e-ISSN: 2962-9179
Universal Journal of Science and Technology

Greenhouse Gases and Determinants of Growth: An Analysis of the Environmental Kuznets Curve Hypothesis on ASEAN-5 Countries

Claire Daiynes V. Pama[#1], *Abigail Joy M. Pastrana*[#2], *Jasmine Isabella S. Rogel*[#3], *Marie Antoinette L. Rosete*[#4]

[#]*University of Santo Tomas - Manila,*
College of Commerce and Business Administration, Business Economics Department,
España Blvd, Sampaloc, Manila, 1008 Metro Manila, Philippines

[1]clairedaiynes.pama.comm@ust.edu.ph
[2]abigailjoy.pastrana.comm@ust.edu.ph
[3]jasmineisabella.rogel.comm@ust.edu.ph
[4]mlrosete@ust.edu.ph

Abstract *— The Environmental Kuznets Curve (EKC) hypothesis is the most notable method for measuring environmental degradation and its relationship with economic growth. In this research paper, the researchers examine the validity of the relationship between carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (F-Gas) to Gross Domestic Product, population, renewable energy consumption, trade openness, and inflation of the ASEAN-5 countries' data from 1990-2018, using panel regression tests which are POLS, FE model, and RE model. Results reveal that the independent variables do not affect CH_4 based on the RE model while CO_2, N_2O, and F-GAS are partially affected based on the FE model. The EKC is confirmed only for F-GAS, suggesting that a turning point is established. Other emissions imply that these economies are still in their early stages of development, hence the non-existence of EKC. Based on the outcomes, recommended actions specifically for the agricultural and industrial sectors include the following: (1) investing in renewable energy, (2) provision of subsidies and incentivization, and (3) adopting and modifying emission-related systematic waste management and recycling to better suit each countries' economy.*

Keywords **—** Environmental Kuznets Curve, Gross Domestic Product, Renewable energy, Population, Trade Openness

I. INTRODUCTION

Global warming is the primary consequence of industrialization and other human activities, and its impact has become drastically noticeable over the past decades. The Paris Agreement (2015) proposed a collective pursuit of limiting the continuous global increase in temperature to 1.5° Celsius, but the Intergovernmental Panel on Climate Change (IPCC) Special Report said this limit will be reached by 2040. The effects of climate change on the global economy have been under scrutiny since the 1980s. Policies and regulations on the green economy were promoted as choices of action during a crisis.

The Environmental Kuznets Curve (EKC) theory analyzes the possible correlation of GDP per capita and pollution, resulting in an inverted U-shape diagram that assumes environmental deterioration will eventually decrease as the economy grows (Ginevicius *et al.*, 2017, as cited in Özcan & Öztürk, 2019). Grossman and Krueger introduced the EKC hypothesis in their works in 1991 and 1995, while the Kuznets Curve developed by Simon Kuznets (1955) served as the basis. Countless works confirmed and contributed to the EKC literature, yet some noticed discrepancies in the concept. These involved the formula being too simple (Kijima *et al.*, 2010, as cited in Anwar *et al.*, 2022); tested only on selected gas emissions and water quality (Uchiyama, 2016); considered few factors (Dasgupta *et al.*, 2002, as cited in Anwar *et al*., 2022); and different results of the same sample and location. Pincheira and Zuniga (2020) added capital distribution, accounting for financial development, corruption, and tourism as determinants to answer some arguments raised. Others included more pollutants to be tested, consumption, urbanization and population (Inglesi-Lotz, 2018, as cited in Özcan & Öztürk, 2019), electricity consumption (Ahmad *et al.*, 2021), and foreign direct investments (Kaya Kanlı & Küçükefe, 2022).

The Association of Southeast Asian Nations (ASEAN) has shown remarkable growth and development in its economy over the past few decades. Its ten member countries include Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam — economies that differ vastly in their stages of development but all share immense growth potential after it was established in 1967 (Nasir *et al*., 2019). In 2019, ASEAN had a total GDP of approximately $3.2 trillion, placing it as the 5th largest economy internationally. It was projected to rank as the 4th largest economy by 2030, according to Lee and Adam (2022) of the World Economic Forum. Despite the impressive increase in economic growth in these economies, its ecological and environmental consequences must not be put aside. The region's demand for primary energy was projected to increase by 2.5 times from 625 MTOE (Million Tonnes of Oil Equivalent) in 2017 to 1,589 MTOE in 2040, according to the 6^{th} ASEAN Energy Outlook issued by ASEAN Centre for Energy (2020). This continuous increase in GHG emissions is particularly relevant to the region as ASEAN member states are among those who will be severely affected by the climate crisis.

As most of the research focused primarily on evaluating economic growth and CO_2 emissions, an analysis of other emissions and variables is yet to be done in the region. However, due to the lack of data on several member states, the researchers opted to examine the ASEAN-5 states, the founding members of the economic union, instead. The member states include Indonesia, Malaysia, the Philippines, Singapore, and Thailand. This research examined the relationship between four leading Greenhouse Gas Emissions (CO_2, N_2O, CH_4, F-Gas) and multiple factors of growth (GDP, GDP squared, population, renewable energy consumption, trade openness, and inflation) of the ASEAN-5 countries to create environmental policies and assessed the validity of the EKC. The researchers utilized panel data analysis from the years 1990 up to 2018 drawn from the World Bank Database and Climate Watch. Apart from adding complexity to the formula and broadening the scope of previous studies, the researchers considered appropriate mitigations and sustainable interventions to protect the environment and economic welfare.

II. LITERATURE REVIEW

2.1 The Environmental Kuznets Curve

During the 1990s, the focus was on environmental degradation, and attention turned to the EKC hypothesis. The theory is based on the Kuznets Curve, developed and named after Simon Kuznets in 1955, which observed the linkage between per capita income to inequality in the 1940s (Kuznets, 1955). Kuznets suggested that inequality increases as per capita income increases during the early stages of development. It would reach a turning point and decline, believing that income distribution equality will occur in the long run, thus forming an inverted-U curve.

One of the most cited publications that grounded the theory and served as the origin was Grossman and Krueger—the first to measure the relationship among pollution and GDP per capita (Grossman & Krueger, 1995). His work, 'The environmental impacts of the North American Free Trade Agreement (NAFTA)' in 1991, tested air pollutants in the urban areas of 42 countries and resulted in an inverted U-shape (Grossman & Krueger, 1991, as cited in Pincheira & Zuniga, 2020). Their findings matched the assumption of Kuznets that a decrease will happen after a turning point, stating that degradation will decrease over time at high-income levels (Grossman & Krueger, 1991, as cited in Yandle *et al.,* 2004).

The EKC hypothesis analyzes the relationship between GDP per capita and environmental degradation. Similarly, it assumes that environmental deterioration increases at low-level income, and the later stage of industrialization brings about a decline in pollution as the economy grows (Ginevicius *et al.*, 2017, as cited in Özcan & Öztürk, 2019). Several other works confirmed the theory and eventually evolved to utilize it primarily for analyzing whether the economy is following the path of sustainability, therefore, assisting in constructing suitable policies.

However, there are inconsistencies and challenges to the existence, parameters, estimations, and models of the EKC. Some argued that the quadratic formula did not provide sufficient proof (Kijima *et al.*, 2010, as cited in Anwar *et al.*, 2022), only a few tackled about water quality (Uchiyama, 2016), other factors that influenced the conditions of the economy were not taken into consideration (Dasgupta *et al.*, 2002, as cited in Anwar *et al.*, 2022), no established place of turning points (Shahbaz & Sinha, 2019, as cited in Anwar *et al.*, 2022), contradicting results of the same sample and location in the analysis, and ambiguous relationships of indicators. In light of these criticisms, recent journals explored new variables, methods, and estimations to consider in the equation such as capital distribution, corruption, and tourism (Pincheira & Zuniga, 2020), foreign direct investments, land use, property rights (Kaya Kanlı and Küçükefe, 2022), energy consumption, urbanization, and population (Inglesi-Lotz, 2018, as cited in Özcan & Öztürk, 2019), electricity consumption (Ahmad *et al*., 2021; Rahman, 2020), and international trade (Jiang *et al.*, 2019).

Even with extensive reviews and investigations accomplished by numerous researchers, the EKC hypothesis remains inconclusive as studies yielded different results from the same samples and countries. Hence, the EKC theory is not a general assumption applicable to all (Kaya Kanlı & Küçükefe, 2022). Diverse methodologies, models, and other variables affecting the economy are significant in analyzing EKC and creating policies (Inglesi-Lotz, 2018, as cited in Özcan & Öztürk, 2019).

2.2. Greenhouse Gases to Growth Indicators

Many regional studies had differing views on the inverted-U analysis like in the case of Xia *et al.* (2022) and Le and Ozturk (2020), which confirmed the EKC hypothesis. In another study, Leal and Marques (2020) divided the Organization for Economic Cooperation and Development into two subgroups: High Globalized countries (HGC) and Low Globalized countries (LGC). They found that the EKC exists only in HGC countries. Meanwhile, Mehmood Mirza *et al*. (2022) provided results for the existence of the inverted-U curve in 30 developing countries. In the ASEAN, Buenavista and Palanca-Tan (2021) utilized income, trade, and FDI on CO_2 emissions in their tests. They confirmed the existence of the inverted-U curve in the region but also found that trade and FDI did not significantly affect CO_2 emissions. Correspondingly, Luo *et al.* (2021) and Farhani *et al.* (2013) also affirmed the hypothesis about economic development and overall CO_2 emissions among 11 selected Asian countries and 11 Middle East and North African (MENA) countries, respectively. In contrast, Chandran and Tang (2013) did not reach the same conclusion in the ASEAN-5 countries, especially Indonesia, Malaysia, and Thailand. Meanwhile, a study conducted by Yeh and Liao (2017) in Taiwan showed that during the initial stages, an increase in the population and economic growth led to an increase in its carbon emissions. Taiwan is projected to reach the inverted-U turning point by 2025 (Uchiyama, 2016). These findings signified the responsibility of the developing countries in the environmental deterioration process and how relevant it was for them to integrate policies and development plan measures to mitigate greenhouse gas emissions. The results provided evidence for the existence of EKC in developing countries, indicating that energy efficiency largely contributed to reducing carbon emissions as structural shifts increased carbon emissions because these economies moved towards sectors that intensively use energy While Liu *et al.* (2017), Bekun *et al.* (2021), and Wang *et al*. (2022) approved and recommended the use of sustainable energy resource to reduce CO_2 emissions, Leal and Marques (2020) argued that renewable energy consumption was not an effective tool in extenuating carbon emissions in the less globalized countries in the long run and that investing in an efficient technology will be more efficient in mitigating CO_2 emissions.

There were also empirical evaluations that considered the effects of macroeconomic variables on nitrous oxide (N_2O) emissions. In a study in Germany, N_2O was tested against the effects of economic growth, use of land for agriculture, and exports. Results showed that Germany was already at the decreasing part of the EKC curve hypothesis (Zambrano-Monserrate & Fernandez, 2017). Additionally, Bahrain also supported the EKC hypothesis on N_2O emissions and economic growth. Moreover, energy use had a positive effect on N_2O, while FDI and financial development had a negative impact on N_2O emissions (Naser & Alaali, 2021). Given the existence of EKC concerning N_2O emissions in the sample countries, Zambrano-Monserrate and Fernandez (2017) suggested that policies must be implemented in these countries, especially in the agricultural sector that contributed significantly to N_2O emissions. Supporting environmentally friendly sectors by providing subsidies would also help reduce N_2O emissions (Naser & Alaali, 2021).

CO_2 and N_2O emissions were not the only subjects for environmental degradation variables used in the research. For instance, a test conducted on the Organization of Islamic Cooperation (OIC) by Ali *et al.* (2020) concluded that the inverted-U hypothesis existed in all the OIC countries where CO_2, methane (CH_4), and carbon footprint as the environment related variable while N_2O had a U-shaped curve in low-income countries. In the European Union (EU) 12, the higher-income countries in the region also exhibited inverted U-shaped EKC for N_2O and CH_4 emissions (Madaleno & Moutinho, 2021). The 22 countries within the Organization for Economic Co-operation and Development (OECD) supported the EKC hypothesis (Cho *et al.,* 2013). Looking at the EKC in an agricultural context of developing and advanced economies, the inverted-U hypothesis was found in both groups (Jovanović *et al*., 2015). Marques *et al.* (2018) also verified Australia's economy on the EKC hypothesis by deviating from the frequently used independent variables and utilizing GDP, renewable energy, oil consumption, and coal consumption. Meanwhile, Okon (2021) concluded that the inverted U-shaped relationship was nonexistent for F-Gas emissions in Nigeria. Nevertheless, he emphasized the need for industrial users to adopt F-Gas recycling and search for alternatives as they had a high global warming potential. Ali *et al*. (2020) recommended that the imposition of pollution charges and fines would help mitigate GHG emissions.

Studies that covered national policies and assessed their effect on the income-emissions relationship of the sampled countries were also collected. Apergis and Ozturk (2015) included population density, land, industry shares, political stability, peace and order, government action effectiveness, quality of regulation, and corruption index in their analysis of income and CO_2 emissions. Apergis and Ozturk (2015), Bekun *et al.* (2021), and Le and Ozturk (2020) supported the EKC hypothesis according to their studies. Ozturk and Al-Mulali (2015) proposed that lower corruption levels and effective governance would reduce CO_2 emissions. However, Akhbari and Nejati (2019) noted that the corruption level had no significant effect in developed countries, even though a decline in corruption levels in developing countries led to decreased CO_2 emissions. Given how developing countries produce emissions significantly, Ozturk and Al-Mulali (2015) recommended improved urban planning for cities, especially in controlling the movement of wastes — industrial and solid wastes. Promoting renewable energy use is also vital in reducing each country's emissions because of their low environmental impact while also being perpetual such as energy derived from water, wind, and solar energy.

Ecological footprint was also employed instead of the most commonly used CO_2 emissions (Ulucak & Bilgili, 2018; Al-Mulali *et al.*, 2015; Arshad Ansari *et al.*, 2020). The studies of Ulucak and Bilgili (2018) and Al-Mulali *et al.* (2015) confirmed the inverted U-shaped diagram, while Arshad Ansari *et al.* (2020) ended up with mixed findings on EKC.

2.3. Greenhouse Gases to Other Economic Variables

A study on EKC specifically focused not on macroeconomic variables but the socio-economic development of G20 countries. Still, it supported the traditional EKC hypothesis between CO_2 and Human Development Index (HDI) and Legatum Prosperity (LPI) (Alotaibi & Alajlan, 2021). Additionally, an investigation by Kasioumi and Stengos (2020) examined the EKC hypothesis on recycling and real GDP in the United States of America was characterized by a J-shaped EKC. Thus, as each state gets rich, more effort into recycling is being put in.

Interestingly, Shehzad *et al.* (2021) evaluated the EKC hypothesis while focusing on the effect of the imports and production of Information, Communication, and Technology (ICT) instruments in Pakistan. This study identified that importing ICT devices harmed the country's environmental quality as it generated electronic waste. It also revealed the U-shaped association of economic growth with CO_2 emission.

2.4. Other EKC Hypothesis

Based on the previously mentioned evidence, different GHGs were affected differently by macroeconomic variables, but the inverted-U hypothesis persisted. Nevertheless, some studies argued that the continued growth of income would deteriorate the environment again (Lorente & Alvarez-Herranz, 2016).

To better understand the theory, a scale effect happens due to the increase in production and growth of the economy, and little attention is paid to its environmental impact. The second stage, the compositional and technical effect, happens when a country's growth is sufficient for policymakers to shift from industrialization to a more eco-friendly and sustainable approach (Koilo, 2019). The technical obsolescence effect happens when innovation reaches its peak, and the scale effect becomes outweighed by the technical effect (Zhang, 2021).

As proof, China is a notable country for its rapid development and is the largest CO_2 emitter worldwide. In a regional study by Liu (2020), CO_2 and regional growth have a relationship that confirmed the inverted U-shaped EKC. Comparing such results to the national level, Zhang (2021) revealed that CO_2 emissions and real GDP per capita had an N-shaped relationship. Kang *et al.* (2016) also found that there was an inverted-N trajectory in the relationship among economic expansion and CO_2 emissions in China. Aljadani *et al.* (2021) supported the N-shaped curve in the Kingdom of Saudi Arabia (KSA). Allard *et al.* (2017) also supported N-shaped EKC by testing 74 countries, and the theorem was validated by varying developing countries. Malaysia, for instance, indicated an inverse N-shaped EKC when investigating CO_2 emissions, renewable energy utilization, and economic upturn (Bekhet & Othman, 2018).

2.5. Theoretical Framework

The researchers utilized the EKC theory as the guide in testing the validity of the measurement used to assess the level of pollution, including the four leading Greenhouse Gases (CO_2, N_2O, CH_4, F-Gas). The GHGs mentioned will be assessed in the ASEAN-5 region. Grossman and Krueger (1995) first introduced the hypothesis that an inverted-U curve existed between economic expansion and environmental deterioration. Niu *et al.* (2022) provided a general formula for estimating the EKC hypothesis:

$$Y_{it} = \alpha_i + \beta x_{it} + \gamma x^2{}_{it} + u_{it}$$

Where: Y_{it} = per capita emissions

x_{it} = real GDP per capita

u_{it} = random disturbance term

Multiple studies such as Apergis and Ozturk (2015) and Farhani *et al.* (2013) supported the EKC theory. However, there were also observations from the likes of Chandran and Tang (2013), Ozturk and Al-Mulali (2015), and Liu *et al.* (2017) that disproved the EKC hypothesis in certain situations. Existing literature found almost always tested on one pollutant only, CO_2 or N_2O, due to these emissions taking a large share in contributing to global warming. Therefore, the researchers opted to include all leading GHGs in the atmosphere in testing against selected macroeconomic variables to compare the results and see if the EKC would apply to all four situations among the ASEAN-5 countries and assist in recommending policies to be implemented.

2.6. Research Simulacrum

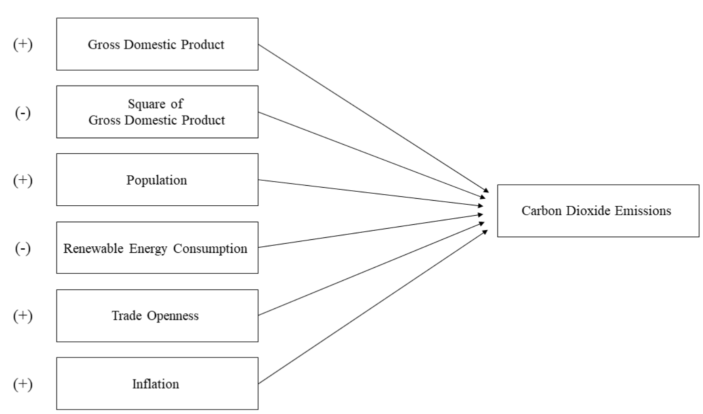

Figure 2.1. Determining the Relationship of Each Macroeconomic Variables to Carbon Dioxide Emissions.

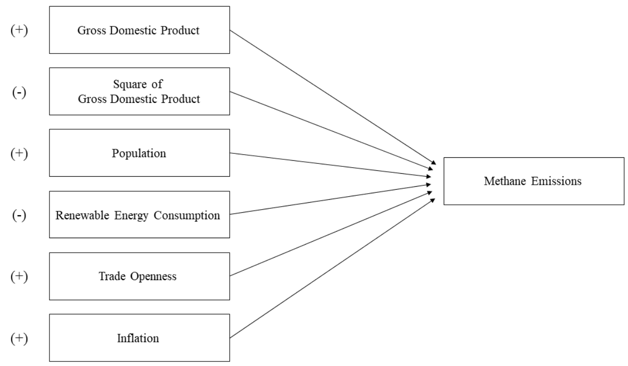

Figure 2.2. Determining the Relationship of Each Macroeconomic Variables to Methane Emissions.

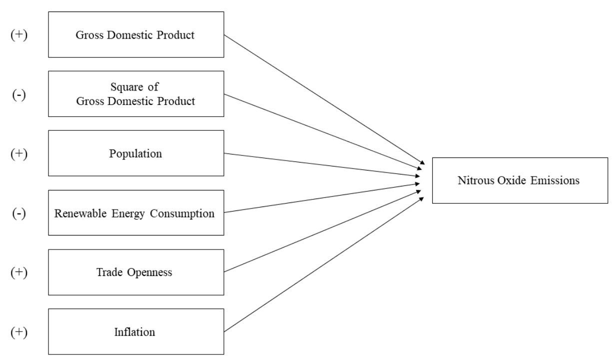

Figure 2.3. Determining the Relationship of Each Macroeconomic Variables to Nitrous Oxide Emissions.

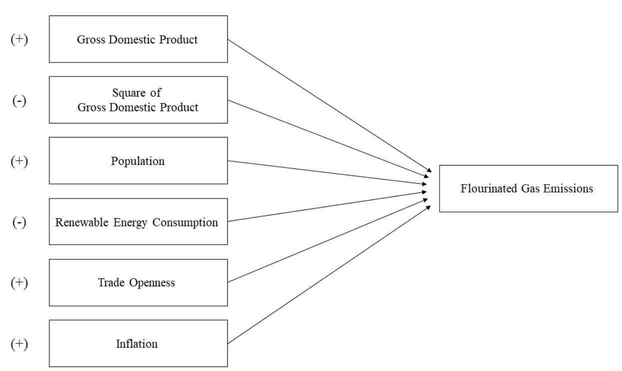

Figure 2.4. Determining the Relationship of Each Macroeconomic Variables to Fluorinated Gas Emissions

2.7. Hypothesis

This research's null hypothesis includes the following:

H1: GDP, SGDP, POP, RNW, TOP, and INF each does not affect ASEAN-5' CO_2 emissions

H2: GDP, SGDP, POP, RNW, TOP, and INF each does not affect ASEAN-5' CH_4 emissions

H3: GDP, SGDP, POP, RNW, TOP, and INF each does not affect ASEAN-5' N_2O emissions

H4: GDP, SGDP, POP, RNW, TOP, and INF each does not affect ASEAN-5' F-GAS emissions

2.8. Synthesis

Based on the studies gathered, an increase in income per capita ultimately affected CO_2 emissions positively in the short-run. Moreover, a peak was reached, which varied across countries, and continuous income per capita growth would ease its effects on CO_2 emissions. Consequently, urbanization had a positive relationship with CO_2 emissions, while trade openness and renewable energy consumption had negative relationships with CO_2 emissions. In addition, the relationship between economic growth and N_2O varied per study. Some agreed on the existence of the EKC, while others showed a U-shaped EKC. Moreover, some evidence suggested that FDI had a negative impact on N_2O emissions. CH_4 and F-Gas are part of the leading human-caused GHG emissions, hence included in this research.

Previous research observed that GDP was the most commonly used indicator of a country's economic performance. Mudgill (2018, as cited in Ahmad *et al.*, 2021) mentioned the rise in inflation in India during 1991 led the government to make sector improvements with each of them contributing to a large scale of economic growth and global significance in the later years. As inflation influenced economic activity, the study utilized Consumer Price Index (CPI) as the variable for inflation. Several variables from different journals were also present in the analysis, and these were population, renewable energy consumption, and trade openness (imports and exports).

The recent increase in attention on the effects of national growth on environmental deterioration is due to the worrying growth in accumulated emissions and its impact on global warming (Kalaitzidakis *et al.*, 2018). Empirical studies performed on countries and regions of the world were keys to making policies that would help guide the development planners for long-term economic growth (Buenavista & Palanca-Tan, 2021). It is clear that a lack of uniformity in the results of the EKC hypothesis exists, and it is imperative to retest the hypothesis with a different set of variables at hand.

III. METHODOLOGY

This study investigated four GHG emissions, particularly carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O), and fluorinated gas (F-Gas) emissions as dependent variables. Several works considered the influence of different macroeconomic variables in examining the EKC hypothesis. Hence, in this study, GDP, GDP squared, population, renewable energy consumption, trade openness, and inflation were employed as independent variables. **Table 3.1** gives a breakdown of the variables evaluated in this study.

A quantitative, correlational research design was used to test the balanced data from 1990 to 2018 obtained from the World Bank database and Climate Watch for the ASEAN-5 countries, specifically

Indonesia, Malaysia, Philippines, Singapore, and Thailand. Each country's historical emissions and macroeconomic variables in 29 years were combined and observed in the study.

Table 3.1 Description of Variables and Data Sources

Variables	Description	Unit of measurement	Data Sources
CO_2	Carbon dioxide emissions	Metric tons of CO_2 equivalent ($MtCO_2e$)	Climate Watch
CH_4	Methane emissions	Metric tons of CO_2 equivalent ($MtCO_2e$)	Climate Watch
N_2O	Nitrous oxide emissions	Metric tons of CO_2 equivalent ($MtCO_2e$)	Climate Watch
F-GAS	Fluorinated gas emissions	Metric tons of CO_2 equivalent ($MtCO_2e$)	Climate Watch
GDP	GDP	Constant LCU	World Bank
SGDP	Square of GDP	Square of GDP	Own computation
POP	Population	Total number of residents	World Bank
RNW	Renewable energy consumption	% of total final energy consumption	World Bank
TOP	Trade Openness	% of gross import and export to GDP	World Bank
INF	Inflation	Consumer prices (annual %)	World Bank

In agreement with the similar previous study by Buenavista and Palanca-Tan (2021), static panel data testing was employed, wherein different cross-sections of observations across time were examined. In the case of this paper, selected macroeconomic variables from ASEAN-5 countries were evaluated, together with the level of GHG emissions, from 1990 to 2018. The focus of panel data series modeling is to evaluate the probability of interdependence among data sets within the same set.

The econometric models used to test the aforementioned variables are as follows:

(1) $CO_{2i,t} = \beta_0 + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(2) $CH_{4i,t} = \beta_0 + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(3) $N_2O_{i,t} = \beta_0 + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(4) $F\text{-}GAS_{i,t} = \beta_0 + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$

To confirm the breakdown of the equations, the subscript *i* and *t* refer to the country and year, respectively.

To prove the EKC hypothesis, the β coefficient of GDP must be greater than zero ($\beta_1 > 0$), while the β coefficient of SGDP must be less than zero ($\beta_2 < 0$). Furthermore, the β coefficient of POP, TOP, and INF must also be greater than zero (β_3, β_5, $\beta_6 > 0$) to validate the hypothesis that these variables positively correlate with each GHGs to be tested. On the other hand, the β coefficient of RNW must be negatively correlated or less than zero ($\beta_4 < 0$) to demonstrate that renewable energy use positively helps the environment.

Three models on panel analysis were employed to estimate the appropriateness or suitability of the model to data: (1) Fixed Effect model (FE), (2) Random Effects model (RE), and (3) Pooled Ordinary

Least Squares model (POLS). The FE model assumed that the dependent variables (in this case, GHGs) were constant with the independent variables. The effects of the explanatory variables that did not change over a period of time were not shown in the FE model. The standard equation for the FE model is $y_{it} = \alpha_i + \beta_1 x_{it}' + \varepsilon_{it}$.

Following the standard model of the FE equation, we derived the formulas:

(1) $CO_{2i,t} = \alpha_i + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(2) $CH_{4i,t} = \alpha_i + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(3) $N_2O_{i,t} = \alpha_i + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(4) $F\text{-}GAS_{i,t} = \alpha_i + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$

However, the RE model assumed that there were variations that existed among the observations and were not correlated with the independent variables. This model exhibited the variance that existed over a period of time on the dependent variables. Thus, these differences were significant in explaining the dependent variables. Swamy and Arora estimator was adapted for variance components or regressors, and the Hausman test for FE or RE suitability. This model was presented as $y_{it} = \alpha_i + \mu_{it} + \beta_1 x_{it}' + \varepsilon_{it}$.

(1) $CO_{2i,t} = \alpha_i + \mu_{i,t} + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(2) $CH_{4i,t} = \alpha_i + \mu_{i,t} + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(3) $N_2O_{i,t} = \alpha_i + \mu_{i,t} + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$
(4) $F\text{-}GAS_{i,t} = \alpha_i + \mu_{i,t} + \beta_1 GDP_{i,t} + \beta_2 SGDP_{i,t} + \beta_3 POP_{i,t} + \beta_4 RNW_{i,t} + \beta_5 TOP_{i,t} + \beta_6 INF_{i,t} + \varepsilon_{i,t}$

On the other hand, the POLS leaned towards time-series information rather than the cross-sectional data found in the FE and RE models. Pooled OLS equation was stated as $y = \alpha + \beta_1 x' + \varepsilon$.

(1) $CO_{2i,t} = \alpha + \beta_1 GDP + \beta_2 SGDP + \beta_3 POP + \beta_4 RNW + \beta_5 TOP + \beta_6 INF + \varepsilon$
(2) $CH_{4i,t} = \alpha + \beta_1 GDP + \beta_2 SGDP + \beta_3 POP + \beta_4 RNW + \beta_5 TOP + \beta_6 INF + \varepsilon$
(3) $N_2O_{i,t} = \alpha + \beta_1 GDP + \beta_2 SGDP + \beta_3 POP + \beta_4 RNW + \beta_5 TOP + \beta_6 INF + \varepsilon$
(4) $F\text{-}GAS_{i,t} = \alpha + \beta_1 GDP + \beta_2 SGDP + \beta_3 POP + \beta_4 RNW + \beta_5 TOP + \beta_6 INF + \varepsilon$

Data analysis was performed using the software Eviews 12 Student Lite version. After employing the models and validity testings, all results were evaluated to provide policy implications and recommendations. Given how the GHGs affected various sectors in the economy, concentrating on energy production through burning of fossil fuels and agricultural practices, the researchers tailored recommendations for the benefit of these sectors. Non-normality and heterogeneity would be evident in a panel data regression as the time component and cross-sectional data were combined. Aligned with Buenavista and Palanca-Tan (2021) and Khan and Rana (2021), it is inevitable to produce a non-normal distribution, cross-sectionally dependent and heteroskedastic results due to the lack of annual data found for each country and the structure of the data which limited the study. The FE model "fixed" the time component and invariant characteristics of a variable. The RE model was then utilized to measure the differences as the time component was assumed to be "fixed". This approach presented another limitation to the study. Multicollinearity test was performed using the Gretl software as Eviews 12 Student Lite version did not have this function.

IV. RESULT AND DISCUSSION

The researchers tested the EKC theory and the validity of the measurement used to assess the level of pollution, as represented by the four leading GHG emissions and selected macroeconomic variables (**Table 2**) amongst the ASEAN-5 countries (Indonesia, Malaysia, Philippines, Singapore, Thailand). Eviews 12 Student Lite version was utilized in employing the POLS, FE, and RE models. The researchers used the Hausman Test to figure out the optimal model that best represents the EKC hypothesis.

4.1 Descriptive results and Cross-sectional Line Graphs

Table 4.1 Summary Statistics of All Variables

	CO_2	CH_4	N_2O	*F-GAS*	*GDP*
Mean	307.2828966	101.9303448	24.80924138	4.373103448	1.15E+15
Standard Error	31.05619964	10.77323501	2.160917219	0.648303611	2.07E+14
Median	168.62	56.13	12.65	2.1	5.36E+12
Mode	#N/A	76.76	8.42	0.43	#N/A
Standard Deviation	373.9661652	129.7269283	26.02088907	7.806609247	2.49E+15
Sample Variance	139850.6927	16829.07592	677.0866682	60.94314794	6.22E+30
Kurtosis	1.96262472	1.151712967	0.762025778	20.51771769	3.587641
Skewness	1.724491951	1.574044663	1.534513193	4.218175833	2.137571
Range	1543.55	567.79	98.14	54.85	1.04E+16
Minimum	28.92	1.28	0.23	0.15	9.75E+10
Maximum	1572.47	569.07	98.37	55	1.04E+16
Sum	44556.02	14779.9	3597.34	634.1	1.66E+17
Count	145	145	145	145	145

	SGDP	*POP*	*RNW*	*TOP*	*INF*
Mean	7.48857E+30	80394998.48	21.11231	152.2799208	4.550457671
Standard Error	1.64168E+30	6520686.616	1.419876	9.294227769	0.472267922
Median	2.86799E+25	64069093	22.43	120.5752273	3.488559459
Mode	#N/A	#N/A	0.58	#N/A	#N/A

Standard Deviation	1.97685E+31	78519464.61	17.09757	111.9173227	5.686858851
Sample Variance	3.90794E+62	6.16531E+15	292.3269	12525.48712	32.34036359
Kurtosis	10.90504269	-0.019842487	-1.07768	-0.175887993	56.35112969
Skewness	3.267072371	1.109754994	0.265495	1.062832623	6.301160831
Range	1.08698E+32	264623417	58.4027	399.9053731	59.35146944
Minimum	9.50541E+21	3047132	0.194834	37.4213418	-0.900424963
Maximum	1.08698E+32	267670549	58.59753	437.3267149	58.45104447
Sum	1.08584E+33	11657274780	3061.285	22080.58852	659.8163623
Count	145	145	145	145	145

Individual Cross Sectional Line Graphs on each Emissions from 1990-2018

Figure 2.5. Carbon Dioxide Emissions across ASEAN - 5 Countries

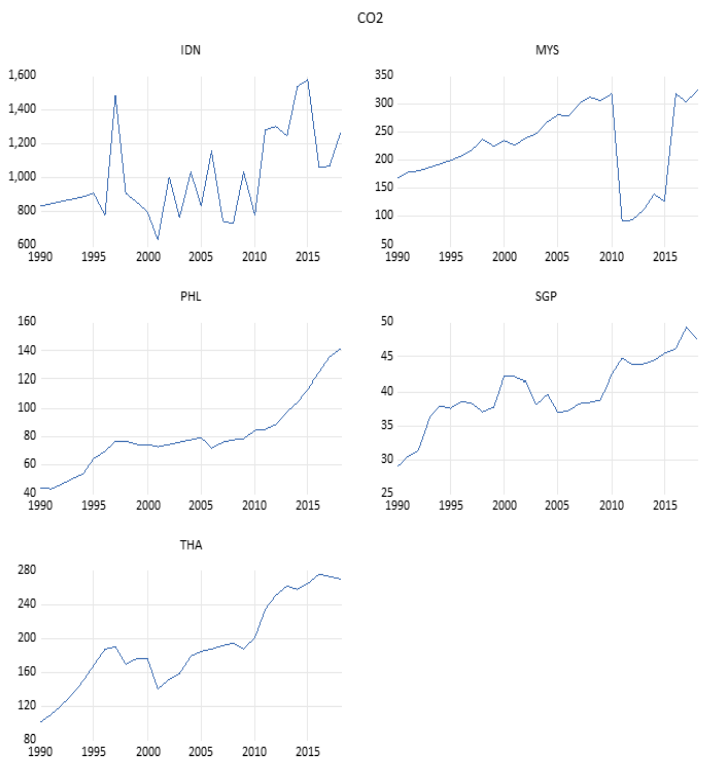

Figure 2.6. Methane Emissions across ASEAN - 5 Countries

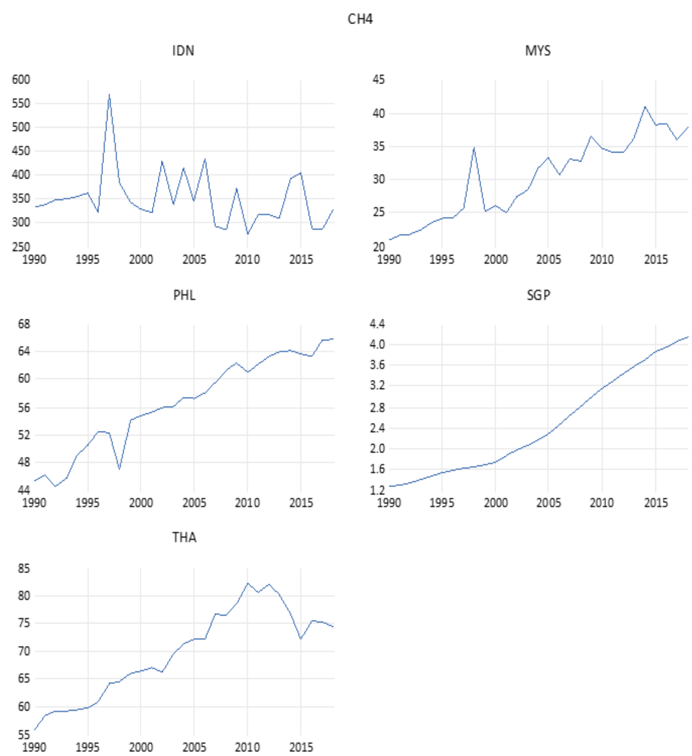

Figure 2.7. Nitrous Oxide Emissions across ASEAN - 5 Countries

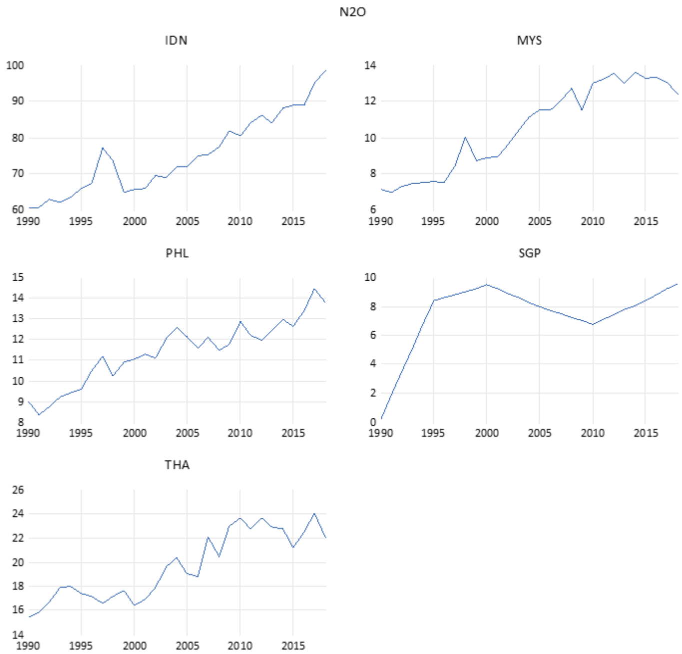

Figure 2.8. Fluorinated Gas Emissions across ASEAN - 5 Countries

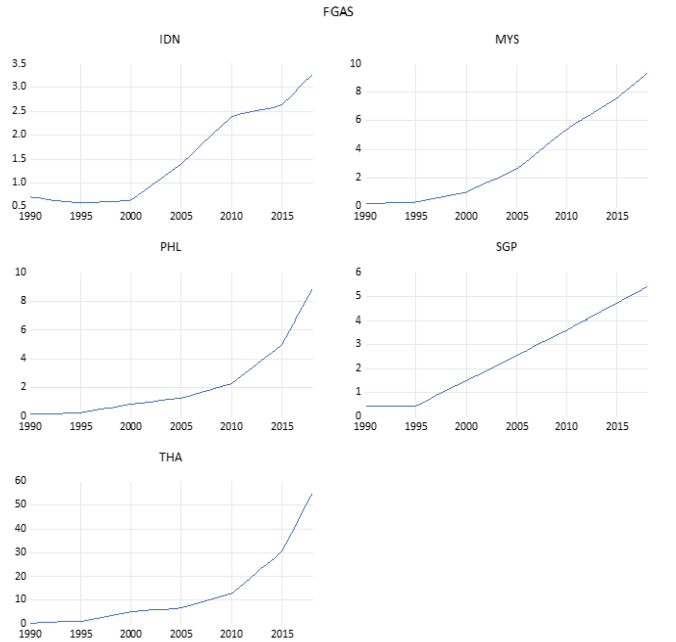

Figure 2.9. Gross Domestic Product across ASEAN - 5 Countries

Figure 2.10. Squared Gross Domestic Product across ASEAN - 5 Countries

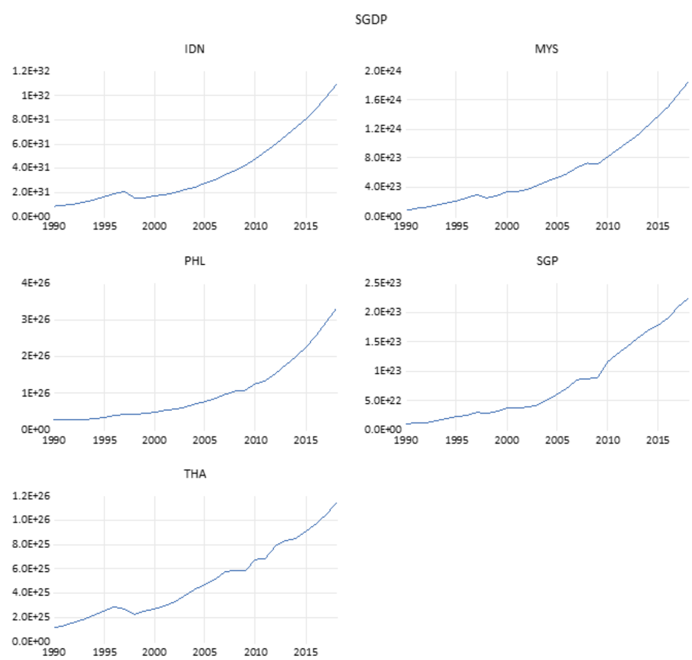

Figure 2.11. Population across ASEAN - 5 Countries

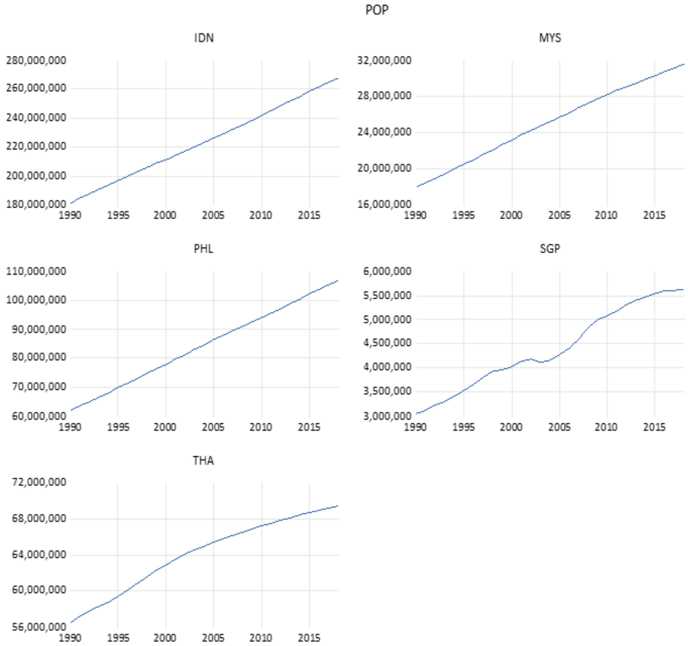

Figure 2.12. Renewable Energy Consumption across ASEAN - 5 Countries

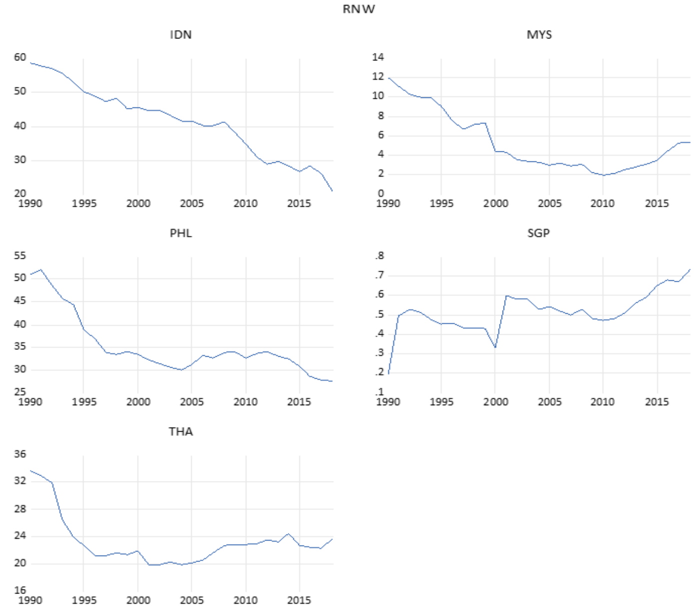

Figure 2.13. Trade Openness across ASEAN - 5 Countries

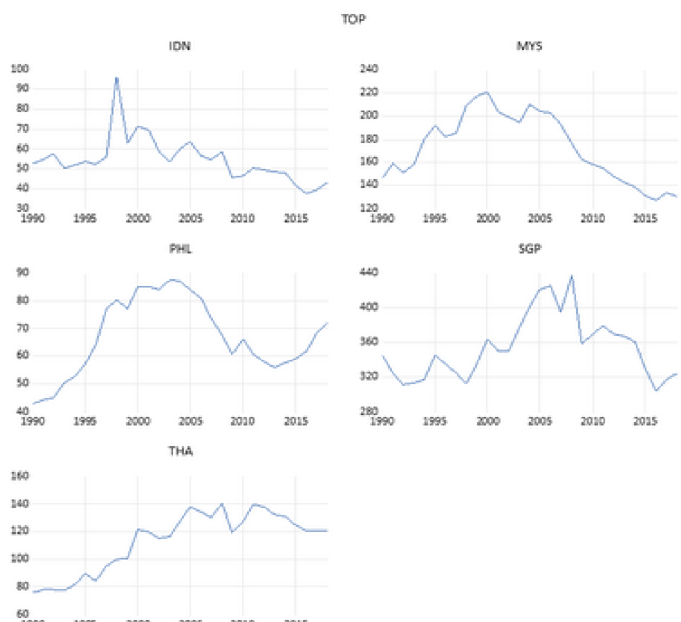

Figure 2.14. Inflation across ASEAN - 5 Countries

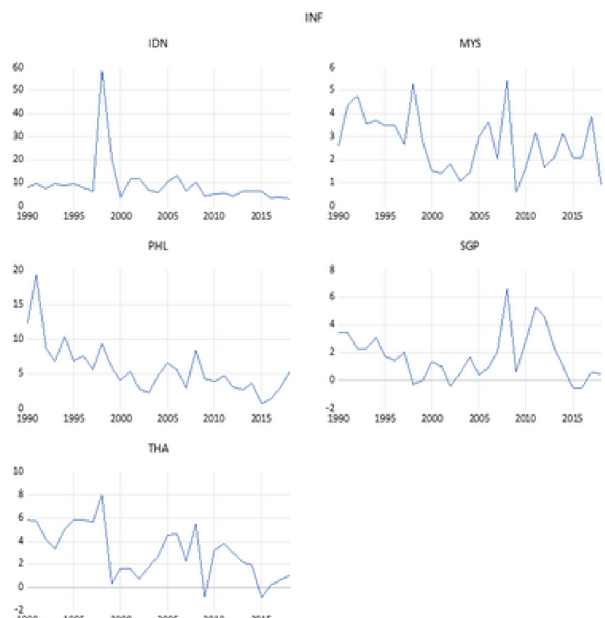

Table 4.1 shows the descriptive statistics of the four Greenhouse Gas emissions and macroeconomic variables utilized in the study. The average CO_2 emission of the ASEAN-5 countries from 1990 to 2018 was 307.28 $MtCO_2e$. Meanwhile, for CH_4, N_2O, and F-GAS, these countries released an average of 101.93, 24.81, and 4.373 $MtCO_2e$, respectively. The median results indicated that 50% of

each of the GHG emissions lied below the following values: 168.62 $MtCO_2e$ of CO_2, 56.13 $MtCO_2e$ of CH_4, 12.65 $MtCO_2e$ of N_2O, and 2.1 $MtCO_2e$ of FGAS.

As for the GDP (constant LCU), the ASEAN-5 countries recorded a mean of 1.15 and 7.49 for SGDP. Meanwhile, the other determinants of growth—POP, RNW, TOP, and INF—recorded an average of 80394998.48, 21.11, 152.28, and 4.55, respectively, with its corresponding standard deviations: 78519464.61, 17.09757, 111.9173227, 5.68685885. This result indicated that there was a large variability in the data of each growth determinant selected in the study.

It was observed in **Figure 2.5** that the CO_2 emissions released by the ASEAN-5 countries increased over time, although Indonesia's carbon emission experienced frequent fluctuations, while Malaysia encountered a significant decrease from 2010. This could be because of Malaysia's announcement in 2009 to committedly reduce 40% of its greenhouse gas emissions by 2020 (Zaid *et al*., 2015). Malaysia's rapid transformation from being an agricultural to an industrialized economy from 1990 to 2005 led to an increase of 235.6% carbon emissions, thus raising concern over the country's unsustainable path to development.

In the case of CH_4 emissions, Singapore showed a steady increase from 1990 to 2018, while Malaysia, Philippines, and Thailand displayed a fluctuating upward trend. On the other hand, Indonesia showed a fluctuating, but downtrend in its emissions. It was reported that there was a significant decrease in emission from the country's forest and other land use (FOLU) sectors, mainly from peat fire emissions (UNFCCC, 2021) thus, could be the reason for its downward trend. Since 85% of the waste in Indonesia was said to be derived from organic material and aerobic composting did not cause methane emissions, it could considerably reduce the GHG emissions, particularly of methane (Danielson, 2020). All of the ASEAN-5 countries displayed an upward trend in terms of N_2O and F-GAS emissions.

Regarding the determinants of growth observed in this study, both the short-run and long-run estimates of the ASEAN-5 countries' GDP illustrated an upward trend. For renewable energy consumption, Malaysia, Indonesia, Philippines, and Thailand showed a downtrend, while Singapore displayed an increase in its RNW over time. Despite the fact that Singapore had limited access to renewable energy, energy efficiency was one of their core carbon emission mitigation strategies (UNFCCC, 2018). In terms of trade openness, Indonesia, Malaysia, Philippines, and Singapore established an inverted U-shaped, fluctuating trend. Thailand, although showing fluctuation, displays an uptrend in terms of the country's TOP. It should be noted that Thailand's value of exports and imports was equivalent to about 135% of GDP in 2010 (WTO, 2012). The outward-orientation of this country contributed to the resilience of the economy in adapting to challenges, thus the uptrend. Lastly, the inflation rate of the ASEAN-5 countries showed constant fluctuations from 1990 to 2018.

4.2 Panel OLS, FE model, and RE model Results

Dependent Variable: **CO_2**
Sample: **1990 - 2018**
Periods included: **29**
Cross-sections included: **5**
Total Panel (balanced) observations: **145**

Table 4.2

Summary of Panel OLS, Fixed Effects, and Random Effects model results

	POLS		**FE**		**RE***	
Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
constant	391.8958	0.0000	681.2422	0.0139	440.4231	0.0426
GDP	2.72E-13	0.0000	1.57E-13	0.0493	4.83E-14	0.4700
SGDP	-1.65E-29	0.0000	-6.99E-30	0.2144	9.34E-31	0.8418
POP	-4.23E-07	0.5973	-5.28E-06	0.0422	-1.40E-06	0.4427
RNW	-4.941419	0.0019	-11.35368	0.0185	-5.399148	0.1209
TOP	-0.0913124	0.0000	1.071875	0.0365	0.212026	0.5697
INF	0.853642	0.6780	-0.121845	0.9549	-0.265441	0.8855

Table 4.3

Correlated Random Effects - Hausman Tests Results

Test period random Effects

Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Period random	13.710851	6	0.0330

****WARNING:** estimated period random effects variance is zero.

Table 4.2 shows the three panel regression runs for the EKC on selected macroeconomic variables and carbon dioxide emission of the ASEAN-5 countries. POLS showed the hypothesized relationship that in the short-run, there was a direct significant relationship between GDP and CO_2 emissions, while there was a negative relationship between GDP in the long-run (as represented by the SGDP) and CO_2 emissions. Likewise, RNW was also significant and had proven a negative relationship with the selected emission. TOP was also statistically significant, but with a negative relationship—opposite of the predicted relationship. The FE model showed that only SGDP and INF were insignificant. Hence, EKC was not present in ASEAN-5 countries. As GDP continued to increase, so did the CO_2 emissions of the countries tested. RNW echoed the same results from POLS, while as POP was significant, the resulting relationship was negative. TOP remained significant, and exhibited a positive relationship. No variables were significant in the RE model. Therefore, after running the Hausman Test (**Table 4.3**), the FE model was fit to be the appropriate model used for further discussion.

The hypothesis was partially confirmed on CO_2 emissions and variables on determinants of growth. Evidence suggested that economic growth had an effect on this particular emission in ASEAN-5 countries. However, there was no proof that the EKC existed within these parameters, consistent with the findings of Chandran and Tang (2013) on the ASEAN-5, as well as findings amongst low to middle income countries (Leal & Marques, 2020). These findings stressed that most of the countries tested were still in their earlier stages of development. Meanwhile, the employment of renewable energy resources did mitigate CO_2 emissions. Liu *et al*. (2017), Bekun *et al*. (2021), and Wang *et al*. (2022) all suggested in their papers that these alternative energy resources were helpful in lowering CO_2 in the country. Subsequently, as countries opened up in trading more across borders, it also generated more CO_2 emission. This was true to developing countries whose CO_2 emissions were higher as they produced and traded more as compared to developed countries (World Trade Organization, 2021). Meanwhile, the results on the relationship between POP and CO_2 emissions defied existing studies (Wang *et al.*, 2022; Yeh & Liao, 2017). To support this paper's claim, a study by Oxfam International (2020) found that the world's richest top 10% individuals were responsible for more than 52% of the cumulative carbon emissions while the poorest members of the entire population only accounted for 7% of the emissions. This suggested that the population increase from the ASEAN-5 countries, who were mostly composed of low to middle income populations, did not necessarily affect carbon emissions, for these individuals' general consumption was much more controlled compared to the upper-class minority in the society. Lastly, INF did not affect carbon emissions in any way even if it influenced economic growth which contradicted existing studies (Musarat *et al.,* 2021). This may be because there were other measures, such as investments in projects to stimulate economic performance, that can be better used in measuring effects related to INF.

Dependent Variable: **CH_4**

Sample: **1990 - 2018**

Periods included: **29**

Cross-sections included: **5**

Total Panel (balanced) observations: **145**

Table 4.4

Summary of Panel OLS, Fixed Effects, and Random Effects model results

	POLS		**FE**		**RE***	
Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
constant	23.70475	0.1619	125.7324	0.0863	134.6586	0.0204
GDP	7.96E-14	0.0000	3.09E-15	0.8837	-1.06E-15	0.9527
SGDP	-6.81E-30	0.0000	-9.47E-31	0.5272	-8.32E-31	0.5050
POP	5.31E-07	0.0154	-1.46E-07	0.8315	2.61E-09	0.9957
RNW	0.112595	0.7900	-0.559680	0.6593	-1.200306	0.1954
TOP	-0.058749	0.2656	0.005717	0.9663	-0.011507	0.9078
INF	0.432747	0.4372	0.535801	0.3523	0.351564	0.4750

Table 4.5

Correlated Random Effects - Hausman Tests Results

Test period random Effects

Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Period random	5.257409	6	0.5112

****WARNING:** estimated period random effects variance is zero.

In **Table 4.4**, the results of the POLS revealed that there was a significant positive correlation between GDP and CH_4 emissions in the short run, while there existed a negative relationship between the aforementioned variables in the long run. The coefficient of POP also had a positive and significant relationship with CH_4 emissions. Meanwhile, RNW, TOP, and INF were all insignificant; with RNW and INF showing a positive relationship with CH_4 emissions and with TOP exhibiting a negative relationship with CH_4 emissions. The FE model results showed that all of the variables utilized in the study were insignificant. However, aside from GDP having an indirect relationship with CH_4 emissions in the long run, POP and RNW also showed a negative relationship with the said emission. In comparison, the RE model yielded the same results as the FE model in terms of significance, but with a negative relationship between GDP and CH_4 emission in the short- and long-run. In this method, the POP and INF showed a positive relationship with CH_4 emissions, while RNW and TOP showed a negative relationship with CH_4 emissions. The result of the Hausman test indicated that RE is the more appropriate method for the data set as the p-value signified the acceptance of the null hypothesis.

In this case, the alternative hypothesis was not accepted on CH_4 emissions and macroeconomic variables. The findings of the RE model showed that there was no direct relationship between GDP and CH_4 emissions, and that there was no inverted U-shaped EKC that exists in ASEAN-5 countries. This was consistent with the studies of Ari and Senturk (2020) on G7 countries, and Williamson (2017) on 181 countries. According to Jiahui and Wong (2022), several Southeast Asian countries faced similar challenges in mitigating methane emissions. The UN Environment Programme (2021) identified that around 60% of the global methane emissions are human-caused, and a large part of it came from agriculture, fossil fuels, and waste. When it came to agricultural methane, the focus was on livestock. As the population continues to grow, so is the demand for animal protein; and an increase in consumption tends to increase the methane emissions. However, given the projected future growth in the demand for meat, whether or not population continues to grow, its effect on methane emissions would be relatively small because demographic changes influence the consumption patterns of people (National Science Foundation, 2010; Sharma *et al.*, 2018). Thus, it varies across different countries and it is not dependent entirely on how much population increases. In relation to that, one of the suggested actions to reduce methane emissions is to provide animals with more nutritious feeds (UNEP CCC, 2021), and it was expected that trade openness gave these countries an opportunity to do so. However, evidence suggested that trade openness did not significantly impact nutrient use (Dang *et al.*, 2018) which might explain the results for TOP.

Contrary to what most of the previous studies suggested, RNW in this case did not have a direct impact on CH_4 emissions. There is an ongoing discourse as to whether or not renewable natural gas (RNG) could be used as an alternative for fossil natural gas. It was mentioned by Grubert (2020) that RNG was produced from waste methane which could still end up being discharged into the atmosphere. Although it would be better to use RNG than fossil natural gas, doing so was not enough to respond to the urgency of climate change. Meanwhile, even though environmental changes influenced inflation, it's not exactly the same the other way around. The insignificant effect of inflation to CH_4 emissions aligned with the results found by Majeed *et al.* (2021). This was because the source of CH_4 emissions largely came from land management activities and human practices, and not on how much the price of goods and services increase or decrease.

Dependent Variable: **N_2O**
Sample: **1990 - 2018**
Periods included: **29**
Cross-sections included: **5**
Total Panel (balanced) observations: **145**

Table 4.6

Summary of Panel OLS, Fixed Effects, and Random Effects model results for N_2O

	POLS		FE		RE*	
Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
constant	9.841442	0.0000	21.72200	0.0000	12.16118	0.0008
GDP	1.18E-14	0.0000	3.57E-15	0.0073	1.93E-15	0.0828
SGDP	-6.69E-31	0.0000	5.61E-32	0.5461	7.51E-32	0.3325
POP	1.23E-07	0.0000	-1.75E-08	0.6810	1.32E-07	0.0000
RNW	-0.123642	0.0280	0.045641	0.5621	-0.087819	0.1270
TOP	-0.006302	0.3649	-0.008506	0.3117	0.005682	0.3573
INF	0.031696	0.6659	0.069967	0.0517	0.060073	0.0504

Table 4.7

Correlated Random Effects - Hausman Tests Results

Test period random Effects

Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Period random	85.307959	6	0.0000

****WARNING:** estimated period random effects variance is zero.

Only TOP and INF were not significant in **Table 4.6** from the results of the POLS model. The EKC was evident and had a positive and negative correlation in the short-run and long-run, respectively. POP was significant and had a positive relationship with N_2O, while RNW exhibited negative correlation at significance level. As reflected from the FE model, the EKC did not exist, hence, as GDP—which is statistically significant—increases, N_2O emissions would only increase over time. INF also had a positive correlation with the selected GHG, consistent with the predicted relationship. The remaining macroeconomic variables were not statistically significant. The EKC was also not present when the RE regression was employed. While GDP remained significant and had a positive relationship with the GHG, there was no relationship between N_2O and SGDP. POP had a negative effect on the independent variable and was significant. The outcome of the Hausman test determined that the FE model was the most appropriate for the macroeconomic variables and N_2O.

The hypothesis was partially confirmed on N_2O emissions and macroeconomic variables. The appropriate panel model, FE, discredited the existence of the inverted-U curve between GDP andN_2O emissions. The economies within the ASEAN-5 countries are still in their early stages of development, thus, no turning point was established (Och, 2017). INF's positive relationship with N_2O was consistent with its relationship towards economic growth as general production in the region increased, resulting in more N_2O emissions in the atmosphere. POP, RNW, and TOP did not have any direct relationship with N_2O due to the nature of this emission. Since N_2O emissions are primarily generated in the agricultural sector of the ASEAN-5 countries (except for Singapore), the increase in POP did not encourage an increase in crop production. In fact, crop production has slowly been declining in Southeast Asian countries, in general (Liu *et al.*, 2020). Food production does not also have a direct impact on RNW, and therefore does not affect N_2O. Lastly, TOP had a relatively small effect to be significant to the emission that's largely originating from the agriculture sector (Cole & Elliot, 2003 as cited in Van Tran, 2020).

Dependent Variable: **F-GAS**

Sample: **1990 - 2018**

Periods included: **29**

Cross-sections included: **5**

Total Panel (balanced) observations: **145**

Table 4.8

Summary of Panel OLS, Fixed Effects, and Random Effects model results

	POLS		FE		RE*	
Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
constant	-0.261835	0.9475	-3.941445	0.7685	-48.35648	0.0000
GDP	-7.19E-15	0.0005	9.55E-15	0.0151	-8.91E-15	0.0073
SGDP	3.11E-31	0.0350	-7.61E-31	0.0066	4.32E-31	0.0613
POP	1.92E-07	0.0002	1.66E-07	0.1904	5.32E-07	0.0000
RNW	-0.250806	0.0128	0.002725	0.9907	0.522838	0.0025
TOP	0.008873	0.4747	0.111429	0.0000	0.043830	0.0177
INF	-0.210224	0.1103	-0.135922	0.2004	-0.165125	0.0696

Table 4.9

Correlated Random Effects - Hausman Tests Results

Test period random Effects

Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Period random	105.551543	6	0.0000

****WARNING:** estimated period random effects variance is zero.

In **Table 4.8**, the POLS model revealed that the relationship between GDP and F-GAS emissions was negatively significant but positive and significant in the short- and long-run, respectively, as opposed to the concept of EKC. POP exhibited a positive and significant relationship, while RNW showed a negative and significant relationship—both aligned with their predicted relationships. Meanwhile, only TOP and INF had insignificant relationships with F-GAS emissions; TOP displayed a positive relationship while INF was negative. The FE model resulted in GDP, SGP, and TOP as significant and followed their expected signs. In contrast to the POLS model, GDP and F-GAS had a direct and significant relationship initially but an inversely significant relationship in the long-run, proving the existence of EKC. However, the relationships between the said emission and POP, RNW, and INF were insignificant. The RE model exhibited the same result for GDP in the short run, but SGDP was positive and insignificant which invalidated the EKC. While POP and TOP were positively significant with

F-GAS emissions, RNW was significant but did not follow the anticipated relationship. INF remained negative and insignificant, like in the previous models. For the Hausman test result, the FE model was the most suitable method for the data set as the null hypothesis was accepted.

H4 was partially confirmed due to varying reasons. The ASEAN-5's economic growth and F-GAS had a direct relationship in the short-run, but the mentioned GHG emission would eventually decrease as economies continuously flourish. Contrary to the results yielded by Okon (2021), the findings suggested that the ASEAN-5 might have reached the turning point wherein an inverse relationship would be evident in the long-run. The study about the relationship between the Italian geographical location and F-GAS (specifically benzene and sulfur hexafluoride) supported the EKC validity, while the opposite occurred to hydrofluorocarbons even though the inverted U-shaped relationship was established (Sica & Sušnik, 2014). Due to these, the difference in income and developmental stage per region or country were important determinants for the EKC presence and the effect of the said GHG emission on the economy. ASEAN-5 countries were the leading producers in the industrial sector, especially in electronics (ASEAN Secretariat, 2012), proving the positive relationship between TOP and F-GAS, as the TOP and the industrial sector were closely woven with each other. It also reflected the study on Africa by Twerefou *et al.* (2019) regarding the "Direct Trade Effect"; however, it is noteworthy to distinguish that the former is focused only on consumption. Additionally, free trade in the Asia-Pacific region encouraged more production and consumption, hence, increasing the impact of climate change. Meanwhile, POP, RNW, and INF did not have a direct influence on F-GAS. Due to the focus on production and the nature of ASEAN-5 as developing countries, utilizing renewable energy was not viable because the economies may not be able to sustain it and cover the equipment costs. Another reason was that manufacturing renewable energy machines also uses materials that increase the dangerous effects of climate change. Iwata and Okada (2012) pointed out that the Kyoto Protocol mainly focused on CO_2 reduction and less on the other GHGs, therefore, laws and regulations on F-GAS may not be sufficient in minimizing the detrimental consequences to the environment. Furthermore, POP had an insignificant relationship because of the difference in lifestyle and financial capability to afford household appliances or factory machinery. Likewise, price changes were not vital factors to establish a positive relationship between INF and F-GAS.

As with Buenavista and Palanca-Tan (2021), this paper acknowledged the existence of cross-sectional dependence and heteroskedasticity in the data at hand. The limits of the study posed that FE and RE models exhibit inconsistency when tested with cross sectional dependence and non-normality (Le & Ozturk, 2020). Moreover, all equations revealed that there was no excessive to moderate collinearity in the data.

CO_2, CH_4, N_2O, and F-GAS are dominantly present in the agricultural and industrial sectors. The appropriate model for CO_2, N_2O, and F-GAS was the FE method, but the RE was most fitting for CH_4. There were mixed results on the EKC existence in the relationship between GHG emissions and macroeconomic variables. CO_2, CH_4, and N_2O discredited its existence, for ASEAN-5 countries are still in the early stages of development. Only F-GAS exhibited an inverted-U diagram in economic growth, but other variables were held insignificant. It is also noteworthy that this emission was considered to be at the Environmental Improvement stage even though much is still needed in its mitigation. In the case of POP, the results remained to not affect its relationship with the GHGs due to several underlying factors. It was inconclusive for RNW as its relationship to CO_2 yielded the predicted negative sign, but the other emissions had no impact because of the debatable nature of using renewable energy. Moreover, the relationships of TOP with CO_2 and F-GAS were consistent with their expected positive signs, indicating that as the ASEAN-5 countries traded more, there would be a consequent increase in these emissions. Only the relationship of INF to N_2O showed a positive and significant influence on the environment which puts the risk of further pollution as the economy grows. Based on the various test results, only H2 was confirmed while the others were partially true.

V. CONCLUSION

The researchers tested the Environmental Kuznets Curve hypothesis against the level of pollution, as represented by the four leading Greenhouse Gas released from various industries and economic expansion for ASEAN-5 countries from 1990 - 2018. Furthermore, other macroeconomic variables, namely population, renewable energy consumption, trade openness, and inflation, were also tested against the chosen GHGs to evaluate the relationship between these variables. The data went through three Panel Regression tests, namely the POLS, FE, and RE model.

The EKC theory presents that in the short-run, environmental degradation and economic growth have a positive relationship with each other until such time that continued growth of a country would lead to a decrease of environmental degradation in the long-run (Grossman & Krueger, 1995). In this paper, environmental degradation was represented by four major GHGs (CO_2, CH_4, N_2O and F-Gas) while economic growth was represented by GDP. The validity of EKC in the linkage between greenhouse gas emissions and macroeconomic indicators showed varied results in this research, with only F-GAS as the only one consistent with the EKC hypothesis as presented by GDP and SGDP.

As for the other macroeconomic variables, due to a number of underlying reasons, the population of ASEAN-5 countries did not contribute to any of the GHG emissions' increase. The results for RNW showed varying results. Its relationship with CO_2 remained consistent with the simulacrum, while the other emissions showed that there was no impact due to the nature of the major contributor industries. TOP's ties with CO_2 and F-GAS levels were in line with the expectations, indicating that emissions will rise when the ASEAN-5 trades goods or raw materials with other countries. Only the relationship between INF and N_2O has a favorable and large impact on the environment, putting the economy at danger of greater pollution as it increases. Overall, only H2 was confirmed, while the rest of the hypothesis statements were only partially accepted.

Based on the results of the study, the researchers would like to recommend the promotion of environmentally-sound policies amongst ASEAN-5 countries. As for CO_2 emissions, strategies should be focused on transitioning to renewable energy resources such as solar, wind, geothermal, hydroelectric, ocean, and other forms of bioenergy. Government incentives could also be implemented to encourage their citizens and corporations to make use of various low-carbon technologies. For CH_4 reduction, reformation and innovation in the agricultural and waste sector is a must. The government and other relevant industries should help farmers in providing them with feed additives that would provide more nutritious and healthier livestock with less resources all while reducing the animals' methane production. Other mitigation practices that should be used more include capturing and burning methane gas from landfills. Reducing fuel consumption would greatly reduce N_2O emissions, for N_2O is a byproduct of fuel combustion. Government incentives for citizens to buy electric vehicles or plug-in hybrid models are one way to promote the use of cars with little to no exhaust pollutants. Moreover, N_2O is also an emission coming from the agricultural industry, hence, government policies and subsidies to help farmers use less nitrogen-based fertilizers. There are tools to test the soil and plants, and visual signs to know how to manage nitrogen consumption on crops, and minimizing excess use. More research and innovation should be done for a more effective way to mitigate nitrous oxide emissions in the agricultural sector. Lastly, fluorinated gases are often found as by-products, reactants, and leaks throughout various industrial processes and even from some home appliances, such as refrigerators. Governments and other concerned industries could begin by adopting F-GAS capturing and recycling. Furthermore, they can promote the research and development of alternatives that are less harmful to the environment.

Moving forward, the various economic sectors and the government should invest more in building a greener future for everyone in the ASEAN-5 region. In general, investments on useful instruments and methods for authorities to help with monitoring the effects of environmental degradation to optimize, control, and even forecast economic performances to stabilize the GHG emissions to a more sustainable level. Economic stability and achieving sustainable development goals shouldn't be seen as two separate entities that restrict each other. In fact, the government should develop and support goals and policies that are interdependent with both economic growth and climate action.

REFERENCES

[1] Ahmad, M., Muslija, A., & Satrovic, E. (2021). Does economic prosperity lead to environmental sustainability in developing economies? Environmental Kuznets curve theory. *Environmental Science and Pollution Research, 28*(18), 22588–22601. https://doi.org/10.1007/s11356-020-12276-9

[2] Akhbari, R., & Nejati, M. (2019). The effect of corruption on carbon emissions in developed and developing countries: empirical investigation of a claim. *Heliyon, 5*(9), e02516. https://doi.org/10.1016/j.heliyon.2019.e02516

[3] Al-mulali, U., Weng-Wai, C., Sheau-Ting, L., & Mohammed, A. H. (2015). Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. *Ecological Indicators, 48*, 315–323. https://doi.org/10.1016/j.ecolind.2014.08.029

[4] Ali, S., Yusop, Z., Kaliappan, S. R., & Chin, L. (2020). Trade-environment nexus in OIC countries: fresh insights from environmental kuznets curve using GHG emissions and ecological footprint. *Environmental Science and Pollution Research*, *28*(4), 4531–4548. https://doi.org/10.1007/s11356-020-10845-6

[5] Aljadani, A., Toumi, H., Toumi, S., Hsini, M., & Jallali, B. (2021). Investigation of the N-shaped environmental Kuznets curve for COVID-19 mitigation in the KSA. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-12713-3

[6] Allard, A., Takman, J., Uddin, G. S., & Ahmed, A. (2017). The N-shaped environmental Kuznets curve: an empirical evaluation using a panel quantile regression approach. *Environmental Science and Pollution Research*, *25*(6), 5848–5861. https://doi.org/10.1007/s11356-017-0907-0

[7] Alotaibi, A. A., & Alajlan, N. (2021). Using Quantile Regression to Analyze the Relationship between Socioeconomic Indicators and Carbon Dioxide Emissions in G20 Countries. *Sustainability*, *13*(13), 7011. https://doi.org/10.3390/su13137011

[8] Anwar, M. A., Zhang, Q., Asmi, F., Hussain, N., Plantinga, A., Zahar, M. W., & Sinha, A. (2022). Global perspectives on environmental kuznets curve: A bibliometric review. *Gondwana Research, 103*, 135-145. https://doi.org/10.1016/j.gr.2021.11.010

[9] Apergis, N., & Ozturk, I. (2015). Testing Environmental Kuznets Curve hypothesis in Asian countries. *Ecological Indicators*, *52*, 16–22. https://doi.org/10.1016/j.ecolind.2014.11.026

[10] Ari, I., & Şentürk, H. (2020). The relationship between GDP and methane emissions from solid waste: A panel data analysis for the G7. *Sustainable Production and Consumption*, *23*, 282–290. https://doi.org/10.1016/j.spc.2020.06.004

[11] Arshad Ansari, M., Haider, S., & Khan, N. (2020). Environmental Kuznets curve revisited: An analysis using ecological and material footprint. *Ecological Indicators*, *115*, 106416. https://doi.org/10.1016/j.ecolind.2020.106416

[12] ASEAN Centre for Energy & Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH. (2020, November). *The 6th ASEAN Energy Outlook (AEO6)*. ASEAN Centre for Energy. https://aseanenergy.org/the-6th-asean-energy-outlook/

[13] ASEAN Secretariat. (2012). *Industry Focus*. ASEAN. Retrieved October 3, 2022, from https://asean.org/industry-focus/

[14] Bekhet, H. A., & Othman, N. S. (2018). The role of renewable energy to validate dynamic interaction between CO_2 emissions and GDP toward sustainable development in Malaysia. *Energy Economics*, *72*, 47–61. https://doi.org/10.1016/j.eneco.2018.03.028

[15] Bekun, F. V., Gyamfi, B. A., Onifade, S. T., & Agboola, M. O. (2021). Beyond the environmental Kuznets Curve in E7 economies: Accounting for the combined impacts of institutional quality and renewables. *Journal of Cleaner Production*, *314*, 127924. https://doi.org/10.1016/j.jclepro.2021.127924

[16] Buenavista, M. J. M., & Palanca-Tan, R. (2021). Carbon Dioxide Emissions and the Macroeconomy: Evidence from the ASEAN Region. *Philippine Journal of Science, 150*(3), 737-745. https://philjournalsci.dost.gov.ph/105-vol-150-no-3-june-2021/1382-carbon-dioxide-emissi

[17] Chandran, V. G. R., & Tang, C. F. (2013). The impacts of transport energy consumption, foreign direct investment and income on CO_2 emissions in ASEAN-5 economies. *Renewable and Sustainable Energy Reviews*, *24*, 445–453. https://doi.org/10.1016/j.rser.2013.03.054

[18] Cho, C.-H., Chu, Y.-P., & Yang, H.-Y. (2013). An Environment Kuznets Curve for GHG Emissions: A Panel Cointegration Analysis. *Energy Sources, Part B: Economics, Planning, and Policy*, *9*(2), 120–129. https://doi.org/10.1080/15567241003773192

[19] Climate Watch. (2020). *Historical GHG Emissions* [Data File]. Retrieved from https://www.climatewatchdata.org/ghg-emissions

[20] Dang, Q., Konar, M., & Debaere, P. (2018). Trade openness and the nutrient use of nations. *Environmental Research Letters*, *13*(12), 124016. https://doi.org/10.1088/1748-9326/aaebcb

[21] Danielson, J. (2020). *How organic waste processing in Bali helps build a viable circular economy for plastic*. Alliance To End Plastic Waste. Retrieved from https://endplasticwaste.org/our-stories/how-organic-waste-processing-in-bali-helps-build-a-viable-circular-economy-for-plastic

[22] Farhani, S., Shahbaz, M., & Arouri, M. (2013). Panel analysis of CO_2 emissions, GDP, energy consumption, trade openness and urbanization for MENA countries. *Munich Personal RePEc Archive*. https://mpra.ub.uni-muenchen.de/49258/

[23] Grossman, G. M., & Krueger, A. B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics, 110*(2), 353–377. https://doi.org/10.2307/2118443

[24] Grubert, E. (2020). At scale, renewable natural gas systems could be climate intensive: The influence of methane feedstock and leakage rates. *Environmental Research Letters*, *15*(8), 084041. https://doi.org/10.1088/1748-9326/ab9335

[25] IPCC. (2018). Summary for Policymakers, In: *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. *World Meteorological Organization, Geneva, Switzerland, 32 pp*. https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_version_stand_alone_LR.pdf

[26] Iwata, H., & Okada, K. (2012). Greenhouse gas emissions and the role of the Kyoto Protocol. *Environmental Economics and Policy Studies*, 16(4), 325–342. https://doi.org/10.1007/s10018-012-0047-1

[27] Jiahui, Q., & Wong, R. (2022). *Understanding and Reducing Methane Emissions in Southeast Asia*. Retrieved from https://www.iseas.edu.sg/wp-content/uploads/2022/04/TRS8_22.pdf

[28] Jiang, L., He, S., Zhong, Z., Zhou, H., & He, L. (2019). Revisiting environmental kuznets curve for carbon dioxide emissions: The role of trade. *Structural Change and Economic Dynamics, 50*, 245-257. https://doi.org/10.1016/j.strueco.2019.07.004

[29] Jovanović, M., Kašćelan, L., Despotović, A., & Kašćelan, V. (2015). The Impact of Agro-Economic Factors on GHG Emissions: Evidence from European Developing and Advanced Economies. *Sustainability*, *7*(12), 16290–16310. https://doi.org/10.3390/su71215815

[30] Kalaitzidakis, P., Mamuneas, T., & Stengos, T. (2018). Greenhouse Emissions and Productivity Growth. *Journal of Risk and Financial Management*, *11*(3), 38. https://doi.org/10.3390/jrfm11030038

[31] Kang, Y.-Q., Zhao, T., & Yang, Y.-Y. (2016). Environmental Kuznets Curve for CO_2 emissions in China: A spatial panel data approach. *Ecological Indicators*, *63*, 231–239. https://doi.org/10.1016/j.ecolind.2015.12.011

[32] Kasioumi, M., & Stengos, T. (2020). The Environmental Kuznets Curve with Recycling: A Partially Linear Semiparametric Approach. *Journal of Risk and Financial Management*, *13*(11), 274. https://doi.org/10.3390/jrfm13110274

[33] Kaya Kanlı, N., & Küçükefe, B. (2022). Is the environmental Kuznets curve hypothesis valid? A global analysis for carbon dioxide emissions. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02138-4

[34] Khan, M., & Rana, A. T. (2021). Institutional quality and CO_2 emission–output relations: The case of Asian countries. *Journal of Environmental Management*, *279*, 111569. https://doi.org/10.1016/j.jenvman.2020.111569

[35] Koilo, V. (2019). Evidence of the Environmental Kuznets Curve: Unleashing the Opportunity of Industry 4.0 in Emerging Economies. *Journal of Risk and Financial Management*, *12*(3), 122. https://doi.org/10.3390/jrfm12030122

[36] Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review, 45*(1), 1-28. https://www.jstor.org/stable/1811581

[37] Le, H. P., & Ozturk, I. (2020). The impacts of globalization, financial development, government expenditures, and institutional quality on CO_2 emissions in the presence of environmental Kuznets curve. *Environmental Science and Pollution Research*, *27*(18), 22680–22697. https://doi.org/10.1007/s11356-020-08812-2

[38] Leal, P. H., & Marques, A. C. (2020). Rediscovering the EKC hypothesis for the 20 highest CO_2 emitters among OECD countries by level of Globalization. *International Economics*, *164*, 36–47. https://doi.org/10.1016/j.inteco.2020.07.001

[39] Lee, J.-O., & Adam, S. (2022). *ASEAN is poised for post-pandemic inclusive growth and prosperity – here's why*. World Economic Forum. https://www.weforum.org/agenda/2022/01/asean-is-poised-for-post-pandemic-inclusive-growth-and-prosperity-heres-why/

[40] Liu, W. (2020). EKC test study on the relationship between carbon dioxide emission and regional economic growth. *Carbon Management*, *11*(4), 415–425. https://doi.org/10.1080/17583004.2020.1768776

[41] Liu, J., Wang, M., Yang, L., Rahman, S., & Sriboonchitta, S. (2020). Agricultural productivity growth and its determinants in south and Southeast Asian countries. Sustainability, 12(12), 4981. https://doi.org/10.3390/su12124981

[42] Liu, X., Zhang, S., & Bae, J. (2017). The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries. *Journal of Cleaner Production, 164*, 1239-1247. https://doi.org/10.1016/j.jclepro.2017.07.086

[43] Lorente, D. B., & Álvarez-Herranz, A. (2016). Economic growth and energy regulation in the environmental Kuznets curve. *Environmental Science and Pollution Research*, *23*(16), 16478–16494. https://doi.org/10.1007/s11356-016-6773-3

[44] Luo, R., Ullah, S., & Ali, K. (2021). Pathway towards Sustainability in Selected Asian Countries: Influence of Green Investment, Technology Innovations, and Economic Growth on CO_2 Emission. *Sustainability*, *13*(22), 12873. https://doi.org/10.3390/su132212873

[45] Madaleno, M., & Moutinho, V. (2021). Analysis of the New Kuznets Relationship: Considering Emissions of Carbon, Methanol, and Nitrous Oxide Greenhouse Gases—Evidence from EU countries. *International Journal of Environmental Research and Public Health*, *18*(6), 2907. https://doi.org/10.3390/ijerph18062907

[46] Majeed, M. T., Mazhar, M., & Sabir, S. (2021). Environmental Quality and Output Volatility: The Case of South Asian Economies. *Environmental Science and Pollution Research*, *28*, 31276–31288 . https://doi.org/10.1007/s11356-021-12659-6

[47] Marques, A. C., Fuinhas, J. A., & Leal, P. A. (2018). The impact of economic growth on CO_2 emissions in Australia: the environmental Kuznets curve and the decoupling index. *Environmental Science and Pollution Research*, *25*(27), 27283–27296. https://doi.org/10.1007/s11356-018-2768-6

[48] Mehmood Mirza, F., Sinha, A., Rehman Khan, J., Kalugina, O. A., & Wasif Zafar, M. (2022). Impact of energy efficiency on CO_2 Emissions: Empirical evidence from developing countries. *Gondwana Research*, *106*, 64–77. https://doi.org/10.1016/j.gr.2021.11.017

[49] Musarat, M. A., Alaloul, W. S., Liew, M. S., Maqsoom, A., & Qureshi, A. H. (2021). The effect of inflation rate on CO_2 emission: A framework for Malaysian construction industry. Sustainability, 13(3), 1562. https://doi.org/10.3390/su13031562

[50] Naser, H., & Alaali, F. (2021). Mitigation of Nitrous Oxide Emission for Green Growth: An Empirical Approach using ARDL. *Advances in Science, Technology and Engineering Systems Journal*, *6*(4), 189–195. https://doi.org/10.25046/aj060423

[51] Nasir, M. A., Duc Huynh, T. L., & Xuan Tram, H. T. (2019). Role of financial development, economic growth & foreign direct investment in driving climate change: A case of emerging ASEAN. *Journal of Environmental Management*, *242*, 131–141. https://doi.org/10.1016/j.jenvman.2019.03.112

[52] National Science Foundation. (2010). *Population Change: Another Influence on Climate Change*. NSF. Retrieved from https://www.nsf.gov/news/news_summ.jsp?cntn_id=117817

[53] Niu, M., Zhang, S., Zhang, N., Wen, Z., Xu, M., & Yang, Y. (2022). Progress in the Research of Environmental Macroeconomics. *Sustainability, 14*(3), 1190. https://doi.org/10.3390/su14031190

[54] Oberthür, S., & Ott, H. (1999). *The Kyoto Protocol: International Climate Policy for the 21st Century*. [E-book]. Springer. Retrieved from https://link.springer.com/book/10.1007/978-3-662-03925-0

[55] Och, M. (2017). Empirical Investigation of the Environmental Kuznets Curve Hypothesis for Nitrous Oxide Emissions for Mongolia. International Journal of Energy Economics and Policy, 7(1), 117–128. Retrieved from https://www.econjournals.com/index.php/ijeep/article/view/3557

[56] Okon, E. O. (2021). Nigeria: Is there an Environmental Kuznets curve for fluorinated gases?. *Open Economics*, 4(1), 57–71. https://doi.org/10.1515/openec-2020-0113

[57] Oxfam International. (2020). Carbon emissions of richest 1 percent more than double the emissions of the poorest half of humanity. Oxfam International. Retrieved September 24, 2022, from https://www.oxfam.org/en/press-releases/carbon-emissions-richest-1-percent-more-double-emissions-poorest-half-humanity

[58] Özcan, B., & Öztürk, I. (2019). *Environmental Kuznets Curve (EKC): A Manual* (1st ed.). [E-book]. Academic Press. Retrieved from https://www.elsevier.com/books/environmental-kuznets-curve-ekc/ozcan/978-0-12-816797-7

[59] Ozturk, I., & Al-Mulali, U. (2015). Investigating the validity of the environmental Kuznets curve hypothesis in Cambodia. *Ecological Indicators*, *57*, 324–330. https://doi.org/10.1016/j.ecolind.2015.05.018

[60] Pincheira, R., & Zuniga, F. (2020). Environmental Kuznets curve bibliographic map: a systematic literature review. *Accounting & Finance, 61*(S1), 1931-1956. https://doi.org/10.1111/acfi.12648

[61] Rahman, M. M. (2020). Environmental degradation: The role of electricity consumption, economic growth and globalisation. *Journal of Environmental Management, 253,* 109742. https://doi.org/10.1016/j.jenvman.2019.109742

[62] Sharma, R., Nguyen, T., & Grote, U. (2018). Changing consumption patterns—drivers and the Environmental Impact. *Sustainability*, *10*(11), 4190. https://doi.org/10.3390/su10114190

[63] Shehzad, K., Xiaoxing, L., & Sarfraz, M. (2021). Envisaging the asymmetrical Association among FDI, ICT, and climate change: a case from developing country. *Carbon Management*, *12*(2), 123–137. https://doi.org/10.1080/17583004.2021.1890449

[64] Sica, E., & Sušnik, S. (2014). *Geographical dimension and environmental Kuznets curve: the case of some less investigated air pollutants. Applied Economics Letters, 21(14), 1010–1016.* https://doi.org/10.1080/13504851.2014.904485

[65] The World Bank, World Development Indicators (2022). *GDP (constant LCU)* [Data file]. Retrieved from https://data.worldbank.org/indicator/NY.GDP.MKTP.KN

[66] The World Bank, World Development Indicators (2022). *Inflation, consumer prices* [Data file]. Retrieved from https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG

[67] The World Bank, World Development Indicators (2022). *Population, total* [Data file]. Retrieved from https://data.worldbank.org/indicator/SP.POP.TOTL

[68] The World Bank, World Development Indicators (2022). *Renewable energy consumption* [Data file]. Retrieved from https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS

[69] The World Bank, World Development Indicators (2022). *Trade* [Data file]. Retrieved from https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS

[70] Twerefou, D. K., Akpalu, W., & Mensah, A. C. (2019). Trade-induced environmental quality: The role of Factor Endowment and Environmental Regulation in Africa. *Climate and Development, 11*(9), 786-798. https://doi.org/10.1080/17565529.2018.1562868

[71] Uchiyama, K. (2016). *Environmental Kuznets Curve Hypothesis and Carbon Dioxide Emissions* (1st ed.). [E-book]. Springer. https://doi.org/10.1007/978-4-431-55921-4

[72] Ulucak, R., & Bilgili, F. (2018). A reinvestigation of EKC model by ecological footprint measurement for high, middle and low income countries. *Journal of Cleaner Production*, *188*, 144–157. https://doi.org/10.1016/j.jclepro.2018.03.191

[73] UN Environment Programme. (2021). *Methane emissions are driving climate change. Here's how to reduce them.* UNEP. Retrieved from https://www.unep.org/news-and-stories/story/methane-emissions-are-driving-climate-change-heres-how-reduce-them

[74] United Nations Environment Programme and Climate and Clean Air Coalition (2021). *Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions.* Nairobi: United

Nations Environment Programme. Retrieved from https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions

[75] UNFCCC Conference of the Parties. (2015, December). *Adoption of the Paris Agreement*. Paris Climate Change Conference - November 2015. https://unfccc.int/documents/9064

[76] UNFCCC. (2021). *INDONESIA'S Third Biennial Update Report.* Directorate General of Climate Change, Ministry of Environment and Forestry. Retrieved from https://unfccc.int/sites/default/files/resource/IndonesiaBUR%203_FINAL%20REPORT_2.pdf

[77] UNFCCC. (2018). *SINGAPORE'S Fourth National Communication and Third Biennial Update Report.* National Environment Agency. Retrieved from https://unfccc.int/sites/default/files/resource/067382541_Singapore-NC4-BUR3-1-Singapore%20Fourth%20National%20Communication%20and%20Third%20Biennia_0.pdf

[78] Van Tran, N. (2020). The environmental effects of trade openness in developing countries: Conflict or cooperation? *Environmental Science and Pollution Research, 27*, 19783-19797. https://doi.org/10.1007/s11356-020-08352-9

[79] Wang, Q., Wang, X., & Li, R. (2022). Does urbanization redefine the environmental Kuznets curve? An empirical analysis of 134 countries. *Sustainable Cities and Society*, *76*, 103382. https://doi.org/10.1016/j.scs.2021.103382

[80] Williamson, C. (2017). Emission, Education, and Politics: An Empirical Study of the Carbon Dioxide and Methane Environmental Kuznets Curve. *The Park Place Economist, 25*(1), 9. https://digitalcommons.iwu.edu/parkplace/vol25/iss1/9

[81] World Trade Organization. (2012). Trade policy review: Thailand 2011. *Trade Policy Reviews*, 12-181. https://doi.org/10.30875/caf7640e-en

[82] World Trade Organization. (2021). Trade and climate change - World Trade Organization. Retrieved September 24, 2022, from https://www.wto.org/english/news_e/news21_e/clim_03nov21-4_e.pdf

[83] Xia, W., Apergis, N., Bashir, M. F., Ghosh, S., Doğan, B., & Shahzad, U. (2022). Investigating the role of globalization, and energy consumption for environmental externalities: Empirical evidence from developed and developing economies. *Renewable Energy*, *183*, 219–228. https://doi.org/10.1016/j.renene.2021.10.084

[84] Yandle, B., Bhattarai, M., & Vijayaraghavan, M. (2004). Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications. *PERC*, Research Study 02-1 UPDATE. https://www.perc.org/wp-content/uploads/old/rs02_1a.pdf

[85] Yeh, J.-C., & Liao, C.-H. (2017). Impact of population and economic growth on carbon emissions in Taiwan using an analytic tool STIRPAT. *Sustainable Environment Research*, *27*(1), 41–48. https://doi.org/10.1016/j.serj.2016.10.001

[86] Zaid, S., Myeda, N. E., Mahyuddin, N., & Sulaiman, R. (2015). Malaysia's rising GHG emissions and carbon 'lock-in' risk: A review of Malaysian Building Sector Legislation and policy. *Journal of Surveying, Construction and Property*, *6*(1), 1–13. https://doi.org/10.22452/jscp.vol6no1.1

[87] Zambrano-Monserrate, M. A., & Fernandez, M. A. (2017). An Environmental Kuznets Curve for N_2O emissions in Germany: An ARDL approach. *Natural Resources Forum*, *41*(2), 119–127. https://doi.org/10.1111/1477-8947.12122

[88] Zhang, J. (2021). Environmental Kuznets Curve Hypothesis on CO_2 Emissions: Evidence for China. *Journal of Risk and Financial Management*, *14*(3), 93. https://doi.org/10.3390/jrfm14030093