric distribution from its mean. Kurtosis was used to measure the tailing of the data series, and found that the data series follows negative kurtosis.

Table1. Descriptive Statistics

Variables	Obs	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
Co2EMI	147	3.394	1.960	10.571	0.161	2.2990	0.806	2.184
REN	147	28.002	26.690	81.580	0.330	22.316	0.616	2.743
GFC	147	24.381	23.886	35.107	15.829	4.445	0.429	2.539
GDS	147	30.278	30.507	55.466	5.959	11.936	0.364	2.506

4.2 Correlation

Table 2 presents the correlation among the variables and confirms a significant relationship between dependent and independent variables. Further, it shows multicollinearity among the variables that lead to using Panel ARDL techniques for the analysis.

Table 2. *Correlation* Matrix

	Co2Emi	Dcpvt_bank	GDP_per_growth	Tech_adv
Co2Emi	1			
ren	-0.852***	1		
gfc	0.196**	-0.305***	1	
gds	0.857***	-0.801***	0.408***	1

Notes: ***, ** and * indicate significance at 1%, 5%, and 10%, respectively.

4.3 Multi Collinearity Test

Table 3 confirms no multicollinearity among the variables since the Variance Inflation Factor (VIF) values are lower than five, and the tolerance ratio presents values greater than 0.2.

Table 3. Multicollinearity Test

Variable	VIF	1/VIF
REN	3.04	0.329
GFC	2.79	0.358
GDS	1.20	0.832
Mean VIF	2.35	

4.4 Cross-sectional Dependency

The study used Breush-Pagan (1980) LM test, Pesaran (2004) scaled LM test, Baltagi, Feng, and Kao (2012) bias-corrected scaled LM test, and Pesaran (2004) CD test as key examining tools to confirm the cross-sectional dependency and the results are presenting in Table 4.

Table 4. Cross-sectional dependency

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
CO_2EMI	268.4456***	38.1817***	38.0067***	8.5638***
REN	144.5666***	19.0668***	18.8918***	1.2413***
GFC	90.8056***	10.7712***	10.5962***	-1.3183***
GDS	119.1243***	15.1409***	14.9659***	-0.8522***

Notes: ***, ** and * indicate significance at 1%, 5%, and 10%, respectively.

4.5 Panel Unit Root

The cross-sectional dependency test proves dependency among the cross sections of ASEAN countries. Therefore, the study used second-generation CIPS and CADF panel unit root tests to examine the data series' stationarity; the results are shown in Table 5. As per the test results of CIPS, all the variables show a statuary distribution in their first difference, while CADF says Renewable energy usage (REN) and Gross Domestic savings (GDS) get stationary at their first difference.

Table 5. Unit root test

Variable	CIPS		CADF	
	Level	First Difference	Level	First Difference
CO_2EMI	-2.1027	-3.3450***	-0.9197	-1.5113
REN	-1.5920	-3.2202***	-1.9769	-3.3150*
GCF	-1.7887	-2.9082***	-0.9781	-2.3867
GDS	-1.6058	-4.3791***	-1.5727	-3.7239**

Notes: ***, ** and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

4.6 Panel data estimation

The long-run and short-run influence of renewable energy, industrial development and domestic savings on environmental degradation is tested with the panel ARDL technique. The results are shown in Table 6. Further, the best method to explain the cointegration was selected with the Hausman test, presented in Table 7. Table statistics show that PMG is the most appropriate technique to explain the long-run and short-run relationship between explanatory variables and response variables. It does not reject the long-run homogeneity restriction hypothesis if the p-values associated with the Hausman test are greater than 0.05. In other words, PMG is more appropriate compared to MG. The model's significance is shown by the negative value of the speed of adjustment with a P-value less than 0.05.

Table 6. Panel Cointegration

DV (Co2Emi)	Mean Group (MG)	Pooled Mean Group (PMG)	Dynamic Fixed Effect (DFE)
		LONG RUN	
REN	0.0322	-0.013***	-0.0412
	(0.1024)	(0.0025)	(0.0117)
GFC	0.0442	0.015**	-0.0005
	(0.0240)	(0.008)	(0.0230)

GDS	0.0036 (0.0180)	0.016** (0.007)	-0.0390 (0.0238)
	SHORT RUN		
Speed of adjustment	-0.6510*** (0.1707)	-0.3293** (0.1299)	-0.2426*** (0.0457)
REN	-0.0319 (0.0531)	-0.0183 (0.0326)	-0.0076 (0.0100)
GFC	-0.0109 (0.0175)	-0.0109 (0.0153)	-0.0085 (0.0113)
GDS	0.0168 (0.0109)	0.0079 (0.0100)	0.0247 (0.0100)
Number of groups	7	7	7
Number of observations	140	140	140

Notes: Standard error in parenthesis; ***, ** and * indicate significance at the levels of 1%, 5%, and 10%, respectively.

The Pooled Mean Group (PMG) analysis proves that all the variables (REN, GFC and GDS) are significantly influencing environmental degradation in the long run, while renewable energy consumption (REN) reduces environmental degradation. However, industrial development and domestic savings positively affect environmental degradation in ASEAN countries. Despite the long run, none of the variables shows any significant relationship to environmental degradation in the short run. However, the speed of adjustment (convergent coefficient) value indicates that the market takes more than three years (37 months) to readjust to its equilibrium after the influence of independent variables.

Table 7. Hausman Test

Test	Chi2 value	Probability value	Decision
MG vs PMG	4.03	0.2582	PMG is appropriate
PMG vs DFE	146.7	0.0000	PMG is appropriate

We can conclude from the findings that renewable energy consumption contributes negatively to environmental degradation in the long run. This finding supports the results of previous empirical evidence, such as Balsalobre-Lorente et al. (2018), Majeed and Luni (2019), and Amin (2022). Continuing this discussion, increasing renewable energy consumption is crucial for ASEAN to avoid environmental degradation, particularly CO2 emission. The natural environment of the flora and fauna can be preserved due to these countries' increased reliance on renewable energy sources. Therefore, the policy design in these nations must look into public property rights strictly, alongside implementing and incentivizing cleaner technologies in the existing and potential production processes (Roy et al., 2017; Sharif et al., 2020). This can be possible only through rising levels of renewable energy consumption. In this sense, the goals of SDG 12, or responsible consumption and production, and SDG 9, or industry, innovation, and infrastructure, can be aligned.

However, domestic savings and industrial sector development cause to increase swell the carbon emission. Therefore, policymakers must take action to design sustainable economic development mechanisms and convert industrial investments to environmentally friendly projects, and direct domestic savings to improve green technology. Furthermore, the government must promote green consumption patterns in ASEAN countries. Moreover, stringent environmental regulations will significantly improve the country's trade competitiveness (Othman et al., 2023) and thus lead to sustainable economic growth.

5.0 Conclusion and recommendation

This study examined the long-run and short-run effects of renewable energy consumption (REN), gross fixed capital formation (GFC) and gross domestic savings (GDS) on environmental degradation (CO2) in ASEAN countries. The results revealed that all the explanatory variables significantly influence greenhouse gas emissions in the long run. Gross fixed capital formation and gross domestic savings positively correlate with environmental degradation, while renewable energy consumption work in the opposite direction. However, no variable shows a relationship with environmental degradation in the short run. Greater efforts are needed for the ASEAN region to transition to a more sustainable energy pathway. The potential advantages of diversifying and encouraging to use of renewable energy are significant, thus decreasing vulnerability to climate change and volatile fossil fuel prices as well as improving economic opportunities from the growth of renewable energy.

Moreover, countries must have a sustainable development policy and consider an ecological civilization policy to reduce carbon emissions. On the other hand, regions must think about altering their energy use patterns and seek sources of foreign direct investment to finance green technological innovation and research and development to adopt eco-friendly production methods and equipment. Additionally, governments should devise plans to convert their industrial sectors from those that depend on economic growth to those that do while promoting green purchasing patterns. In order to control environmental degradation, laws and regulations for environmental protection must also be implemented.

6.0 Limitations of the Study

There are some limitations to this study that should be addressed in future research. First, the ASEAN group consists of only seven countries: Cambodia, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. Future studies could include a bigger collection of Southeast Asian countries. Furthermore, renewable energy can be divided into subcategories (solar, wind, hydro, geothermal, and biomass) so that policy recommendations can be tailored to specific types of energy. Another constraint of this study is the use of panel data estimation (various GMMs that look at both time series and cross-sectional data). Qualitative methods, such as the Analytical Hierarchy Process (AHP) with expert evaluation, can also be used for a clearer picture.

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