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# *The Effects Of Carbon Emissions, Renewable Energy Consumption, And Foreign Direct Investment On Economic Growth In The Asean-5: A Panel Data Analysis With Global Crisis Controls*

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**Abstract: This study examines the effects of carbon emissions, renewable energy consumption, and foreign direct investment (FDI) on the economic growth of five ASEAN countries—Indonesia, Malaysia, Thailand, Singapore, and the Philippines—during the period 1990–2021. The analysis employs a balanced panel dataset comprising 160 observations and estimates panel data regression model. Model selection was conducted using the Chow test and the Breusch–Pagan Lagrange Multiplier (LM) test. To account for the effects of major external shocks, three dummy variables representing the 1998 Asian Financial Crisis, the 2008–2009 Global Financial Crisis, and the 2020 COVID-19 pandemic were incorporated into the model. The Chow test ($F = 1.809$, $p = 0.130$) and the LM test ($\chi^2 = 0.924$, $p = 0.336$) indicate that the Common Effect Model (CEM), or Pooled OLS, is the most appropriate specification. Estimation using robust standard errors reveals that carbon emissions, renewable energy consumption, and FDI have no statistically significant effects on economic growth ($p > 0.05$). In contrast, all three crisis dummy variables exert negative and statistically significant effects ($p < 0.01$), with the 1998 Asian Financial Crisis and the COVID-19 pandemic producing the largest declines in economic growth. The model explains 55.75% of the variation in economic growth ($R^2 = 0.5575$). These findings suggest that economic growth in the ASEAN-5 is driven more by global macroeconomic shocks than by carbon emissions, renewable energy consumption, or FDI over the study period.**

**Keywords: Economic Growth; Carbon Emissions; Renewable Energy Consumption; Foreign Direct Investment; ASEAN-5.**

## 1. INTRODUCTION

Economic growth is one of the primary indicators of a country's development success. In Southeast Asia, the ASEAN-5 countries Indonesia, Malaysia, Thailand, Singapore, and the Philippines have exhibited significant economic growth dynamics over the past three decades, driven by trade openness, foreign investment inflows, and regional economic integration (Tran et al., 2024). Nevertheless, the region has also experienced several sharp contraction periods due to exogenous global economic crises, underscoring the vulnerability of the ASEAN-5 economies to external shocks amid their deep interconnection with the world economy (Pata et al., 2023; Wang et al., 2022).

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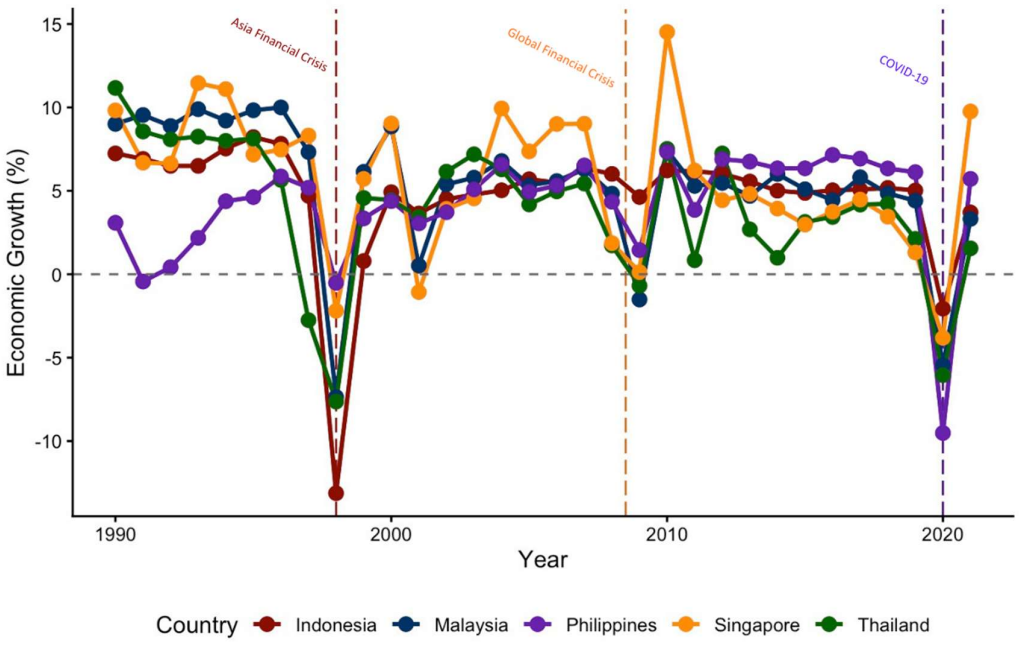


Figure 1. Economic Growth of ASEAN – 5 Countries, 1990-2021

Source: Created by authors, data from World Bank (2026).

As shown in Figure 1, all five countries experienced sharp contractions simultaneously in 1998, 2009, and 2020, indicating that these shocks were external and systemic in nature rather than merely reflecting each country's domestic fundamentals. It is worth noting that the ASEAN region as a whole remains one of the world's leading investment destinations, with Foreign Direct Investment (FDI) inflows continuing to rise and positioning ASEAN as the largest FDI recipient among developing regions (The ASEAN Secretariat & United Nations Trade and Development, 2024). On the other hand, environmental sustainability has become an increasingly pressing issue that needs to be integrated into economic growth analysis, given that intensive economic activity in this region is often correlated with increased fossil energy consumption and carbon emissions (Debone et al., 2021; Tran et al., 2024).

A growing body of literature reveals a complex relationship between environmental variables such as carbon emissions and renewable energy consumption and economic growth. Studies grounded in the Environmental Kuznets Curve (EKC) framework in ASEAN countries have found that urbanization and economic growth significantly increase carbon emissions (Bölük & Mert, 2014). On the other hand, renewable energy consumption has the potential to curb carbon emissions and support environmental quality, although its effect on long-term economic growth remains heterogeneous across countries (Li et al., 2023).

Beyond economic growth itself, the environmental dimension is an important consideration in the ASEAN-5 context. Per capita $CO_2$ emissions in the region have generally continued to rise since 1990, in line with the expansion of economic activity and industrialization, with income growth and transport energy consumption proving to be key determinants of rising emissions in the ASEAN-5 countries (Chandran & Tang, 2013; Tran et al., 2024). Nevertheless, this pattern has begun to show signs of shifting since the 2010s, marked by an acceleration in the growth of renewable energy's share of consumption in several ASEAN countries (Tran et al., 2024). This condition suggests that an energy transition is beginning to take place in the region, although it

has not yet been strong enough to produce an absolute decline in carbon emissions a pattern consistent with EKC literature findings that the relationship between economic growth and environmental quality in developing countries tends to be non-linear and requires a long period before reaching a turning point of declining emissions (Bölük & Mert, 2014; Chandran & Tang, 2013).

Beyond the environmental dimension, Foreign Direct Investment (FDI) is also frequently regarded as a catalyst for economic growth through technology transfer, job creation, and enhanced domestic production capacity (Emako et al., 2022; Phommouny et al., 2024). Interestingly, the relationship between FDI and the environmental issues discussed above is also intertwined and does not always move in the same direction: some studies find that FDI in the ASEAN-5 region is in fact negatively associated with carbon emissions across most of the data distribution, indicating a pollution halo effect (Zhu et al., 2016), whereas other studies on ASEAN countries with the highest FDI realization find mixed results across countries positive in Singapore and Indonesia, but negative in Vietnam in the short run (Febriyanto et al., 2024). This inconsistency in findings across studies (Febriyanto et al., 2024; Zhu et al., 2016) reinforces the argument that the relationship between FDI and both economic growth and the environment remains far from conclusive in the empirical literature, as its effectiveness heavily depends on domestic absorptive capacity, institutional quality, and each country's degree of economic openness (Emako et al., 2022).

This instability in the relationships among variables is precisely the reason why crisis periods need to be treated specifically in this study. The 1990–2021 observation period encompasses three major global crisis episodes with far-reaching impacts the 1997–1998 Asian Financial Crisis, the 2008–2009 Global Financial Crisis, and the 2020 COVID-19 Pandemic each of which caused sharp economic contractions across nearly all ASEAN-5 countries, regardless of their individual economic fundamentals. Empirical literature further shows that financial crises and economic openness to global markets can significantly alter the direction and strength of the relationship between energy-environment variables and other macroeconomic variables, such that the patterns observed before and after a crisis can differ substantially (Pata et al., 2023; Wang et al., 2022). Consequently, without controlling for the influence of these crisis periods, a regression model risks producing biased estimates, as extreme variation in the dependent variable would be incorrectly attributed to the main explanatory variables. Based on this background, the present study aims to analyze the effects of carbon emissions, renewable energy consumption, and FDI on economic growth in the ASEAN-5 countries, incorporating a control variable in the form of a global crisis period dummy.

## 2. LITERATURE REVIEW

### *2.1* Economic Growth and Carbon Emissions

The relationship between economic growth and carbon emissions has been widely examined through the Environmental Kuznets Curve (EKC) framework, which argues that environmental degradation initially increases during the early stages of economic development but declines after a certain income threshold is reached due to structural economic transformation and the adoption of cleaner technologies. Othman et al. (2024) found that the EKC hypothesis holds for ASEAN countries using the Pooled Mean Group (PMG) approach, indicating an inverted U-shaped relationship between economic growth and greenhouse gas emissions. Consistent with these findings, Ponce & Manlangit (2023) employing panel data for ASEAN countries over the period 1960–2021, identified a per capita income turning point of approximately USD 4,808**,** beyond which $CO_2$ emissions began to decouple from income growth. However, Ansari (2022) reported that the validity of the EKC hypothesis in the ASEAN region depends heavily on the environmental indicator employed. The inverted U-shaped relationship was confirmed when using the ecological footprint as the environmental indicator but was not supported when $CO_2$ emissions were used directly. These mixed findings suggest that the relationship between carbon emissions and economic growth in ASEAN remains inconclusive and is highly sensitive to the estimation methods and environmental indicators applied.

### *2.2* Renewable Energy Consumption and Economic Growth

Renewable energy consumption is widely regarded as a key strategy for mitigating climate change while simultaneously supporting long-term economic growth. (Rusiadi et al., 2024) found that renewable energy, together with natural resources and foreign direct investment (FDI), has a significant positive effect on economic growth in ASEAN countries using both static and dynamic panel data approaches. Similarly, Carandang et al. (2023) reported a significant positive correlation between renewable

energy consumption and gross domestic product (GDP) in the ASEAN-5 economies using the Pooled Ordinary Least Squares (Pooled OLS) method. However, Tran et al. (2024) in their study examining the energy–growth–emissions nexus in ASEAN, found that total energy consumption exerts a more significant influence on economic growth than renewable energy consumption alone. This finding suggests that the contribution of renewable energy to economic growth in the region remains at a developmental stage and has not yet become a dominant driver of economic performance.

### *2.3* Foreign Direct Investment and Economic Growth

Theoretically, foreign direct investment (FDI) promotes economic growth in host countries through technology transfer, improvements in labor productivity, and the creation of linkages with domestic industries, consistent with endogenous growth theory. Huay et al. (2024) employing the Autoregressive Distributed Lag (ARDL) approach for Malaysia over the period 1990–2022, found that FDI has a positive effect on economic growth in both the short and long run. At the regional level, Chizema (2025) analyzed panel data from South and Southeast Asian countries covering 2006–2022 and reported that FDI consistently stimulates economic growth across various model specifications. However, Ductor & Grechyna (2015) in a panel study encompassing 101 countries, found that the aggregate effect of FDI on economic growth is not statistically significant, with its effectiveness depending largely on the host country's level of economic development. These findings suggest that the relationship between FDI and economic growth is conditional rather than automatic, implying that the growth-enhancing effects of FDI depend on country-specific economic conditions and institutional capacity.

### *2.4* Global Crises and Macroeconomic Stability

Global economic crises tend to exert severe but relatively short-term contractionary effects on economic growth, with impacts that are substantially greater than fluctuations driven by changes in fundamental economic factors. The 1997–1998 Asian Financial Crisis triggered a dramatic economic downturn across ASEAN countries. According to the Corporate Finance Institute (2023), nominal GDP per capita declined by 43.2% in Indonesia, 21.2% in Thailand, and 19.0% in Malaysia between 1996 and 1997 as a result of sharp currency depreciations and massive capital outflows. Similarly, the COVID-19 pandemic caused a synchronized economic contraction throughout the ASEAN region. The Asian Development Bank reported that the region's GDP contracted by 4.0% in 2020, compared with 4.4% growth in 2019, with the Philippines and Thailand experiencing the most severe economic downturns (Hapsari & Yang, 2023). These findings reinforce the argument that global economic shocks are systemic in nature and propagate across countries through trade, financial, and market confidence channels, regardless of each country's underlying structural economic conditions.

### *2.5* The Use of Dummy Variables in Panel Data Regression Models

In regression analysis, not all relevant factors can be measured on a quantitative scale. Gujarati & Porter (2009) explain that dummy variables (also referred to as indicator or qualitative variables) are used to quantify categorical attributes or events, such as specific time periods, by assigning a value of 1 to observations belonging to the category of interest and 0 otherwise. In the context of panel data analysis, time dummy variables are specifically employed to capture the effects of events that simultaneously affect all cross-sectional units during a particular period but cannot be explained by the primary explanatory variables included in the model.

The use of crisis dummy variables in economic growth models has been widely adopted in the empirical literature. For example, Cerra & Saxena (2008) incorporated a banking crisis dummy into a dynamic output growth model and found that the effects of financial crises are highly persistent, with output contractions reaching up to 7.5% of GDP. Similarly, Furceri & Mourougane (2012) included a Global Financial Crisis (2008–2009) dummy in a cross-country panel model to isolate the effects of the crisis from those of fiscal policy and other macroeconomic variables. Following this established approach, the present study incorporates crisis dummy variables as control variables to ensure that the estimated coefficients of the main explanatory variables carbon emissions, renewable energy consumption, and foreign direct investment (FDI) are not biased by extreme fluctuations in economic growth resulting from systemic external shocks.

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## 3. RESEARCH METHODS

This study employs a quantitative approach using a causal-comparative research design based on panel data regression. According to Sugiyono (2018), quantitative research is a method grounded in the positivist philosophy, designed to investigate a particular population or sample through the use of research instruments and quantitative/statistical data analysis to test predetermined hypotheses. This approach was selected because the study aims to examine the effects of multiple independent variables on economic growth across countries and over time simultaneously, while controlling for the effects of systemic global shocks, which are commonly analyzed using panel data techniques (Gujarati & Porter, 2009).

This study utilizes secondary data in the form of a balanced panel dataset obtained exclusively from the World Bank's World Development Indicators (WDI) database, and others resources, such as books, journal, article, document, and website. The dataset covers the period from 1990 to 2021 (32 years) for five countries, yielding a total of 160 observations (5 countries × 32 years). Then, sthe study population comprises the member countries of the Association of Southeast Asian Nations (ASEAN). The sample was selected using purposive sampling based on the criterion of complete time-series data availability throughout the observation period. Accordingly, five ASEAN countries—Indonesia, Malaysia, Thailand, Singapore, and the Philippines (ASEAN-5)—were included in the analysis. These countries were selected because they represent the largest economies in the ASEAN region and have complete data available in the World Development Indicators (WDI) database for all variables used in this study.

### *3.1* Operational Definition of Variables

The dependent variable in this study is economic growth (Y), measured as the annual growth rate of Gross Domestic Product (GDP) expressed as a percentage. The independent variables consist of: (1) carbon emissions (X1), measured in million metric tons of $CO_2$; (2) renewable energy consumption (X2), measured as a percentage of total final energy consumption; and (3) Foreign Direct Investment (FDI) (X3), measured as a percentage of GDP. As control variables, this study incorporates three time dummy variables, following the time dummy approach proposed by Gujarati and Porter (2009), to account for major global economic crises: the 1998 Asian Financial Crisis (coded as 1 for 1998 and 0 otherwise), the 2008–2009 Global Financial Crisis (coded as 1 for 2008 and 2009, and 0 otherwise), and the 2020 COVID-19 pandemic (coded as 1 for 2020 and 0 otherwise).

Table 1. Operational Definition of Variables

| Variable | Code | Operational Definition | Unit | Scale |
|---|---|---|---|---|
| Economic Growth | Y | The annual growth rate of Gross Domestic Product (GDP), representing changes in a country's economic performance compared with the previous year. | Annual GDP growth rate (%) | Ratio |
| Carbon Emissions | $X_1$ | The total amount of carbon dioxide ($CO_2$) emissions generated by a country within a given year. | Million metric tons of $CO_2$ | Ratio |
| Renewable Energy Consumption | $X_2$ | The share of energy consumption derived from renewable energy sources relative to total final energy consumption. | Percentage (%) of total final energy consumption | Ratio |
| Foreign Direct Investment (FDI) | $X_3$ | The value of foreign direct investment inflows relative to a country's Gross Domestic Product (GDP). | Percentage (%) of GDP | Ratio |

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| Variable | Code | Operational Definition | Unit | Scale |
|---|---|---|---|---|
| 1998 Asian Financial Crisis Dummy | $D_1$ | A dummy variable indicating the occurrence of the 1998 Asian Financial Crisis. | 1 = 1998; 0 = Otherwise | Nominal (Dummy) |
| 2008–2009 Global Financial Crisis Dummy | $D_2$ | A dummy variable indicating the occurrence of the 2008–2009 Global Financial Crisis. | 1 = 2008–2009; 0 = Otherwise | Nominal (Dummy) |
| COVID-19 Pandemic Dummy | $D_3$ | A dummy variable indicating the initial economic impact of the COVID-19 pandemic. | 1 = 2020; 0 = Otherwise | Nominal (Dummy) |

### *3.2* Model and Estimation Method

This study employs a panel data regression model with the following specification:

$$Y_{it} = \beta_0 + \beta_1 X1_{it} + \beta_2 X2_{it} + \beta_3 X3_{it} + \beta_4 Crisis1998_t + \beta_5 Crisis2008_t + \beta_6 Crisis2020_t + \varepsilon_{it}$$

where $i$ denotes the country and $t$ denotes the year. The estimation model was selected through a sequential two-stage testing procedure. First, the Chow test (F-test) was conducted to compare the Common Effect Model (CEM) and the Fixed Effect Model (FEM). If the Chow test produced a $p$-value $\geq 0.05$, the CEM was considered more appropriate than the FEM. Second, the Breusch–Pagan Lagrange Multiplier (LM) test was performed to compare the CEM and the Random Effect Model (REM). If the LM test yielded a $p$-value $\geq 0.05$, the CEM was selected as the final model. Conversely, if the $p$-value was $< 0.05$, the REM was selected. The selected model was then evaluated using classical assumption tests, including the Breusch–Pagan test for heteroskedasticity, the Breusch–Godfrey test for autocorrelation, and the Variance Inflation Factor (VIF) for multicollinearity. If any assumption violations were detected, the final estimation was performed using robust standard errors based on the Arellano-HC1 estimator. All data analyses were conducted using the R statistical software with the **plm** and **lmtest** packages.

## 4. RESULT

### *4.1* Descriptive Statistics

Table 2 presents the descriptive statistics of the study variables. The average economic growth rate of the ASEAN-5 countries over the study period was 4.78%, with a wide range from -13.13% (Indonesia in 1998) to 14.52%, reflecting the substantial volatility in economic growth observed during certain periods.

Table 2. Descriptive Statistics of the Research Variables (N = 160).

| Variable | N | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Economic Growth (%) | 160 | 4.78 | 3.90 | -13.13 | 14.52 |
| Carbon Emissions (Mt $CO_2$) | 160 | 456.09 | 571.61 | 36.62 | 2905.11 |
| Renewable Energy Consumption (%) | 160 | 22.68 | 17.89 | 0.20 | 59.20 |
| Foreign Direct Investment (FDI) (% of GDP) | 160 | 5.46 | 7.12 | -2.76 | 32.60 |

### *4.2* Estimation Model Selection

The estimation model was selected through a sequential two-stage testing procedure, consisting of the Chow test and the Breusch–Pagan Lagrange Multiplier (LM) test, as presented in Table 3.

Table 3. Estimation Model Selection Test Results (Chow Test and Breusch–Pagan Lagrange Multiplier Test)

| Test | Comparison | Statistic | p-value | Decision |
|---|---|---|---|---|
| Chow Test (F-test) | CEM vs FEM | F = 1.809 | 0.130 | CEM is preferred over FEM |
| Uji LM Breusch-Pagan | CEM vs REM | $\chi^2 = 0.924$ | 0.336 | CEM is selected |

In the first stage, the Chow test produced an F-statistic of 1.809 with a *p*-value of 0.130 (≥ 0.05), indicating that the null hypothesis could not be rejected. This result suggests that there are no significant individual effects across countries; therefore, the Common Effect Model (CEM) is preferred to the Fixed Effect Model (FEM). In the second stage, the Breusch–Pagan Lagrange Multiplier (LM) test, which compares the CEM and the Random Effect Model (REM), yielded a $\chi^2$ statistic of 0.924 with a *p*-value of 0.336 (≥ 0.05). Consequently, the null hypothesis could not be rejected, indicating that there are no significant random effects across countries. Therefore, the CEM is preferred to the REM. Based on the results of these two model selection tests, the Common Effect Model (CEM), also referred to as the pooled ordinary least squares (Pooled OLS) model, was selected as the final estimation model for this study.

### *4.3* Classical Assumption Tests

Before interpreting the estimation results, the classical assumptions of the Common Effect Model (CEM) were examined, as presented in Table 4.

Table 4. Classical Assumption Test Results for the Common Effect Model (CEM)

| Test | Test Statistic | p-value | Conclusion |
|---|---|---|---|
| Heteroskedastisitas (Breusch-Pagan) | BP = 16.027 | 0.014** | Heteroskedasticity detected |
| Autokorelasi (Breusch-Godfrey) | $\chi^2 = 63.944$ | 0.001*** | Autocorrelation detected |
| Multikolinearitas (VIF maks.) | VIF = 2.03 | — | No multicollinearity detected |

The heteroskedasticity test using the Breusch–Pagan test produced a BP statistic of 16.027 with a *p*-value of 0.014 (< 0.05), indicating the presence of heteroskedasticity in the model. In addition, the Breusch–Godfrey test for autocorrelation yielded a $\chi^2$ statistic of 63.944 with a *p*-value of 0.001 (< 0.05), suggesting the presence of autocorrelation in the idiosyncratic errors, which is commonly observed in panel datasets with a relatively long time dimension (32 years). Meanwhile, no evidence of multicollinearity was detected, as the maximum Variance Inflation Factor (VIF) was 2.03, well below the commonly accepted threshold of 10. To simultaneously address both heteroskedasticity and autocorrelation, the final model was estimated using robust standard errors based on the Arellano-HC1 estimator. This approach ensures that the statistical inference remains valid and reliable despite violations of the classical error assumptions.

### *4.4* Common Effect Model (CEM) Estimation Results

Table 5 presents the final estimation results of the Common Effect Model (CEM) using robust standard errors that account for both heteroskedasticity and autocorrelation (Arellano-HC1 estimator). Overall, the CEM is statistically significant,

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with an F-statistic of 32.131 (df = 6, 153) and a *p*-value < 0.001. This result indicates that the explanatory variables included in the model are jointly significant in explaining economic growth across the ASEAN-5 countries.

Table 5. Common Effect Model (CEM) Estimation Results with Robust Standard Errors

| Variable | Coefficient | Std. Error | t-stat | p-value |
|---|---|---|---|---|
| Constant | 5.7895 | 0.6346 | 9.123 | 0.000*** |
| Carbon Emissions (X1) | 0.0001 | 0.0003 | 0.581 | 0.562 |
| Renewable Energy Consumption (X2) | -0.0180 | 0.0205 | -0.879 | 0.381 |
| FDI (X3) | 0.0464 | 0.0431 | 1.076 | 0.284 |
| 1998 Crisis Dummy | -11.7855 | 2.0090 | -5.866 | 0.000*** |
| 2008–09 Crisis Dummy | -3.3184 | 0.9542 | -3.478 | 0.001*** |
| 2020 Crisis Dummy | -11.1621 | 1.0616 | -10.514 | 0.000*** |
| $R^2$ | 0.5575 | — | — | — |
| Adjusted $R^2$ | 0.5402 | — | — | — |
| F-statistic | 32.131 | df (6; 153) | — | 0.000*** |
| Number of Observations (N) | 160 | — | — | — |

*Notes:* $R^2 = 0.5575$; Adjusted $R^2 = 0.5402$; $F(6, 153) = 32.131$; $p < 0.001$; $N = 160$. *** Significant at the 1% level ($\alpha = 0.01$); ** Significant at the 5% level ($\alpha = 0.05$).

$$\text{Growth} = 5.7895 + 0.0001\text{Emission} - 0.018\text{Renewable} + 0.046\text{FDI} - 11.785D1998 - 3.318D2008 - 09 - 11.162D2020$$

The estimation results indicate that the three main explanatory variables—carbon emissions, renewable energy consumption, and foreign direct investment (FDI)—do not have a statistically significant effect on economic growth at the 5% significance level. The coefficient for carbon emissions is 0.0001 ($p = 0.562$), indicating that increases in carbon emissions are not significantly associated with economic growth in the sample. Likewise, the coefficients for renewable energy consumption (-0.0180, $p = 0.381$) and FDI (0.0464, $p = 0.284$) are also statistically insignificant.

In contrast, all three global crisis dummy variables exhibit statistically significant and consistent negative effects on economic growth. The 1998 Crisis dummy has a coefficient of -11.7855 ($p < 0.001$), indicating that, on average, economic growth during 1998 was 11.79 percentage points lower than during non-crisis periods, holding all other variables constant. The 2008–2009 Global Financial Crisis dummy has a coefficient of -3.3184 ($p = 0.001$), suggesting a more moderate but still statistically significant adverse effect. Similarly, the 2020 Crisis dummy (COVID-19 pandemic) has a coefficient of -11.1621 ($p < 0.001$), indicating an economic impact that is nearly as severe as that of the 1998 Asian Financial Crisis. Overall, the model explains 55.75% of the variation in economic growth ($R^2 = 0.5575$), representing a substantial improvement over the model without the

crisis dummy variables, which explained only 4.21% of the variation ($R^2 = 0.0421$). These findings underscore that global crisis periods were the dominant determinants of economic growth fluctuations in the ASEAN-5 countries during the study period, far outweighing the contribution of the fundamental economic factors examined in this analysis.

## 5. DISCUSSION

The insignificant effect of carbon emissions on economic growth suggests that, at the aggregate level of the ASEAN-5 countries, the relationship between economic activity and carbon emissions is not characterized by a simple linear pattern. This is broadly consistent with Ansari (2022), who found that the validity of the Environmental Kuznets Curve in ASEAN is highly sensitive to the environmental indicator used, holding for ecological footprint but not for direct $CO_2$ emissions. Because the present model estimates a linear relationship rather than testing for a non-linear turning point as in the EKC literature, it is plausible that the true relationship is masked by unmodeled curvature and by structural factors such as differences in sectoral composition and energy intensity across countries. Similarly, the insignificant effect of renewable energy consumption is consistent with Tran et al. (2024), who found that total energy consumption, rather than renewable energy specifically, is the dominant driver of growth in ASEAN. This suggests that the energy transition in many ASEAN countries is still at an early stage, meaning that its contribution to economic growth has not yet fully materialized over the observation period.

The insignificant effect of foreign direct investment (FDI) echoes Ductor & Grechyna (2015), who found no significant aggregate FDI–growth relationship across 101 countries and concluded that its effectiveness is conditional upon a country's absorptive capacity and level of economic development. Moreover, the substantial variation in FDI inflows across the ASEAN-5 countries—from an average of 1.27% of GDP in Indonesia to 17.8% of GDP in Singapore—highlights considerable cross-country heterogeneity that a single pooled coefficient may average out rather than reflect a uniform, region-wide relationship, suggesting that interaction effects or other heterogeneous modeling approaches would capture the relationship more accurately.

The most notable finding of this study is the dominant influence of global crises relative to the fundamental economic variables examined, with the 1998 Asian Financial Crisis and the 2020 COVID-19 pandemic producing the largest contractions, compared with a more moderate effect from the 2008–2009 Global Financial Crisis. This ordering is economically intuitive: the 1998 crisis involved simultaneous currency collapse, capital flight, and banking-sector failure concentrated within the region itself, while COVID-19 combined a demand shock with direct mobility and production restrictions, both more severe transmission channels than the primarily financial-sector contagion of 2008–2009, against which ASEAN-5 economies were comparatively better insulated following post-1998 reforms. This pattern is consistent with Cerra & Saxena (2008), who documented highly persistent output losses following financial crises, and with Furceri & Mourougane (2012), who isolated comparable crisis effects in OECD panels. The fact that adding the crisis dummies raised model $R^2$ from 4.21% to 55.75% further confirms that these dummy variables absorb genuine, previously unexplained variance rather than merely improving fit artificially. These findings imply that macroeconomic stabilization policies and global crisis risk mitigation are as important as if not more important than long-term structural policies related to environmental sustainability and investment in maintaining stable economic growth across the ASEAN region.

## 6. CONCLUSION

This study examines the effects of carbon emissions, renewable energy consumption, and foreign direct investment (FDI) on the economic growth of the ASEAN-5 countries over the period 1990–2021 while controlling for the impacts of major global crises, namely the 1998 Asian Financial Crisis, the 2008–2009 Global Financial Crisis, and the 2020 COVID-19 pandemic. Based on the Chow test and the Breusch–Pagan Lagrange Multiplier test, the Common Effect Model (Pooled OLS) was selected as the preferred estimation approach. The estimation results, using standard errors robust to heteroskedasticity and autocorrelation, indicate that carbon emissions, renewable energy consumption, and FDI do not have statistically significant effects on economic growth. In contrast, all three global crisis dummy variables exhibit negative and statistically significant effects, with the 1998 Asian Financial Crisis and the COVID-19 pandemic having the largest impacts. These findings suggest that long-term fluctuations in economic growth among the ASEAN-5 countries are driven primarily by exogenous global macroeconomic shocks rather than by environmental factors or foreign direct investment. From a policy perspective, the results

highlight the importance of strengthening macroeconomic resilience through measures such as maintaining adequate foreign exchange reserves, enhancing fiscal and monetary policy coordination, and reinforcing social safety nets to better withstand future global crises. At the same time, efforts to advance the energy transition and environmental sustainability should remain integral components of the region's long-term development strategy.

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