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Dual-Region Comparative Study on the Impact of Renewable Energy, FDI, CO$_2$ Emissions, and Population on Economic Growth: Evidence from ASEAN and OECD Asia-Pacific

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Abstract

This study analyzes the effect of renewable energy consumption, Foreign Direct Investment (FDI), CO$_2$ emissions per capita, and population on economic growth at two different levels of development, namely ASEAN countries as developing countries and OECD Asia Pacific countries as developed countries. Using panel data for the period 2000–2021, the estimation methods applied are the Fixed Effect Model for ASEAN and the Common Effect Model with robust standard errors for OECD Asia Pacific. The results show structural differences in the relationship between variables in the two groups of countries. Renewable energy has a significant positive effect on economic growth in ASEAN, but a significant negative effect in OECD Asia Pacific, reflecting the green growth effect in developing countries and the transition cost effect in developed countries. FDI significantly drives economic growth in ASEAN, but not significantly in the OECD Asia Pacific. CO$_2$ emissions are insignificant in ASEAN, but have a significant negative impact in the OECD Asia Pacific, which has entered a phase of emission reduction in accordance with the Environmental Kuznets Curve. Population is insignificant in ASEAN, but has a significant negative effect in the OECD Asia Pacific due to demographic pressures. These findings confirm that the effectiveness of energy and investment policies is influenced by the stage of economic development. Therefore, accelerating green investment and a just energy transition are necessary to ensure sustainable growth in both regions.

Keywords: Renewable Energy; FDI; CO$_2$ Emissions; Population; Economic Growth; ASEAN; OECD Asia Pacific.

INTRODUCTION

Economic growth and environmental sustainability have become two increasingly integrated global issues over the past two decades. The transition to a low-carbon economy has prompted countries around the world to increase the use of renewable energy, manage carbon emissions, and optimize Foreign Direct Investment (FDI) as a source of funding for sustainable development. In this context, the Asian region has become one of the epicenters of this change due to its highly diverse economic, demographic, and environmental characteristics. Therefore, studies on the relationship between renewable energy, FDI, CO_2 emissions, population, and economic growth are important for understanding the dynamics of regional development, both in developing and developed countries.

The ASEAN region, which includes Indonesia, Malaysia, Thailand, Vietnam, the Philippines, Laos, Cambodia, and Myanmar, is a group of developing countries with rapidly increasing levels of industrialization. The region's stable economic growth has been accompanied by increased energy consumption and foreign investment needs (ADB, 2020). However, ASEAN countries also face major challenges such as high dependence on fossil fuels, rising CO_2 emissions due to industrialization, high vulnerability to the impacts of climate change, and limited technology and funding for energy transition.

In addition, ASEAN is one of the largest recipients of climate change mitigation investments, including Clean Development Mechanism (CDM) projects during the Kyoto Protocol era (UNFCCC, 2021). These conditions make ASEAN an important laboratory for assessing how renewable energy, FDI, and emissions affect economic growth in developing countries.

Meanwhile, the Asia-Pacific OECD group, consisting of Japan, South Korea, Australia, and New Zealand, was selected because these four countries are developed countries with strong technological and economic institutional capacities, as global leaders in clean energy and low-carbon technology innovation. These countries are also Annex I members of the Kyoto Protocol, which have binding emission reduction obligations (UNFCCC, 2005) and are highly committed to the Paris Agreement through Nationally Determined Contributions (NDCs).
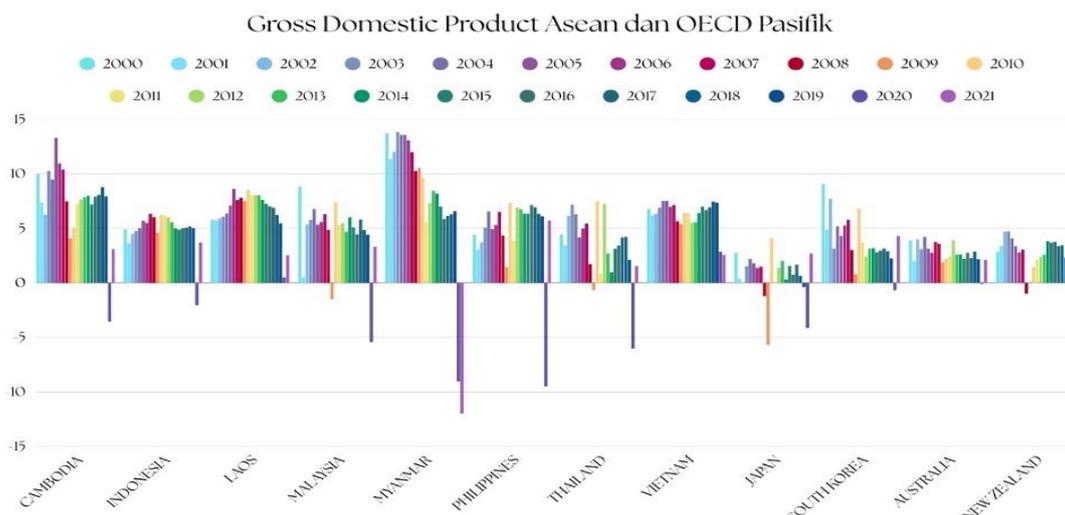

Figure 1. GDP ASEAN and OECD Asia Pacific

The economic growth of ASEAN countries is generally higher but fluctuates, while OECD countries grow more steadily but are approaching economic saturation (IMF, 2022). Compared to ASEAN, Asia-Pacific OECD countries have already entered the decarbonization phase, providing an appropriate benchmark for observing differences in the patterns of economic-environmental variables in developed countries.

METHOD

This study is a quantitative study that aims to analyze the relationship between macroeconomic and environmental variables, particularly the influence of renewable energy, Foreign Direct Investment (FDI), CO_2 emissions, and population on economic growth. The quantitative method was used because this approach allows researchers to test hypotheses empirically using measurable, objective, and statistically analyzable data (Anshori & Iswati, 2009:155).

The quantitative approach was also chosen because it is in line with the research objective to model economic and environmental phenomena through mathematical equations and panel regression models, so that the results obtained can be generalized and support existing empirical theories (Siyoto & Sodik, 2015:19).

Data Sources and Types

The data used is secondary data obtained from the World Development Indicators (WDI) published by the World Bank. The World Bank was chosen because it provides consistent, global-scale data with a long annual coverage that can be compared between countries.

The research period used was 2000–2021, adjusted to the availability of relatively complete data for all variables in both groups of countries.

The sample selection in this study was based on considerations of development characteristics and energy transition dynamics in the Asian region. This study uses two groups of countries, namely ASEAN countries as representatives of developing countries, and OECD Asia-Pacific countries as representatives of developed countries. This separation was made to see the different effects of renewable energy variables, Foreign Direct Investment (FDI), CO_2 emissions, and population on economic growth based on a country's level of economic development.

Justification for Selecting ASEAN Countries

ASEAN was selected because this region consists of countries with continuously developing levels of industrialization, such as Indonesia, Malaysia, Thailand, Vietnam, and the Philippines, as well as countries that are still in the early stages of energy transition, such as Laos, Myanmar, and Cambodia. These countries face the dual challenge of maintaining economic growth while reducing their dependence on fossil fuels (ADB, 2020).

In addition, ASEAN is a region that is highly vulnerable to climate change, both in terms of climate disasters and socio-economic threats related to energy (UN ESCAP, 2022). In the context of development, FDI plays a major role as an engine of growth, particularly in increasing industrial capacity and technology transfer (OECD, 2021). Therefore, ASEAN is an appropriate representation for analyzing the linkages between renewable energy, emissions, and economic growth in developing countries.

Justification for Selecting OECD Asia-Pacific

The OECD Asia-Pacific group consists of Japan, South Korea, Australia, and New Zealand. All are advanced economies with high energy technology capacity, strong institutional systems, and more mature energy transition commitments (IEA, 2023). Japan and South Korea are global leaders in clean technology innovation and green financing, while Australia and New Zealand play an important role in renewable energy production and ambitious emission target commitments (UNFCCC, 2021).

By using the OECD Asia-Pacific as a benchmark for developed countries in the Asian region, this study can identify how differences in economic development levels, industrial structures, and technological readiness affect the relationship between the variables tested.

Table 1. Operational Definition of Variables

Name	Explanation	Unit
Renewable Energy (X1)	Measures the proportion of energy that comes from renewable sources.	% of total final energy consumption
Foreign Direct Investment (X2)	Measured based on the percentage of FDI inflows to GDP.	FDI Inflows, % of GDP
CO_2 Emissions per capita (X3)	Emissions from fossil fuel combustion and cement factories, including carbon emitted during the use of solid, liquid, and gaseous fuels.	Metric tons per capita
Population (X4)	Total population of each country.	Total Population
GDP Growth (Y)	Annual economic growth of a country	GDP Growth, annual %

Analysis Technique

This study uses panel data regression as its analysis technique. The data is divided into two groups, namely ASEAN countries and OECD Asia-Pacific countries, so that the analysis is conducted separately for each group. The panel regression method was chosen because it is able to capture data variations between countries (cross-section) and over time (time series) during the 2000–2021 period.

In this study, the variables of CO_2 emissions per capita (X3) and total population (X4) were transformed using natural logarithms (ln). This transformation was performed to reduce skewness, stabilize variance, and produce a more meaningful interpretation of the coefficients in the form of semi-elasticity.

Gujarati (2004:646) explains that panel data regression does not fully require classical assumption tests as in cross-section or time series regression, because the panel error structure basically follows certain classical assumptions. However, the model selection stage remains very important so that the estimation results are consistent and efficient.

In general, there are three approaches used in estimating panel data regression, namely the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM).

Common Effect Model (CEM)

CEM, or pooled least squares, assumes that all cross-section units (countries) have the same intercept and slope, without considering individual characteristics. This model ignores differences between countries and over time, making it the simplest model.

Fixed Effect Model (FEM)

The Fixed Effect Model assumes that each country has a different intercept, but the slope of the independent variable is fixed. This model focuses the analysis on differences in individual characteristics (country-specific effects) that are considered constant over the observation period.

Random Effect Model (REM)

The Random Effect Model assumes that differences between countries are reflected in random error components. The intercept for each country is a random effect that represents a larger population (Gujarati, 2004:647). This model is appropriate when individual characteristics are not correlated with the independent variable.

The specifications of the panel model used are:

$$\mathbf{GDP}_{it} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \mathbf{RE}_{it} + \boldsymbol{\beta}_2 \mathbf{FDI}_{it} + \boldsymbol{\beta}_3 \ln(\mathbf{CO2}_{it}) + \boldsymbol{\beta}_4 \ln(\mathbf{POP}_{it}) + \boldsymbol{\varepsilon}_{it}$$
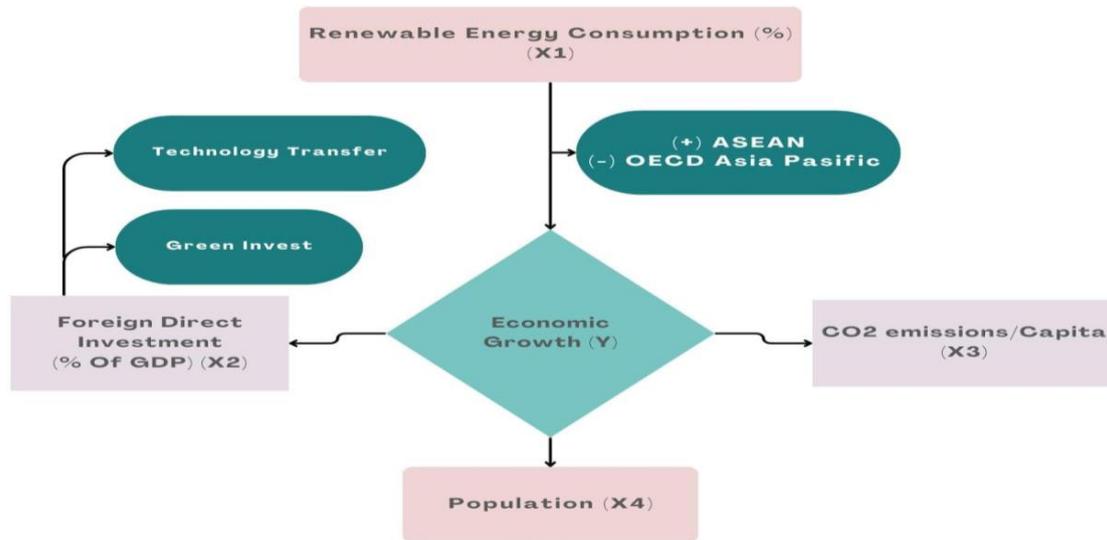
Figure 2. Research Model Flowchart

RESULTS AND DISCUSSION

Statistical Description of Research Variables and Object

The statistical description of the variables includes the mean, lowest observation value, highest observation value, and standard deviation for each variable. The following is the result of the statistical description.

Table 2. Statistical Description of ASEAN Country Group Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
x1	176	41.88182	24.62634	2	85.8
x2	176	3.6084	2.589155	-2.75744	11.15249
x3	176	2.16534	2.231282	0.1599718	8.19206
x4	176	7.50e+07	7.28e+07	5,431,212	2.77e+08
y	176	5.726458	3.684296	-12.01637	13.844

Table 3. Sample of ASEAN and OECD Asia Pacific Countries

No.	Category	Country	Total
1	ASEAN	Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Thailand, Vietnam	8
2	OECD Asia Pacific	Japan, South Korea, Australia, New Zealand	4
Total			12

Table 4. Chow Test Results (CEM vs. FEM)

Category	Prob	Decision
ASEAN	0.0014	FEM
OECD Asia Pacific	0.9427	CEM

Based on the results of the Chow test above, the ASEAN group has a Chow test probability value of <0.05, so the FEM model estimation is selected. Meanwhile, the OECD Asia Pacific group has a Chow test probability value of >0.05 or above 5%, so the CEM model is selected.

Table 5. Hausman Test Results Table 7. Breusch–Pagan LM Test Results

Category	Prob	Decision
ASEAN	0.0014	FEM
OECD Asia Pacific	_	Not performed (CEM selected in Chow test)
Category	Prob	Decision
ASEAN	–	Not required (FEM selected)
OECD Asia Pacific	1.0000	CEM

Based on Table 5, the results of the Hausman test show that the probability value is 0.0014< 0.05, so the FEM model is selected. Meanwhile, in Table 7, the LM test shows a probability value of 1.000>0.05. This means that the most appropriate model to use in estimating the regression equation is the Common Effect Model (CEM).

Table 6. Classical Assumption Test

Category	Multicollinearity	Heteroscedasticity	Model Status
ASEAN (FEM)	Mean VIF = 6.28 (Passed)	Prob = 0.3163 (Passed)	Worth using (FEM + robust SE)
OECD Asia Pacifikc (CEM)	Mean VIF = 5.49 (Passed)	Prob = 0.3600 (Passed)	Worth using (CEM)

The results of the classical assumption test show that the multicollinearity test indicates that the Mean VIF for ASEAN (6.28) and OECD Asia Pacific (5.49) is still below the tolerance limit (<10), so there is no disruptive multicollinearity. The heteroscedasticity test also shows a probability above 0.05, indicating that the model is free of heteroscedasticity. Therefore, the ASEAN FEM and OECD CEM (robust) are declared suitable for use as regression models in this study.

Regression Results

Table 7. Model Statistic ASEAN

Statistic	Result	Interpretation
Prob > F	0.0000	The independent variables jointly have a significant effect on GDP growth.
R-squared (Within)	0.1642	16.42% of the variation in GDP growth is explained by within-country changes over time.
F-test for individual effects	0.0072	Fixed effect model is appropriate compared to pooled OLS.

Table 8. Variable Interpretation ASEAN

Variable	Coefficient	p-value	Interpretation
Renewable Energy Consumption (%)	0.2193	0.000	Positive and statistically significant effect on economic growth.
Foreign Direct Investment (% of GDP)	0.5370	0.001	Positive and statistically significant effect; strongest driver of growth in the model
CO_2 Emissions (tCO_2e per capita)	0.1706	0.768	Not statistically significant.
Total Population	1.38e-08	0.692	Not statistically significant.

Table 9. Model Statistic OECD Asia Pacific

Statistic	Result	Interpretation
Prob > F	0.0000	The independent variables jointly have a significant effect on GDP growth.
R-squared	0.3797	37.97% variation in GDP growth is explained by the model.
Root MSE	1.706	Moderate model error.

Table 10. Variable Interpretation OECD Asia Pasific

Variable	Coefficient	p-value	Interpretation
Renewable Energy Consumption (%)	-0.3408	0.000	Negative and statistically significant impact due to transitional costs of green energy.
Foreign Direct Investment (% of GDP)	0.0989	0.330	Not statistically significant.
CO_2 Emissions (tCO_2e per capita)	-3.0441	0.005	Negative and statistically significant due to strong environmental regulation and structural transformation.
Total Population	-2.7227	0.000	Negative and statistically significant, reflecting aging population and slower labor productivity growth.

Table 11. Direct Comparison of Both Regions

Variable	ASEAN Effect	OECD Asia Pacific Effect
Renewable Energy Consumption (%)	Positive significant	Negative significant
Foreign Direct Investment (% of GDP)	Positive significant	Not significant
CO_2 Emissions (tCO_2e per capita)	Not significant	Negative significant
Total Population	Not significant	Negative significant

Regression Results and Hypothesis Analysis: Comparison between ASEAN and OECD Asia Pacific

Constant (C)

The constant coefficient value in the ASEAN model is –6.8042, while in the OECD Asia Pacific model it is 60.1707 This means that if all independent variables are considered unchanged (zero), economic growth in ASEAN countries will be at a negative level of –6.80 US$, while in OECD Asia Pacific countries it will be at a level of 60.17 US$. The difference in the direction and magnitude of these constants indicates a gap in the basic economic capacity between developing and developed countries.

Renewable Energy (X1)

The renewable energy coefficient in ASEAN is positive and significant ($\beta = 0.2193$; $p < 0.01$), indicating that every 1% increase in renewable energy consumption will increase economic growth by 0.2193 US$ per capita. This finding is in line with the concept of green growth in developing countries, which emphasizes renewable energy as the engine of expansion for new economic sectors (IRENA, 2022). Conversely, in OECD Asia Pacific, the renewable energy coefficient is negative and significant ($\beta = –0.3407$; $p < 0.01$). This means that a 1% increase in renewable energy actually reduces GDP per capita by US$0.3407. This occurs because developed countries are facing transition costs such as the elimination of fossil fuel power plants and the restructuring of the energy industry (OECD, 2021).

Hypothesis H1 is accepted in both groups of countries, but the direction of the effect is different. ASEAN is positive while the OECD is negative due to transition costs.

Foreign Direct Investment – FDI (X2)

In ASEAN countries, the FDI coefficient is significantly positive ($\beta = 0.5370$; $p < 0.01$). This means that a 1% increase in FDI drives a 0.537 US$ increase in economic growth, in line with the theory of technology spillover in developing countries (Alvarado et al., 2019).

However, in OECD Asia Pacific, FDI is not significant ($\beta = 0.0989$; $p = 0.330$). This indicates that domestic capital has dominated the contribution to growth in developed countries, so that FDI is no longer a determining factor.

Hypothesis H2 is accepted for ASEAN, but rejected for OECD.

CO$_2$ emissions per capita (lnCO$_2$)

The CO$_2$ emissions variable in ASEAN is not significant (β = 0.1706; p = 0.768). This means that fluctuations in carbon emissions do not have a direct impact on economic growth, because ASEAN is still in the early stages of the EKC curve, where industrialization still relies on fossil fuels (Grossman & Krueger, 1995).

Conversely, in the Asia-Pacific OECD, CO$_2$ emissions have a significant negative effect (β = –3.0440; p < 0.01). This shows that high emissions actually hinder economic growth due to strict climate regulations and the implementation of carbon pricing.

Hypothesis H3 is accepted for the OECD, but rejected for ASEAN.

Population (lnPOP)

In ASEAN, the population coefficient is insignificant (β = 1.38e-08; p = 0.692), indicating that the demographic bonus has not optimally contributed to the economy due to uneven labor quality.

Meanwhile, in the Asia-Pacific OECD, the population is significantly negative (β = –2.7227; p < 0.01). Population growth actually adds to the economic burden due to the high ratio of elderly people and health costs.

Hypothesis H4 is accepted for the OECD, but rejected for ASEAN.

Technical Comparison of Statistical Models Underlying Interpretation

Strong multicollinearity between renewable energy and CO$_2$ in ASEAN reflects a transition-based energy structure (Stern, 2004). However, because this multicollinearity is inherent and still within safe limits (Mean VIF = 6.28), the variables are retained for the sake of theoretical integrity (Wooldridge, 2016).

In the OECD Asia Pacific, robust standard errors are used to ensure the reliability of statistical significance due to differences in economic structures across countries (Petersen, 2009).

Overview of ASEAN and the OECD Asia Pacific

The Asia Pacific region is characterized by dynamic economic growth and high energy demand. Two strategic clusters within this region are ASEAN countries and OECD Asia Pacific countries such as Japan, South Korea, Australia, and New Zealand. These two clusters are of significant concern in the energy transition issue, particularly due to their contribution to global carbon emissions and their role in achieving the Paris Agreement targets (IEA, 2022).

ASEAN

ASEAN is dominated by developing countries with a high dependence on fossil fuels, particularly coal for electricity generation (Aisyah et al., 2023; ERIA, 2022). Despite its significant renewable energy potential such as solar in Indonesia and the Philippines and hydropower in Vietnam and Laos its utilization remains relatively low due to financing constraints, technological limitations, and an unstable policy framework (IRENA, 2021).

ASEAN's economic growth has been generally positive and progressive, driven by rapid industrialization and urbanization (ADB, 2020). However, this increased industrial mobility has contributed to a significant increase in CO$_2$ emissions, particularly in Indonesia, Vietnam, and Thailand.

Thus, ASEAN is currently in a trade-off phase between economic growth and environmental sustainability, consistent with the dynamics of the Environmental Kuznets Curve, where emissions increase in the early stages of economic development (Sadorsky, 2020).

OECD Asia Pacific

OECD Asia Pacific countries are economically advanced, have high GDP per capita, and have the most developed clean energy technologies in the world (OECD, 2021). Japan and

South Korea are pioneers in clean hydrogen, while Australia and New Zealand have a rapidly increasing renewable energy mix, particularly in wind and solar energy (IEA, 2023).

However, these countries are also among the largest energy consumers and still have a historically high carbon emissions footprint, resulting from their long industrialization history. They are currently accelerating net-zero emission policies through energy innovation and transportation electrification (Bian et al., 2022).

The OECD's leadership role in clean technology has spillover effects for developing countries in the region through technology transfer and green energy investment, including in ASEAN (Li & Leung, 2021).

Discussion

The discussion of the research results confirms that there are fundamental differences in the relationship between renewable energy, FDI, CO_2 emissions, and population on economic growth in ASEAN and OECD Asia Pacific countries. These differences are mainly influenced by the level of economic development, technological capacity, and the readiness of state institutions to transition to a low-carbon economy.

In particular, renewable energy consumption has a positive and significant impact on economic growth in the ASEAN region. This shows that renewable energy investment in developing countries has provided direct economic benefits such as new job creation and energy mix diversification, which reduces dependence on fossil fuel imports. This condition is in line with the green-led growth mechanism, where economic growth is driven by the development of the clean energy sector (Apergis & Payne, 2010; IRENA, 2022).

Meanwhile, the results in the OECD Asia Pacific show a different direction of relationship. Renewable energy has a negative impact on economic growth in the short term. This reflects the transition costs that arise when developed countries have to replace long-established fossil fuel energy infrastructure with low-carbon technologies that are still costly, such as the decommissioning of coal and gas-fired power plants, the construction of new energy networks, and investment in energy storage technologies (OECD, 2021; IEA, 2023). Thus, while ASEAN is in a phase of economic growth supported by the use of renewable energy, the OECD is still in a transitional phase that causes short-term fiscal and economic pressures before the long-term benefits begin to be felt.

In terms of FDI, the results are very consistent with Romer's endogenous growth theory (1990). In ASEAN, FDI has been proven to have a significant positive impact on economic growth, indicating that foreign capital flows to strategic sectors play a vital role in boosting national productivity, spreading technology, and strengthening domestic industrial capacity. These findings also support the study by Alvarado et al. (2019), which states that FDI is the engine of economic strengthening in developing countries.

In contrast, FDI does not show a significant impact in the OECD Asia-Pacific region. This condition can be explained by the strength of domestic financing sources and the high level of technology possessed by developed countries. In addition, FDI in developed countries tends to be dominated by financial transactions such as mergers and acquisitions, which do not always directly increase production output (Borensztein et al., 1998). Thus, the contribution of FDI to economic growth in developed countries is relatively smaller than in developing countries.

The results obtained for the CO_2 emissions variable also provide a picture that is very consistent with the Environmental Kuznets Curve (EKC). In ASEAN, carbon emissions do not have a significant effect on economic growth, indicating that developing countries are still in the scale effect phase, where increased economic activity is still driven by the intensive use of carbon-intensive fossil fuels (Grossman & Krueger, 1995). Conversely, in OECD Asia Pacific, increased carbon emissions have a negative impact on economic growth. Developed countries have entered the technical effect phase, where economic growth goes hand in hand with a reduction in emission intensity through the application of efficient technologies and strict environmental policies such as carbon pricing and net-zero roadmaps (IEA, 2023; Stern, 2004). Thus, there is strong evidence that developed

countries have reached the EKC turning point, while ASEAN is still in the early stages of emission-intensive industrialization.

The population variable then adds a demographic perspective to the results of this study. In ASEAN, population growth does not have a significant impact on the economy because the region's demographic dividend has not been optimally managed due to disparities in labor quality and uneven urbanization (Bloom & Williamson, 1998). Meanwhile, in OECD Asia Pacific, population has a significant negative impact on economic growth, indicating a demographic burden due to an aging population that affects the productivity and fiscal health of countries (OECD, 2022).

Overall, this discussion confirms that economic structure and a country's position in the stages of sustainable development influence how energy, environment, demographics, and investment variables interact with economic growth. ASEAN still enjoys the direct economic benefits of the initial energy transition, while the OECD is facing the costs of low-carbon technology adaptation as a long-term investment. On the other hand, FDI remains key to the growth of developing countries but no longer plays a dominant role in developed countries. The pattern of the emissions-growth relationship shows that economic and emissions decoupling has only occurred in developed countries, while ASEAN still faces challenges in reducing emissions intensity. In terms of demographics, ASEAN's population bonus has not been optimally implemented, in contrast to the OECD, which is experiencing social pressures due to an aging population.

Thus, the results of this study not only confirm the Sustainable Development Theory, but also support the partial applicability of the Environmental Kuznets Curve (EKC), which shows that the stage of development determines the direction of the relationship between economic growth and carbon emissions.

Policy implications

The findings of this study confirm that developing countries such as ASEAN need to accelerate the use of renewable energy and attract more green FDI as key strategies to promote sustainable economic growth. These efforts must be accompanied by improvements in the quality of the workforce and stronger regulations so that the energy transition does not cause social inequality. Meanwhile, developed countries in the OECD Asia-Pacific region need to minimize the costs of energy transition through technological innovation, energy sector efficiency, and fiscal policy support so that the decarbonization process does not hamper economic competitiveness. Overall, each region requires an energy transition approach that is appropriate to its structural conditions and level of economic development in order to achieve optimal green growth objectives.

CONCLUSION

This study shows that there are differences in the impact of sustainable development indicators on economic growth between ASEAN and OECD Asia-Pacific countries during 2000–2021. Renewable energy and FDI have proven to be significant drivers of economic growth in ASEAN, confirming that the region is still in the green growth phase of the energy transition process. Conversely, in the OECD Asia Pacific, renewable energy has a significant negative impact and population pressures economic performance due to high transition costs and population aging. CO_2 emissions have a significant negative impact in OECD countries, indicating that a turning point has been reached in line with the Environmental Kuznets Curve, while in ASEAN this has not yet had a significant impact.

Overall, the analysis confirms that a country's level of development greatly determines the direction of the relationship between energy, the environment, investment, and economic growth. ASEAN is still utilizing renewable energy and FDI as new engines of growth, while the OECD faces the challenge of maintaining stable growth during the transition to a low-carbon economy.

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