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THE IMPACT OF CLIMATE CHANGE ON ECONOMIC GROWTH: A STUDY OF ASEAN COUNTRIES

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ARTICLE INFO	ABSTRACT
DOI: 10.52932/jfm.vi2.518 *Received:* March 05, 2024 *Accepted:* March 20, 2024 *Published:* March 25, 2024 **Keywords:** ASEAN countries; Climate change; Economic growth.	Climate change is an urgent and worldwide concern that presents substantial risks to a range of industries, such as agriculture, water resources, and economic growth. The purpose of this research is to assess how climate change has affected the economic expansion of ASEAN nations. Land pollution, sea level rise, and carbon dioxide (CO2) emissions are utilized to quantify climate change. Empirically investigating this issue, the Fixed Effects Generalized Least Squares (FGLS) method is utilized in conjunction with panel data spanning the years 1990 to 2018. The findings from the FGLS model estimation suggest that climate change exerts a varied influence on the economic growth of ASEAN member states. More precisely, total pesticide use in agriculture has a positive impact on economic development, whereas CO2 emissions have a detrimental effect. Moreover, economic growth is positively impacted by foreign direct investment, trade openness, and institutional stability. To stimulate economic expansion and bolster growth drivers, ASEAN nations must adopt more robust measures to deal with climate change.

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1. Introduction

Climate change has emerged as a recurring topic of global current affairs in recent years. Malhi et al. (2021) underscored the significance of climate change and the possible economic repercussions stemming from increasing temperatures and shifting environmental circumstances. Diverse effects result from climate change, including an increase in global average temperature and the occurrence of extreme weather phenomena such as droughts, severe cyclones, and intense heatwaves. These have resulted in severe repercussions, including property damage, loss of life, and health problems. Environmental degradation, species extinction, and deforestation are additional repercussions of climate change. In this context, nations across the globe have initiated climate change mitigation measures, including the expansion of sustainable energy and renewable energy sources.

A report presented at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) by Nanyang Technological University (NTU, Singapore) and the University of Glasgow (UK) indicates that the adverse impacts of climate change and severe natural disasters threaten to reduce ASEAN's GDP growth by over 35% by 2050. These challenges disproportionately affect critical sectors, including agriculture, tourism, and fisheries, and have detrimental effects on human health. The report emphasizes that an estimated 600 million individuals residing in the region will be confronted with elevated temperatures, prolonged monsoon seasons, and more severe droughts as a result of the 1.5 °C increase in global temperatures relative to the pre-industrial era over the next two decades. In addition to affecting ASEAN populations, rising sea levels have a significant impact on the region's coastal inhabitants. Soil pollution and elevated temperatures, sea levels, and fluctuations as a result of climate change are impeding economic activities and undermining the long-term, medium-term, and short-term development of ASEAN nations. Therefore, research must be conducted into effective policies to mitigate these hazards.

Numerous researchers, including Grossman and Kreuger (1991), Holtz-Eakin and Selden (1995), Roberts and Grimes (1997), Abidoyean and Odusola (2015), Linh and Lin (2015), Pycroft et al. (2015), Alvarez-Herranz (2017), Malik et al. (2020), Souvannasouk et al. (2021), and Hamurcu (2023), have examined the effect of climate change on economic growth. These studies suggest that economic growth is influenced by climate change manifestations; however, their primary emphasis is on the effects of CO2 emissions, with limited investigation into sea level rise and soil pollution. Furthermore, each manifestation's impact on economic growth is assessed separately in these studies. Therefore, a research void exists concerning the concurrent effects of diverse climate change manifestations on economic growth. As a consequence, the authors endeavor to fill this research void concerning ASEAN nations. Therefore, to examine the way in which economic growth is impacted by climate change manifestations and to suggest potential measures to mitigate the effects of climate change, the authors have selected the subject **"The Impact of Climate Change on Economic Growth: A Study of ASEAN Countries".**

2. Literature review and Previous Studies

The Intergovernmental Panel on Climate Change (IPCC) published the Fourth Assessment Report (AR4) in 2007 with the following definition: Climate change encompasses alterations in all components of the climate system—atmosphere, hydrosphere, biosphere, lithosphere, and cryosphere—now and in the future. Natural and anthropogenic factors cause these modifications, which transpire over a specific time span of decades or millions of years. Potential consequences of climate change include alterations in the distribution of weather events relative to a mean level or modifications in average weather conditions. Climate change has the potential to manifest on a global scale or limit itself to a specific region. Recent years, particularly in the context of environmental policy, have frequently used climate change to refer to the current state of affairs, also known as global warming, land degradation, and sea-level rise. The primary cause of climate change is the escalation of greenhouse gas-emitting activities and the excessive depletion of carbon sinks and reservoirs, such as forests, marine ecosystems, coastal regions, and terrestrial areas.

Grossman & Kreuger (1991) first proposed the Environmental Kuznets' Curve (EKC) in their analysis of the North American Free Trade Agreement (NAFTA) and air pollution in Mexico. For various nations, they discovered a significant c orrelation b etween environmental quality and per capita income. The U-shaped curve delineates this relationship in accordance with Kuznets's original Kuznets curve theory (1955). Economic research has utilized the comparison of environmental indices to economic development to elucidate the Environmental Kuznets Curve. An inverted U-shaped curve represents the theory's correlation between initial environmental degradation and GDP growth, which shows a progressive decline after an initial increase.

Furthermore, several research studies have put forth an EKC model that takes the shape of an inverted N-shape. Inverting the N-shaped EKC model visualizes the correlation between environmental pollution and per capita income. Technological advancements may not fully offset the decline in pollution levels accompanied by economic expansion; consequently, technical delays may result in heightened environmental contamination in the vicinity (Alvarez-Herranz, 2017). Furthermore, with the growing environmental consciousness and the formulation of environmental policies, the resulting correlation may potentially take the form of an inverted N-shape. This phenomenon arises when advancements in technology cease to foster economic expansion and economies revert to a state of environmental degradation through the minimization of technology (Balsalobre and Alvarez, 2016). The outcomes derived from the inverted U-shaped and N-shaped EKC models would provide policymakers with greater flexibility when formulating short-term and long-term policies.

To shed further light on this theory, numerous experimental studies have been conducted as follows:

Pycroft et al. (2015) presented scenarios for projected sea level rise estimates from 2010 to 2021. The study revealed varying impacts on global GDP for each scenario. The AB1 scenario, forecasting a 0.5 m sea level rise, was estimated to cause a global GDP loss of approximately 1.4%, while the rest of the Southeast Asian region could lose up to 10% of total GDP and 4% for China in the case of a 1.12 m sea level rise.

Souvannasouk et al. (2021) investigated the impacts of climate change on the total output of ASEAN countries based on historical data from 1995 to 2018. The results indicated that global warming would negatively affect the total output of ASEAN countries. This finding aligns with the study by Abidoyean and Odusola (2015), which suggested that a 1 °C temperature increase would decrease the total output of a country by 0.27%. The study also revealed that rising temperatures had an adverse effect on the domestic total output (GDP) of ASEAN countries.

Grossman & Krueger (1991) examined the relationship between air quality and economic growth in 42 countries and found a correlation between GDP per capita and two air pollutants, SO2 and smoke. Specifically, these pollutants were positively correlated with GDP per capita in countries with low national income levels but inversely correlated with GDP per capita in countries with higher national income levels.

Holtz-Eakin & Selden (1995) explored the relationship between economic development and CO2 emissions in 130 countries from 1951 to 1986 based on panel data. The results indicated a decreasing trend in CO2 emissions at the margin as GDP per capita increased, with the turning point in the income-emissions relationship identified as $35,428 per capita.

Roberts & Grimes (1997) tested the existence of the Kuznets curve in the relationship between CO2 emissions and economic development in multiple countries over a 30-year period from 1962 to 1991. The study found evidence supporting the existence of an inverted U-shaped relationship between CO2 emissions and environmental pollution.

Kaufmann et al. (1998) substituted CO2 with SO2 to examine the relationship between income, economic growth, and environmental emissions. Using various models such as fixed effects, random effects, and panel data regressions, the study found evidence of an inverted U-shaped relationship between economic growth and SO2 concentration.

Poumanyvong & Kaneko (2010) studied the impact of urbanization on energy use and CO2 emissions during different stages of development. Empirical evidence suggested that urbanization led to decreased energy consumption but increased CO2 emissions in low-income countries, while it resulted in increased energy use but decreased CO2 emissions in middle- and high-income countries.

Linh & Lin (2015) investigated the causal relationship between environmental degradation, economic growth, FDI, and energy consumption in 12 densely populated countries in East Asia based on panel data. The estimated results supported the EKC hypothesis, with CO2 emissions beginning to decrease when income reached $8,934.1 (in logarithmic terms). In East Asian countries, loosening environmental pollution regulations attracted more FDI, but fortunately, FDI increased significantly without exacerbating environmental degradation.

Malik et al. (2020) examined the impact of economic growth, FDI, and oil prices on CO2 emissions in both the short and long term in Pakistan from 1971 to 2014 using the ARDL and nonlinear ARDL methods. The study findings supported the EKC hypothesis in Pakistan under both methods. Symmetric results showed that economic growth and FDI increased CO2 emissions in both the short and long term, while oil prices only increased emissions in the short term and decreased them in the long term. Asymmetric results in the long term indicated that rising oil prices reduced emissions, while falling oil prices increased emissions.

In summary, climate change has a mixed impact on economic growth, with some studies indicating negative effects while others find positive effects. Liu and Liu observed that climate change (temperature) has a non-linear U-shaped impact on economic growth in different climatic regions, with positive effects in coastal regions and negative effects in inland countries (Zhao & Liu, 2023). Alagidede (2014) emphasized the non-linear relationship between temperature and economic efficiency in sub-Saharan Africa, with temperatures above 24.9 °C significantly reducing growth. Roson (2010) and Moore (2015) both found significant negative effects of climate change on GDP growth, especially in developing countries. Climate change is predicted to have adverse effects on economic development in African countries, with income inequality among the highest globally (Baarsch et al., 2020). Bretschger (2017) highlighted the importance of considering the long-term impacts of climate policies on economic growth, especially in the context of resource depletion and technological development. Stern and Stiglitz argued that stronger action on climate change could enhance economic growth and social welfare by reducing market failures and enhancing growth incentives (Benhamed et al., 2023). Salooja and Butler emphasized the risks to economic growth in resource-dependent countries due to climate change and the need for sustainable natural resource management policies (Stern & Stiglitz, 2023). The economic impact of carbon dioxide emissions on population growth, food production, economic growth, and energy consumption in Pakistan has been studied, revealing production associations (Rehman et al., 2021). Financial constraints exacerbate the impact of climate shocks on the economy, while climate damage to companies makes the banking sector more vulnerable (Lamperti et al., 2021). The economic impact of climate-induced disasters on various sectors in Sri Lanka underscores the need to consider the diverse impacts of climate change on growth (Weerasekara et al., 2021). These findings demonstrate that climate change poses a serious threat to global economic growth, particularly in vulnerable regions, and effective climate policies are essential to mitigate these impacts.

3. Research Methodology and Data

3.1. Research Model

Building on the research model proposed by Malik et al. (2020), the authors suggest the following research model:

$$GDP_{it} = \alpha_0 + \beta_1 SLR_{it} + \beta_2 CO2_{it} + \beta_3 PU_{it} + \beta_4 FDI_{it} + \beta_5 OPN_{it} + \beta_5 CPI_{it} + \varepsilon$$

Where:

Dependent variable GDPit: represents the total output of country i at time t.

Independent variables: SLR_{it}; $CO2_{it}$; PU_{it}; FDI_{it}; OPN_{it}; CPI_{it} are factors influencing the total output of country i at time t.

α: is the intercept coefficient; β': are regression coefficients; ε: represents the corresponding error term.

The detailed descriptions of the variables are provided in Table 1.

Table 1. Variables description

Name	Description	Hypothesis	Expected	Data Source	References
Dependent variable					
GDP	National GDP			World Development Indicators (WDI)	Hamurcu (2023)
Independent variables					
SLR	Average sea level rise over the year	H_1	-	National Oceanic and Atmospheric Administration (NOAA)	Nováčková & Tol (2018), Asuncion & Lee (2017), Hallegatte (2012)

Name	Description	Hypothesis	Expected	Data Source	References
CO2	CO2 emissions	H_2	-	World Development Indicators (WDI)	Hamurcu (2023), Souvannasouk et al. (2021), Rehman et al. (2021), Alvarez-Herranz (2017), Pycroft et al. (2015), Grossman and Kreuger (1991),
PU	Total pesticide usage	H_3	-	Food and Agriculture Organization (FAO)	Patil Shreya & Patil Rahul (2022), Hedlund, (2018)
Control variables					
FDI	Foreign direct investment inflows into ASEAN countries	H_4	+	World Development Indicators (WDI)	Hamurcu (2023)
OPN	Trade openness	H_5	+	World Development Indicators (WDI)	Leitão et al. (2020)
CPI	Institutional stability	H_6	+	World Development Indicators (WDI)	Nair et al.(2020)

3.2. Research Methodology and Data

The study collected and utilized data from 10 ASEAN member countries, including Indonesia, Malaysia, the Philippines, Singapore, Thailand, Brunei, Vietnam, Laos, Myanmar, and Cambodia, for the period 1990–2018 (28 years). The data sources included the World Development Indicators (WDI), the National Oceanic and Atmospheric Administration (NOAA), and the and the Food and Agriculture Organization (FAO) (Table 1).

Most previous studies have used conventional estimation methods on panel data, including the Pooled regression model (Ashraf, 2020), Fixed effects model (Liu et al., 2020), and Random effects model (Al-Awadhi et al., 2020). Commonly used for panel data, these basic methods are appropriate if the regression assumptions remain intact. However, all three research models suffer from autocorrelation and heteroscedasticity issues, rendering these estimation methods unreliable. In this case, the Feasible Generalized Least Squares (FGLS) method would be a more appropriate choice (Wooldridge, 2010) to ensure unbiased and efficient estimation results (Beck & Katz, 1995; Hoechle, 2007). Therefore, the FGLS method will be used to estimate the research model assessing the impact of provincial public expenditure on economic growth at the local level in the context of the COVID-19 pandemic.

4. Research Results

4.1. Statistical results

The study utilized Stata 17.0 software to analyze the descriptive statistics of independent and dependent variables as presented in Table 2.

Table 2. Descriptive statistics of research variables (1990-2018)

Indicator	Unit	Average	Minimum	Maximum	Standard Deviation	VIF
Total national output	Billion US$	1,285.88	0.87	26,487.85	4,165.90	
Sea Level Rise	Millimeters	10.26	-40.19	57.50	27.28	1.14
CO2 Emissions	1000 t	895.60	0.51	14,400.00	2,749.02	8.28
Total Pesticide Usage	1000 t	59.14	0.00	526.55	107.72	4.16
Foreign Direct Investment	Billion US$	31.19	-4.55	631.31	102.68	5.64
Trade Openness	%	109.27	0.00	437.33	91.43	2.15
Institutional Stability	Points	0.04	-1.63	2.47	0.85	1.02

The sample statistical results of the 11 ASEAN countries during the period from 1990 to 2018 (Table 2) indicate that the average GDP is $1,285.88 billion USD per country per year, with a significant disparity among countries across years, ranging from a high of $26,487.85 billion USD to a low of $0.87 billion USD. Economic development correlates with climate change, as evidenced by the annual sea level rise, increasing CO2 emissions, and rising pesticide usage. The statistical results show that the average sea level rise is 10.26 mm per year, with the highest increase occurring in 2013 at 57.5 mm; CO2 emissions have reached an average of 895.60 thousand tons with significant variation among countries annually, ranging from a low of 0.51 thousand tons to a high of 14,400.00 thousand tons. The average total pesticide usage per country is 59.14 thousand tons per year, with considerable variation among countries across years, ranging from 0 to 526.55 thousand tons per year.

The results (Table 2) demonstrate that the correlation coefficients between variables are relatively small, and the variance inflation factors (VIF) for all model components are very low (VIF < 10), indicating no serious multicollinearity issues in the model according to Gujarati (2012).

4.2. Regression results and tests

Table 3. Regression results

Dependent variable : Total national output (GDP)	Regression model			
Independent variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Sea Level Rise (SLR)	-0.0425**	-0.0181	-0.0187	-0.0106
	[-1.97]	[-0.86]	[-0.88]	[-1.06]
CO2 Emissions (CO2)	-0.0603***	0.0878***	0.0339	-0.0583***
	[-6.03]	[3.36]	[1.60]	[-5.12]
Total Pesticide Usage (PU)	-0.00096	0.182***	0.145***	0.0767***
	[-0.06]	[5.61]	[4.82]	[3.56]
Foreign Direct Investment in ASEAN (FDI)	0.0561***	0.0528***	0.0555***	0.00868**
	[6.62]	[6.61]	[7.33]	[2.35]

Dependent variable : Total national output (GDP)	Regression model			
Independent variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Trade Openness (OPN)	0.873***	0.777***	0.772***	1.002***
	[31.18]	[13.99]	[17.44]	[51.55]
Institutional Stability (CPI)	0.166***	0.159***	0.172***	0.0447***
	[7.62]	[7.46]	[8.22]	[4.00]
Constant	-4.871***	-5.746***	-5.127***	-6.473***
Model Fit	F(6. 312)	F(6.302)	Wald chi2(6)	Wald chi2(6)
Stat. F/ Wald chi2	1672.07***	273.50***	2112.61***	8104.32***
Controls				
Heteroscedasticity	No	No	No	Yes
Serial Correlation	No	No	No	Yes
Model Selection				
Fixed Effects Test				
(Wald test) F(10, 302)	19.21***			
Hausman Test				
(Hausman test) (chi2(6))			22.06***	
Heteroscedasticity Test				
chibar2(11)		99.29***		
Serial Correlation Test				
Pesaran's test		10.026***		

Note: *Symbols ***, **, and * represent significance levels of 1%, 5%, and 10% respectively.*

t-statistics in brackets [ ]

Model 1: Pooled Model; Model 2: Fixed Effects Model (FEM); Model 3: Random Effects Model (REM); Model 4: Feasible Generalized Least Squares (FGLS) regression.

The results in Table 4 indicate that all three models, POOL, FEM, and REM, have F and Wald statistics with Prob values < α=5%, so all are considered appropriate.

Choosing OLS or FEM: The Wald test results (Table 4) show Prob > F = 0.0000 (< α=5%) with F(10, 302) = 11.19, indicating at the 5% significance level, there is sufficient evidence to demonstrate characteristic differences among companies in the research model. The FEM model is chosen.

Choosing FEM or REM: The Hausman test results show Prob>chi2 = 0.0012 smaller than α=5%, with chi2(6) = 22.06, providing sufficient evidence to assert that the FEM model is more appropriate than the REM model for the research data. Thus, the FEM model will be used for further analysis.

From the test results in Table 3, the Modified Wald test with chi2(11) = 99.29 (Prob > chi2 = 0.000 smaller than 1%) and the Pesaran test with Pr = 0.000 < 1%, indicate that the FEM model exhibits heteroskedasticity and cross-sectional dependence (dependence between cross-units). This reduces the efficiency of the

FEM model. Under the conditions where the assumptions of constant error variance and independence between cross-units are violated, the Feasible Generalized Least Squares (FGLS) estimation method is the appropriate choice to ensure unbiased and efficient estimation results (Beck & Katz, 1995; Hoechle, 2007). The final model estimation results are shown in Table 3 (Model 4).

4.3. Discuss the regression results

According to the regression results of the FEM model adjusted by the FGLS method, hypothesis H1 is not accepted as it does not achieve the required level of statistical significance (Table 4). This implies that the variables Sea Level Rise (SLR) do not have a significant impact on the Gross Domestic Product (GDP).

Table 4. Summary of expected results and statistical significance levels

Variables	Hypothesis	Expected	Result	Significance	Hypothesis Test
Sea Level Rise (SLR)	H1	-	-	None	Not accepted
CO2 Emissions (CO2)	H2	-	-	1%	Accepted
Total Pesticide Usage (PU)	H3	-	+	1%	Accepted
Foreign Direct Investment (FDI)	H4	+	+	5%	Accepted
Trade Openness (OPN)	H5	+	+	1%	Accepted
Institutional Stability (CPI)	H6	+	+	1%	Accepted

Hypotheses H2, H3, H4, H5, and H6 are accepted (Table 4). This means that the variables Carbon Dioxide Emissions (CO2), Pesticide Usage (PU), Foreign Direct Investment (FDI), Trade Openness (OPN), and Institutional Stability (CPI) have a significant impact on the Gross Domestic Product (GDP).

(1) Impact of Carbon Dioxide Emissions

The research results show that carbon dioxide emissions have statistical significance and a negative impact on growth in ASEAN countries. This result is consistent with the studies of Grossman and Kreuger (1991); Alvarez-Herranz (2017); Hamurcu (2023); Pycroft et al. (2015); Souvannasouk et al. (2021); Abidoyean & Odusola (2015), and it also aligns with the Environmental Kuznets Curve (EKC) theory. This finding is also consistent with the practical situation in ASEAN countries.

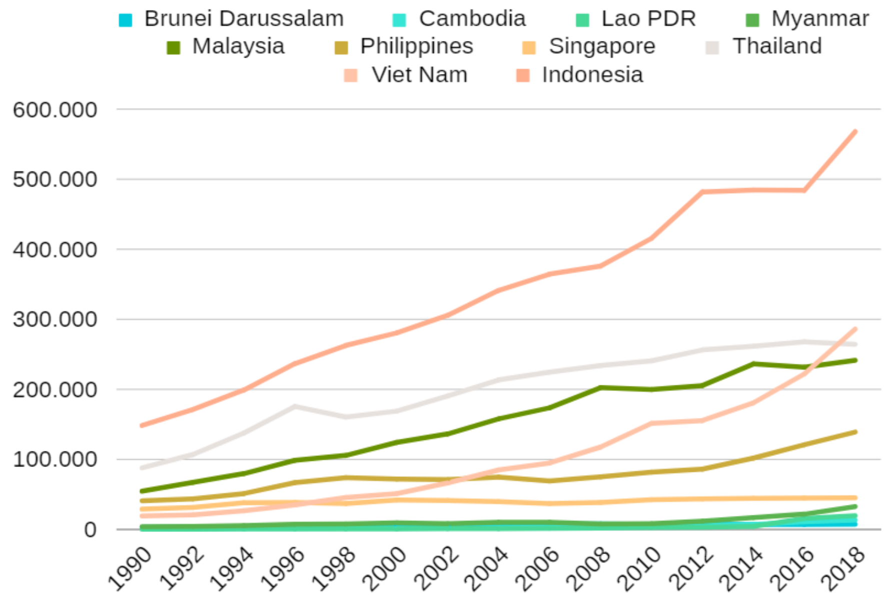

Figure 1. Dynamics of CO2 emissions in ASEAN countries

As shown in Figure 1, from 1990 to 2018, greenhouse gas emissions in the Southeast Asian region have undergone steady growth, with approximately 90% of the total greenhouse gas emissions in the ASEAN bloc coming from five countries: Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. Among these, Indonesia stands out as the country with the largest CO2 emissions in the Asia-Pacific region, with CO2 emissions increasing from 148 million tons to 568 million tons, nearly tripling since 1990. Other countries such as Thailand, Vietnam, the Philippines, and Malaysia have also recorded steady and stable growth in CO2 emissions over the years. According to theory and research results, CO2 levels are inversely related to economic growth, following a U-shaped pattern. ASEAN countries are experiencing excessive CO2 emissions, leading to negative impacts on economic growth, human health, and the environment.

(2) Impact of Pesticide Usage in Agriculture

The total pesticide usage in agriculture (PU) is statistically significant and positively impacts economic growth in ASEAN countries. Currently, ASEAN countries have strengths in agriculture, with agricultural products from ASEAN countries ranking among the world's top exports. Therefore, agricultural revenue significantly contributes to GDP, and pesticide usage in agriculture in ASEAN countries is within permissible levels to control pests and diseases, promote crop growth, and achieve high productivity. Hence, the test results are consistent with the reality in ASEAN countries.

According to the report, in Indonesia, the increase in pesticide usage is primarily due to the use of herbicides and fungicides on real estate crops. About 40% of total pesticide usage in the Philippines is attributed to protecting rice crops and the increased use of less toxic and more effective insecticides. In Thailand, important crops are often attacked by pests such as brown planthoppers and stem borers on rice, locusts and stem borers on corn, diamondback moths on corn, fruit borers, and bollworms. Therefore, in Thailand, approximately 60% of total pesticide consumption is used to protect crops. Vietnam imports about 100-120 tons of plant protection chemicals.

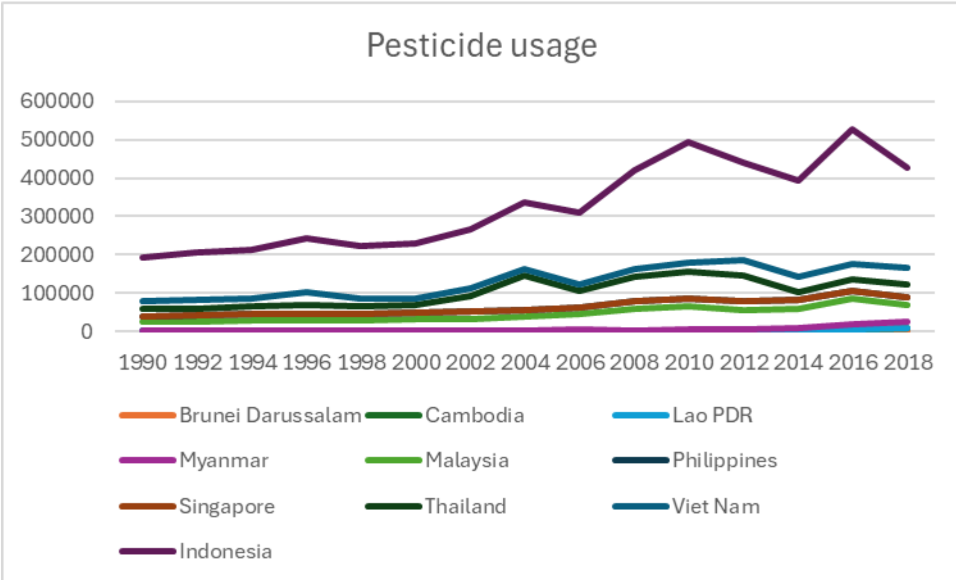

Figure 2. Dynamics of Pesticide Usage in Agriculture in ASEAN Countries

(3) Impact of Sea Level Rise

This research result is not sufficient evidence to conclude that sea level rise affects economic growth in ASEAN countries, consistent with the findings of Nováčková & Tol (2018), which suggest no significant stable impact of sea level rise on economic growth. In contrast, studies by Hallegatte (2012) and Asuncion & Lee (2017) emphasize the significant economic impacts of sea level rise, including land and infrastructure loss, increased costs from extreme events, and the need for coastal protection. Desmet et al. (2021) discussed the economic impact of coastal flooding due to sea level rise, estimating that under the intermediate greenhouse gas concentration pathway, global GDP would decrease by an average of 0.19% in current value terms, with welfare reduced by 0.24%.

5. Conclusion and recommendations

5.1. Conclusion

The study was conducted to analyze the impact of climate change on the economic growth of ASEAN countries during the period 1990-2018. The FGLS method was appropriately used in this study. The main findings from this research are sufficient to assert that climate change impacts the economic growth of ASEAN countries during the period 1990-2018. Specifically, CO_2 emissions have a negative impact, while pesticide usage has a positive impact on the economic growth of ASEAN countries during the period 1990-2018. The study did not find evidence to support the claim that climate change, as manifested through sea level rise, affects economic growth in ASEAN countries during the period 1990-2018. Additionally, control variables such as FDI inflows, trade openness, and institutional stability are important factors that positively impact the economic growth of ASEAN countries.

5.2. Recommendations

Limiting CO_2 emissions for ASEAN countries

As of December 2023, according to the World Bank, 39 countries have implemented carbon taxes, including the UK, France, Sweden, Norway, Finland, Japan, India, and Singapore. The design and implementation of carbon taxes in each country vary due to differences in economic and social conditions, institutional frameworks, and policies. However, they all adhere to certain principles:

(i) Carbon taxes can be applied independently or as supplementary taxes to existing taxes within the national tax system to regulate greenhouse gas emissions.

(ii) The entities subject to carbon taxation are fossil fuels or greenhouse gases that cause the greenhouse effect.

(iii) Carbon tax payers are entities involved in importing, extracting fossil fuels, or directly emitting greenhouse gases.

(iv) The tax rate is determined by an absolute amount per unit of CO2 emissions released into the environment.

Based on the experiences of countries that have implemented carbon taxes, the research group recommends that ASEAN countries consider implementing carbon taxes in the near future:

Firstly, thorough research and assessment of the current situation should be conducted to minimize any negative impacts on society and the current economy when considering the implementation of carbon taxes.

Secondly, consider the timing of implementing carbon taxes to allow opportunities for businesses to innovate technologies to adapt to a new type of tax. The testing process should ensure the stability of macroeconomic goals, avoid conflicts between goals in the context of global economic fluctuations, and be sensitive to trends and actions of other countries worldwide in applying carbon taxes.

Thirdly, consider integrating carbon taxes into existing environmental protection taxes or introducing carbon taxes as an independent tax within the tax system, alongside environmental protection taxes.

Smart pesticide use in agriculture

The research results show that the use of pesticides has a positive impact on economic growth. Pesticides benefit humans by protecting food production, preventing diseases, and controlling weeds. However, indiscriminate pesticide use can have negative impacts on the environment, human health, and social costs. Improper pesticide use can lead to inefficiencies in production, reduce farm profits, and cause external environmental and human health impacts. Additionally, pesticide abuse can lead to loss and destruction of biodiversity, which is crucial for human existence. The use of biopesticides is recommended to achieve higher agricultural productivity with minimal impact on ecosystems. Therefore, policymakers must consider economic factors affecting pesticide use and implement ecological measures to maximize positive effects and promote sustainable economic development activities.

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