Linking Non Renewable Energy, Renewable Energy, Globalization and CO₂ Emission under EKC Hypothesis: Evidence from ASEAN-6 Countries through Advance Panel Estimation

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ABSTRACT

Southeast Asian countries have seen substantial economic growth over the years, but they have not been able to maintain environmental quality at the same time. Non-renewable sources constitute a significant proportion of energy consumption in the ASEAN which can have repercussions for long-term sustainable development. While the impacts of energy consumption and economic growth on environmental quality have been studied before, literature is quiet about the nexus between globalization, renewable and non-renewable energy, economic growth, and CO2 emissions in the ASEAN context. To fill in this gap in the literature, the present study estimates the effect of globalization, economic growth, and renewable and non-renewable energy on CO2 emission under the umbrella of the EKC hypothesis over the 1995 to 2020 period. Due to the presence of cross-sectional dependence and heterogeneity of slope parameters, second-generation techniques of co-integration, unit root, and long and short-run estimations are used. According to the findings of CS-ARDL estimation, non-renewable energy and globalization contribute to environmental deterioration, whereas renewable energy has a positive contribution to environmental quality improvement in ASEAN countries. Moreover, the findings prove the validation of the EKC hypothesis in the selected economies. The study concludes that the region is developing at the expense of environmental quality while also pursuing enormous globalization initiatives. The policy implications and directions of the findings for sustainable development are discussed.

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1.   Introduction

The evidence for climate change and global warming is real and indisputable. In the twenty-first century, many developing and developed economies have seen economic growth and environmental pressure is accompanying these improvements (S. Nathaniel & Khan, 2020). Climate change is predicted to have a greater detrimental impact on emerging countries since they are not capable of effectively dealing with the issues arising from it (Chien, Pantamee, et al., 2021; Nkengfack & Fotio, 2019). Therefore, the effects of economic activity on environmental degradation have become popular research topic (Cohen, Jalles, Loungani, & Marto, 2018; Zhuang et al., 2021).

One prominent theory that explains environmental deterioration and economic growth relationship is the EKC Hypothesis (Chien, Sadiq, Kamran, et al., 2021; Grossman & Krueger, 1991), which suggests that environmental quality deteriorates during the early phases of

growth, reaches its peak, and then improves at later phases, resembling a typical inverted U-shaped curve. This argument can be described as: in initial stages, structure or technology of the economy remains unchanged that aggravates environmental problems, but as the economy continues to grow, there is a shift toward more information intensive industries which help in minimizing pollution. Furthermore, with the improvement in the standards of living, the demand for better environmental quality increases which reduces pollution ultimately (Chien, Sadiq, Nawaz, et al., 2021; Le & Ozturk, 2020). Energy consumption and globalization, in addition to economic growth, also affect environmental quality in significant ways. The consumption of fossil fuels is the chief cause of CO_2 emission particularly in emerging countries in the pursuit of development. Consumption of natural resources and rising demand of traditional energy sources have prompted policymakers and planners to look for alternative energy sources. Sources of renewable energy (geothermal, biomass, hydro, wind, and solar) are considered to be a viable answer to energy security and climate change issues and also one of the important strategies for CO_2 emission reduction (Li et al., 2021; Pata, 2018).

Policymakers have also emphasized the significance of globalization in various social, political, economic elements, and especially environmental deterioration in recent years (Z. Liu, Lan, Chien, Sadiq, & Nawaz, 2022; Shahbaz, Shahzad, & Mahalik, 2018). Globalization is regarded as global phenomenon that eliminates or reduces cross-border restrictions, promotes advanced technological transfer and increases investment and financial flow. Through FDI and the interchange of energy-saving technology, it fosters financial development and economic activity. Modern technology makes it possible to use energy more efficiently which reduces energy consumption and enhances environmental quality by reducing CO_2 emission (Chien, Pantamee, et al., 2021; Saud & Chen, 2018). Nevertheless, globalization is harmful to the environment because it stimulates international trade, investment, and related economic activity that result in rise in energy use and environmental deterioration. Moreover, globalization hastens the spread of pollution by facilitating the movement of nonrenewable resources to economies with insufficient environmental policies. It is a general observation that that governments are forced to cut production costs by neglecting or sacrificing the environment as the level of trade liberalization increases (Le & Ozturk, 2020; Nawaz, Hussain, et al., 2021).

Figure 1: Trend of GDP in ASEAN-6 over 2000-2018 period
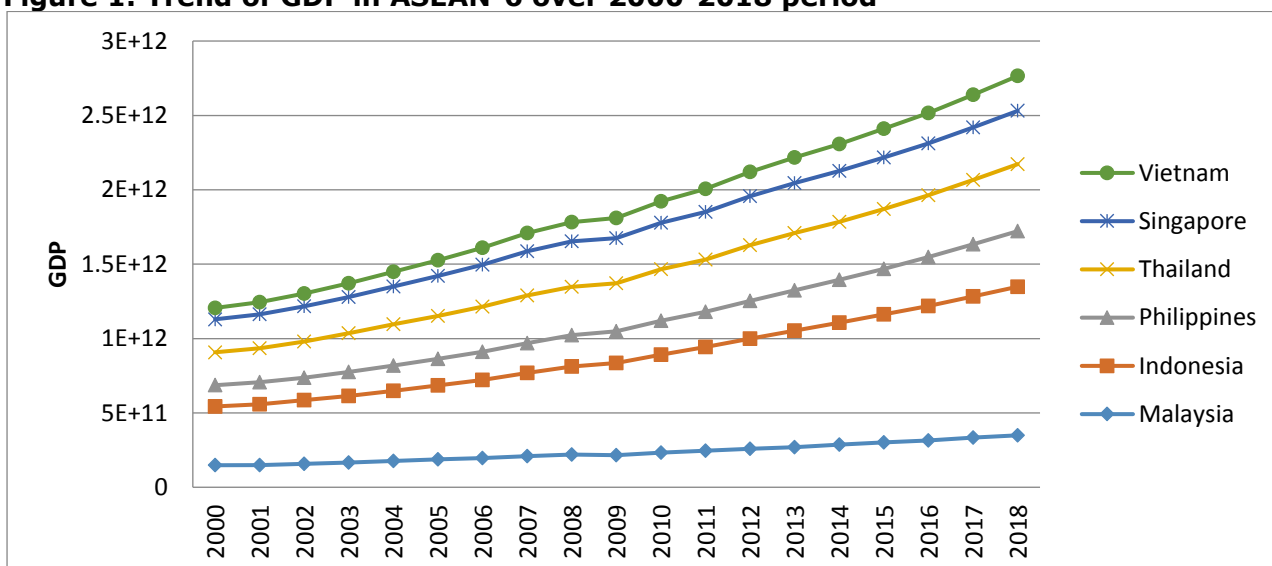
Following this discussion, the main purpose of the study is to estimate the nexus between renewable energy, non-renewable energy, globalization and CO_2 emission in the ASEAN-6 countries namely Malaysia, Thailand, Indonesia, Philippines, Vietnam and Singapore over 1995-2020 period. These six countries are the most powerful members among ASEAN countries. These are more developed countries than the rest of ASEAN and five of them, except Vietnam, are ASEAN founders. From 2000 till present, ASEAN economies grew at a rate of above 5% each year on average, which is a fairly high rate of growth as compared to the average yearly increase of 1.6 percent of OECD countries (Baloch et al., 2021; Nawaz,

Seshadri, et al., 2021; Zhu, Duan, Guo, & Yu, 2016). Because of their significant economic growth, ASEAN has a huge influence in world energy consumption. The ASEAN has seen an almost 50 percent increase in energy demand from 2000 till now (EIA, 2015). Furthermore, from 2013 to 2040, the demand for energy in the region is predicted to increase by 82 percent, doubling the region's CO2 emissions. ASEAN countries are economically open. As a result, they are seeing a massive boost in globalization (Chien, Hsu, Zhang, Vu, & Nawaz, 2021; Phong, 2019) which has the potential to either mitigate or exacerbate their environmental degradation (Ahmed & Le, 2021; Chien, Kamran, et al., 2021; Shair, Shaorong, Kamran, Hussain, & Nawaz, 2021). Figure 1 and figure 2 show the trends of economic growth and CO2 emission in ASEAN-6 countries.

Figure 2: Trend of CO2 Emission in ASEAN-6 Countries over 2000-2018 period
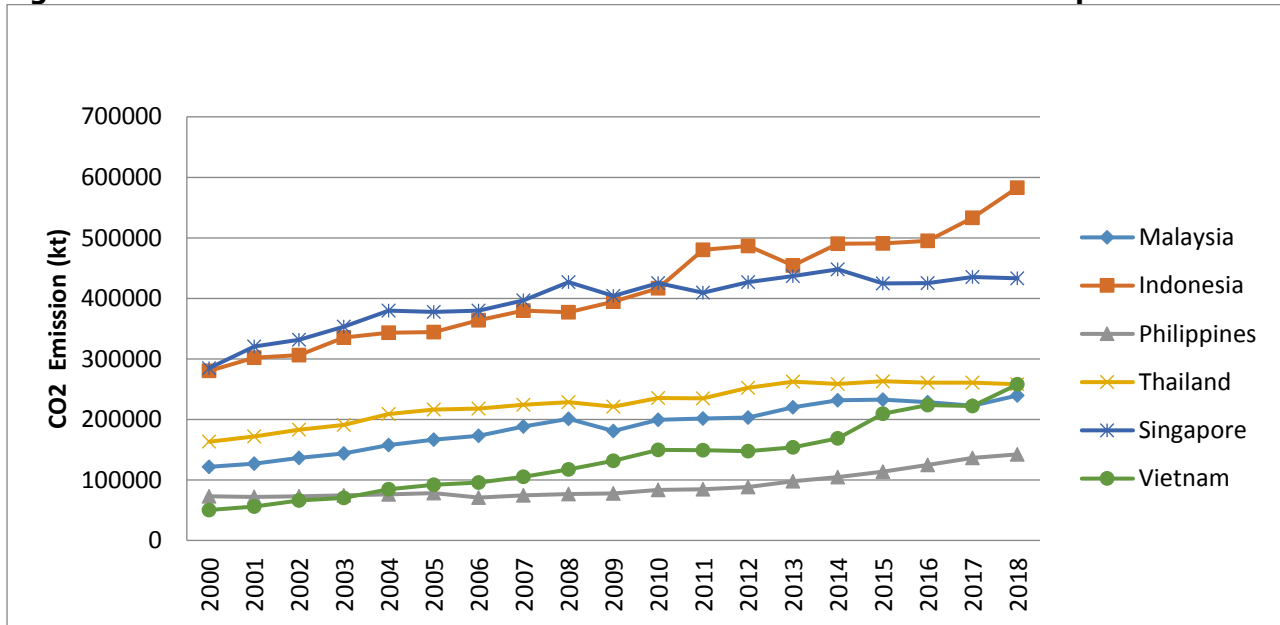
Our study has three prominent contributions to the literature: First, the role of globalization in environmental degradation gained very little attention in the literature in ASEAN countries context. The current study, therefore, accompanies those few studies that investigated globalization-environmental degradation nexus in ASEAN countries (Ahmed & Le, 2021; Bhatti, ur Raheem, & Zafar, 2020; Krisada, Chanakan, Nutnapha, & Kittisak, 2021; S. P. Nathaniel, 2021). Second, our study goes a step further by estimating the effect of non-renewable and renewable energy in addition to globalization in environmental degradation. To our knowledge, none of the earlier studies used this combination of the variables in ASEAN countries context especially under the umbrella of EKC hypothesis.

Third, our study mainly departs from the earlier studies in terms of the methodology employed for analysis purpose. The study applies second generation panel estimation techniques including Pesaran (2004); (Sun et al., 2020) cross sectional dependence test (CSD), Pesaran and Yamagata (2008) test for slope homogeneity, cross-sectional augmented IPS (CIPS) and cross-section augmented Dickey Fuller (CADF) tests for unit root proposed by Pesaran (2007); Westerlund (2007) test for panel cointegration, Cross-sectionally augmented ARDL (CS-ARDL) for the estimation of long run and short run parameters and Common Correlated Effect Mean Group (CCEMG) and Augmented Mean Group (AMG) for robust analysis. These estimations consider the issues of CSD and slope heterogeneity because ignoring these problems can seriously lead to inconsistent and spurious findings. To our best knowledge, earlier studies ignored these estimation techniques while estimating the effect of globalization on environmental quality of ASEAN region.

We organized our study as follows: Section 2 reviews the relevant existing literature. Data, model specification and empirical methodology are discussed in section 3. Section 4 includes empirical results, interpretations and discussions of the results. Last, in section 5, we conclude our study and provide worthy policies on the basis of the findings.

2.   Existing Literature

Economic growth and environmental quality nexus is explained under EKC hypothesis in the existing literature. However, the findings are ambiguous in terms of this relationship. Specifically, for ASEAN countries Chandran and Tang (2013); Lean and Smyth (2010); Narayan and Narayan (2010); Saboori and Sulaiman (2013) found invalidity for EKC hypothesis in ASEAN economies, while Bhatti et al. (2020); Guzel and Okumus (2020); Heidari, Katircioğlu, and Saeidpour (2015); Kisswani, Harraf, and Kisswani (2019) concluded the validity of EKC in ASEAN countries.

A number of studies have examined the relationship between energy consumption and carbon emission for different panels of countries and for individual countries. Out of these studies, Khan, Teng, Khan, and Khan (2019) scrutinized the data for Pakistan over 1971 to 2016 to estimate the nexus between energy consumption, globalization (economic, social and political), forgein direct investment and CO2 emission through Dynamic ARDL Simulations. The authors observed the positive contribution of all of the above mentioned variables on CO2 emission in Pakistan. Erdogan, Okumus, and Guzel (2020); Xiang et al. (2021) considered a panel of OECD countries over 1990-2014 period and tested the role of non renewable energy, renewable energy and oil prices in CO2 emission through FMOLS and DOLS techniques. Renewable energy was observed to have a negative relationship whereas non renewable energy had positive relationship with C02 emission. Similarly, S. P. Nathaniel and Iheonu (2019) studied the effect of non renewable and renewable energy in CO2 emission in individual African countries and observed insignificant impact of renewable energy but positive effect of non renewable energy on carbon emission.

In the context of ASEAN countries specifically, Nawaz, Ahmadk, Hussain, and Bhatti (2020) considered a panel of 9 ASEAN countries over 2000 to 2018 period and applied PMG, FMOLS and DOLS estimation approaches. Energy consumption affected CO2 emission positively in their analyses. Munir, Lean, and Smyth (2020) applied Granger Causality approach to study the effect of energy consumption- environment nexus over 1980-2016 period and observed the presence of positive contribution of energy consumption towards CO2 emission. Similarly, Abbasi, Parveen, Khan, and Kamal (2020) scrutinized the data for 8 ASEAN countries over 1982 – 2017 period. According to the findings of Panel Cointegration and Granger Causality approaches, energy use affected CO2 emission positively in ASEAN-8 economies. Taking the panel of 4 ASEAN countries, over 1970-2013 period, X. Liu, Zhang, and Bae (2017) observed the positive contribution of non renewable energy and agriculture in carbon emission and negative relationship of renewable energy with CO2 emission in these countries. In contrast, Vo, Vo, and Le (2019) considered the time series data for five individual ASEAN countries to estimate the link between energy consumption, economic growth, renewable energy consumption and CO2 emission. Study reported mixed results about the effect of total and renewable energy consumption on carbon emission in different countries. Similar findings were observed by Nuryartono (2017) in case of 4 ASEAN countries.

Similar to energy consumption-environment nexus, uncertain impact of globalization on carbon emissions has been reported in literature. However, this area is under researched for ASEAN countries. For instance Acheampong, Adams, and Boateng (2019) estimated the effect of renewable energy and globalization on emissions of 46 Sub Saharan African economies over the 1980 to 2015 period. According to the findings of random and fixed effects, globalization deteriorated the environmental quality but renewable energy had a positive contribution towards improving the environmental quality. The authors also confirmed the EKC hypothesis in these economies. Zaidi, Zafar, Shahbaz, and Hou (2019) studied the globalization - carbon emissions nexus over 1990 - 2016 period for APEC countries. The authors found that globalization caused CO2 emission to reduce. Furthermore, the EKC theory was supported by the results of this investigation.

Taking G7 countries into consideration, M. Liu, Ren, Cheng, and Wang (2020) studied globalization and CO2 emissions relationship over 1970 to 2015 period. According to the author's findings, globalization first increased CO2 levels but eventually caused the abatement of CO2 emissions after reaching a threshold level. Taking ASEAN countries as the focused group of the study, Krisada et al. (2021) applied Driscoll-Kraay Fixed effect estimation over 2004 to 2018 period and concluded that globalization affected CO2 emission positively. In

contrast, Bhatti et al. (2020) also considered ASEAN group of countries and from the findings of panel ARDL estimation, authors concluded that globalization was responsible to reduce carbon emission in the studied countries. Negative impact of globalization on CO2 emission was also observed by Ahmed and Le (2021) in case of ASEAN countries from the findings of CUP FM and CUP-BC estimation. Qin et al. (2021) also found negative impact of globalization on CO2 emission in their study for E-7 countries through Panel Quantile Regression.

Summing up, previous researches in ASEAN have gave mixed results in terms of globalization-CO2 emission nexus and energy consumption-CO2 emission nexus. A major short coming of these investigations, as we suggested in the introduction part, is that second generation panel estimations had not been applied in these studies that can be a reason for their ambiguous findings.

3. Data, Model and Methodology

The current study investigates the effect of globalization, renewable energy, non renewable energy and economic growth on environmental quality of ASEAN-6 countries. The annual data for the selected countries spanning over 1995 – 2020 period has been used for the purpose of analysis. CO2 emission is taken as the dependent variable, whereas globalization, non renewable energy, economic growth and renewable energy are the independent variables of the study. The general form of the model is given as:

$$CO2 = f\ (GLOB,\ RE,\ NRE,\ GDP,\ GDP^2) \qquad (1)$$

Where, CO2 denotes carbon dioxide emissions, GLOB represents globalization, RE and NRE denote renewable energy and non renewable energy respectively, GDP stands for economic growth and GDP^2 stands for square of GDP. The econometric form of the model is given in equation (2) as;

$$CO2_{it} = \alpha_0 + \beta_1 RE_{it} + \beta_2 NRE_{it} + \beta_3 GLOB_{it} + \beta_4 GDP_{it} + \beta_5 GDP_{it}^2 + \varepsilon_{it} \qquad (2)$$

Table 1 provides the proxies for the variables and their data sources.

Table 1: Variable Measurement and Sources of Data

Variables	Measurement	Source
CO2 Emission	CO2 emissions (kilotons)	WDI
Globalization	Globalization index	SEI
GDP	GDP constant (2015 $)	WDI
Renewable energy consumption	Consumption of energy generated from renewable sources (quadrillion btu)	EIA
Non-renewable energy Consumption	Consumption of energy generated from petroleum and other liquids (quadrillion btu)	EIA

Where, WDI= World Development Indicators, SEI= KOF Swiss Economic Institute and EIA= Energy Information Administration.

4. Empirical Methodology
4.1 Cross Sectional Dependence (CSD) and Slope Heterogeniety Testing

The study first applies (Pesaran, 2004) CSD test to check the absence or presence of CSD. Its equation is as follows:

$$M = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right) \frac{(T-k)\ \hat{\rho}_{ij}^2\ -E(T-k)\hat{\rho}_{ij}^2}{Var(T-k)\hat{\rho}_{ij}^2} \qquad (a)$$

The CD test of Pesaran (2004) assumes a zero mean and constant variance. In above equation (a), $\hat{\rho}_{ij}^2$ is pair-wise correlation. Furthermore, models usually suffer from the issue of slope heterogeneity in panel data, which can cause results to be spurious. Therefore, we use Pesaran and Yamagata (2008) slope heterogeneity test. This test increases the consistency of our empirical findings. Furthermore, the slope heterogeneity test gives efficient findings for small sample and longer time period. The slope homogeneity test equations are as follows:

$$\tilde{\Delta} = \sqrt{N}\ \left(\frac{N^{-1}\check{S}-k}{\sqrt{2k}} \right) \qquad (b)$$

$$\tilde{\Delta}_{adj} = \frac{\sqrt{N}[N^{-1}\tilde{S} - E(\tilde{Z}_{it})]}{\sqrt{Var(\tilde{Z}_{it})}} \quad \text{(c)}$$

4.2 Unit Root Testing

The study uses CADF and CIPS tests that account for CSD and heterogeneity across panels. The CIPS test is especially useful because it can be used with cross sectionally dependent variables. Furthermore, the test yields accurate findings even when slope heterogeneity exists in panel data. The test equation is given as:

$$\Delta y_{it} = \alpha_i + \rho_i^* y_{it-1} + d_0 \bar{y}_{t-1} + \sum_{j=0}^{p} d_{j+1} \overline{\Delta y}_{t-j} + \sum_{k=1}^{p} c_k \Delta y_{it-k} + \varepsilon_{it} \quad \text{(d)}$$

The statistic for CIPS test is as follows:

$$\text{CIPS} = \frac{1}{N} \sum_{i=1}^{N} CADF_i$$

Furthermore, the study uses the CADF panel test for unit root, which takes CSD into consideration. The CADF test however has a severe flaw that it ignores slope heterogeneity.

4.3 Cointegration Testing

This study uses the Westerlund (2007) Cointegration approach after taking into account the CSD, heterogeneity and integration order among variables. In comparison to residual based tests for Cointegration, this test has high power and offers consistent estimates for small sample sizes. There are four test statistics used in this test: two mean statistics for group (Ga & Gt), and two statistics (Pa & Pt) for panel. The panel statistics examine the Cointegration in individual cross sections, whereas the group statistics examine the Cointegration in the entire group.

4.4 CS-ARDL, CCEMG and AMG Estimations

CSARDL approach proposed by Chudik and Pesaran (2015) is used in the study to examine long-run and short run relationship between CO2 emissions and variables. The test out performs alternative cointegration approaches due to its flexibility to models with slope heterogeneity and endogeneity issues. In addition, the test considers CSD and the order in which variables are integrated. One of the most significant advantages of utilizing this approach is that it produces consistent findings even in small samples. The following is the test equation:

$$\Delta Y_{it} = \varphi_i + \sum_{l=1}^{p} \varphi_{it} \Delta Y_{i,t-1} + \sum_{l=0}^{p} \varphi_{il}^{'} EXV_{s,i,t} + \sum_{l=0}^{1} \varphi_{il}^{'} \overline{CSA}_{i,t-1} + \varepsilon_{it} \quad \text{(e)}$$

CSA stands for cross section averages and further shown by $\overline{CSA}_t = ($ $\Delta \bar{Y}_{t,} \overline{EXV}_{s,t})^{'}$ variables, i.e., independent variables are represented by EXV's. For robustness test, CCEMG proposed by Pesaran (2006) (later augmented by Kapetanios, Pesaran, and Yamagata (2011)) and AMG proposed by Bond and Eberhardt (2013) have been used. These estimations take slope heterogeneity, CSD, non stationarity and endogeniety into account.

5. Findings, Interpretation and Discussion

The researchers first apply CSD and slopes homogeneity tests before moving towards the coefficient estimations. The findings of CSD and heterogeneity tests are provided in Table 2 and Table 3 respectively that show the presence of CSD and heterogeneity in data.

Table 2: CSD Results

Variables/series	t-Stat/ (prob-value)	Variables/series	t-Stat/ (prob-value)
CO_2	17.100*** (0.000)	NRE	13.340*** (0.000)
GLOB	23.240*** (0.000)	GDP	19.256*** (0.000)
RE	19.234*** (0.000)	GDP^2	25. 671***(0.000)

Where ***=P <0.05

The unit root test results given reveal that series are integrated of order 1 (Table 4). The probability of Cointegration is likely when variables are integrated of order 1. The study variables, CO2, RE, NRE, GDP, GLOB, GDP^2 possess a long run relationship as shown in Table

5. Therefore, we may proceed towards the estimation of long-term association between the variables.

Table 3: Slope heterogeneity Test

	DV: CO2 emission		
Statistics	**Test stat / Prob-value**	**Statistics**	**Test stat / Prob-value**
($\tilde{\Delta}$) tilde	45.123*** (0.000)	($\widetilde{\Delta}$) tilde adjusted	68.501*** (0.000)

Where ***=P <0.05, DV=Dependent Variable

Table 4: CADF and CIPS Test

	CADF		CIPS	
Series	**Level**	**First difference**	**Level**	**First difference**
CO2	-4.100	-5.891***	-5.497	-5.477***
RE	-5.834	-4.607***	-3.011	-3.319***
NRE	-1.405	-2.897***	-1.340	-1.454***
GLOB	-5.208	-3.671***	-4.189	-2.809***
GDP	-2.679	-3.941***	-3.266	-4.608***
GDP^2	-4.897	-2.342***	-0.915	-3.294***

Table 5: Cointegration Test Results

Stat	**Value**	**Z value**	**P value**
Gt	-2.194	-3.644	0.050
Ga	-3.899	-2.435	0.002
Pt	-1.243	-8.430	0.034
Pa	-2.464	-5.755	0.001

Table 6 reports long and short run effects of our explanatory variables on CO2 emission. Economic growth adds to environmental damage by raising CO2 emission level. With an increase in economic growth by a unit, CO2 emission increase by 0.355 units in the long run and 0.395 units in short run. This estimation is in line with the results of (S. P. Nathaniel, 2021) and (Ahmed & Le, 2021) demonstrating that region is on the way of economic development at the cost of the environment. Moreover, the sign of GDP square is negative that confirms the validity of EKC hypothesis in the ASEAN consistent. CO2 emission decline by 1.29 and 1.39 units in long run and short run respectively, if there is an increase of one unit in RE. From the earlier studies, the findings of (S. P. Nathaniel, 2021), (Munir et al., 2020), (Heidari et al., 2015) and (Kisswani et al., 2019) for ASEAN countries are in line with our findings.

Table 6: CS-ARDL (Shortrun & Longrun) Results

	Long run findings		
Series	**Coeff**	**t-stat**	**Prob**
	DV: CO2 emission		
GLOB	0.4560***	1.998	0.004
RE	-0.344***	2.081	0.000
NRE	0.823***	3.0.62	0.006
GDP	0.355***	2.462	0.009
GDP^2	-1.294***	2.335	0.000
CSD-Statistics	-	0.025	0.601
	Short run findings		
GLOB	0.178***	3.549	0.000
RE	-0.440***	5.527	0.040
NRE	0.748***	3.916	0.000
GDP	0.395**	3.459	0.051
GDP^2	-1.347***	2.679	0.000
ECT(-1)	-0.677***	-4.044	0.000

Where ***=P<0.05, **=P=0.05

GLOB turns out to be a significant contributor to CO2 emission. For a unit rise in globalization, there is an increase of 0.17 and 0.45 units in short and long run respectively in CO2 emission. Since globalization index is taken as a proxy for globalization (political, social and economic globalization), the relations of ASEAN countries in terms of social, political and economic terms motivate the industrialized countries to have more investment in these countries. In this respect, advanced countries shift their environmental polluting technologies in ASEAN countries without any reluctance that causes serious detrimental impacts on environmental quality of these countries. Studies conducted for ASEAN by Krisada et al. (2021) and Bhatti et al. (2020) strongly support our results.

The findings of the short and long-run estimation for RE and CO2 emission relationship show that both variables have negative and significant association. There is a reduction of 0.34 units and 0.44 units in CO2 emission in the long and short run as RE consumption increases by one unit. This shows that higher RE consumption contributes to the reduction in CO2 emissions in ASEAN countries. This is consistent with (Anwar, Siddique, Dogan, & Sharif, 2021; X. Liu et al., 2017) and (S. Nathaniel & Khan, 2020) for ASEAN who argue that more consumption of RE causes reduction in CO2 emission in the ASEAN region. However, the coefficient for NRE is significant and positive that shows the detrimental impact of NRE on CO2 emission. CO2 emission is observed to be increased by 0.74 and 0.82 units in the short and long run respectively, for a unit increase in NRE. This is not a surprising finding as fossil fuels constitute a major portion of energy mix of this region. Studies of (Anwar et al., 2021; Nasir, Huynh, & Tram, 2019; Wang, Chen, & Kubota, 2016) and (S. Nathaniel & Khan, 2020) for ASEAN are in strong agreement with our findings.

CCEMG and AMG estimations are applied for robust test. Interestingly, the signs of the coefficient are the same as in CS-ARDL analysis. Similar to CS-ARDL, both GLOB and NRE have positive association, while RE has negative association with CO2 emission. Moreover, EKC hypothesis is valid in AMG and CCEMG estimations. The significance of the model is clearly indicated from the significant value of Wald test (Table 7).

Table 7: AMG & CCEMG Test

Outcome variable CO2	AMG		CCEMG	
	coeff	p-values	Coeff	p-values
GLOB	0.640***	0.000	0.247***	0.000
RE	-0.240***	0.045	-0.067***	0.000
NRE	0.149***	0.040	0.206***	0.000
GDP	0.101***	0.021	0.037***	0.000
GDP^2	-1.032***	0.000	-0.271***	0.000
Wald test	-	0.000	-	0.000

Where, ***= P<0.05

6. Conclusion and policy implications

Knowing the fact that ASEAN countries have undergone rapid economic growth in current years at the expense of environmental quality, the objective of our study is to investigate the link between globalization, renewable energy consumption, non renewable energy consumption and CO2 emission under the umbrella of EKC hypothesis in 6 ASEAN countries– a reach gap that was needed to be filled. For the purpose of empirical analysis, second generation panel technique of CIPS and CADF unit root test, Westerlund (2007) cointegration test, CS-ARDL method for long run and short run estimation have been applied due to the presence of CSD and slope heterogeneity in data. NRE and GLOB are found to be positively associated with CO2 emission whereas RE has a negative relationship with CO2 emission in ASEAN countries. Additionally, EKC hypothesis has been valid for in selected countries according to our findings. These findings are found robust in AMG and CCEMG analysis.

Based on the findings, we recommend that initiatives and regulations should be implemented in ASEAN countries to raise public awareness about environmental concerns and renewable energy. Furthermore, the government must strengthen low-carbon energy subsidies, grant extra tax exemptions to green-energy businesses, and improve energy efficiency and lower energy intensity. To minimize the cost of utilizing renewable sources of

energy, governments need to provide more support to enterprises engaged in R&D activities. Moreover, to mitigate the effects of globalization on the environment in ASEAN countries, strict environmental rules should be adopted. To secure the sustainability of globalization process as a means of stimulating economy, the ASEAN area must participate actively in global and regional market integration with trading partners. But, as environmental sustainability is a prerequisite for globalization, efforts should be undertaken to improve the quality of environment.

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