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Revisiting EKC Hypothesis Through Income Inequality and Environmental Degradation in ASEAN-5 Countries

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Abstract
This study examines the influence of GDP, corruption, financial development and Trade Openness on environmental degradation within the framework of the Environmental Kuznets Curve (EKC) hypothesis in ASEAN-5 emerging countries. Further, this study investigates the mediating role of income inequality. Utilizing panel data from 1990 to 2022 and the Autoregressive Distributed Lag (ARDL) approach, the findings found support the existence of a U-shaped EKC hypothesis, implying that while economic growth initially degrades environmental quality, it ultimately leads to improvements at higher income levels. The results noted that corruption exacerbates income inequality while trade openness and financial development affect income inequality in the long run. Additionally, the results posit the role of income inequality as a mediator. The results highlight the importance of implementing policies aimed at reducing corruption and income inequality to enhance environmental outcomes thus providing crucial insights for policymakers seeking to balance economic development with environmental sustainability.

Keywords: Corruption Index, Environmental Quality, Kuznets Curve, Income Inequality, Economic Growth

Meninjau Kembali Hipotesis EKC Melalui Ketidaksetaraan Pendapatan dan Degradasi Lingkungan di Negara ASEAN-5

Abstrak
Studi ini meneliti pengaruh korupsi terhadap kualitas lingkungan, dalam kerangka hipotesis Kurva Kuznets Lingkungan (EKC) di negara-negara berkembang ASEAN-5. Studi ini menyelidiki peran mediasi ketimpangan pendapatan dalam hubungan antara korupsi, pertumbuhan ekonomi, keterbukaan perdagangan, perkembangan keuangan, dan kualitas lingkungan. Menggunakan data panel dari tahun 1990 hingga 2022 dan pendekatan Autoregressive Distributed Lag (ARDL), temuan menunjukkan bahwa korupsi memperburuk ketimpangan pendapatan, yang pada gilirannya berdampak negatif pada kualitas lingkungan. Analisis mendukung adanya hipotesis EKC berbentuk U, yang menyiratkan bahwa meskipun pertumbuhan ekonomi awalnya merusak kualitas lingkungan, pada akhirnya hal itu akan membawa perbaikan pada tingkat pendapatan yang lebih tinggi. Selain itu, keterbukaan perdagangan dan perkembangan keuangan secara signifikan mempengaruhi ketimpangan pendapatan dan kualitas lingkungan dalam jangka panjang. Hasilnya menyoroti pentingnya menerapkan kebijakan yang bertujuan mengurangi korupsi dan ketimpangan pendapatan untuk meningkatkan hasil lingkungan di negara-negara berkembang ASEAN.

Kata Kunci: Indeks Korupsi, Kualitas Lingkungan, Kuznet Curve, Income Inequality, Pertumbuhan Ekonomi

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INTRODUCTION

Since the implementation of economic reforms and liberalization, ASEAN has achieved remarkable progress in both economic and social growth. Nevertheless, ASEAN has faced challenges stemming from rampant corruption and detrimental environmental degradation. Corruption, which refers to the misuse of governmental authority for personal gain is a worldwide problem that exhibits varied degrees of severity across different regions (Bhargava, 2005). The CPI (Corruption Perceptions Index) published by Transparency International sheds light on the prevalence of corruption in ASEAN countries, indicating that a significant number of these nations face substantial challenges due to elevated levels of corruption, which impede both economic and social progress. A country's economic development and growth can be hindered if the country has a high level of corruption. If economic growth decreases, it will lead to increased income inequality due to the disruption of the process of reducing poverty levels (Handayani et al., 2022; Hesniati et al., 2019; Mohamad et al., 2020; Houssou and Alinsato, 2023; (Y. Wang et al., 2021)

In the Asia and Pacific region, seventy-one percent of countries scored an average CPI score of 45 and globally the average was 43 out of a possible 100. These low scores indicate that the implementation of the anti-corruption agenda by elected officials remains ineffective. As depicted in Figure 1, the overall average level of corruption in ASEAN countries is at a score of (40), indicating that many of these nations struggle with high corruption levels that hinder economic and social development.

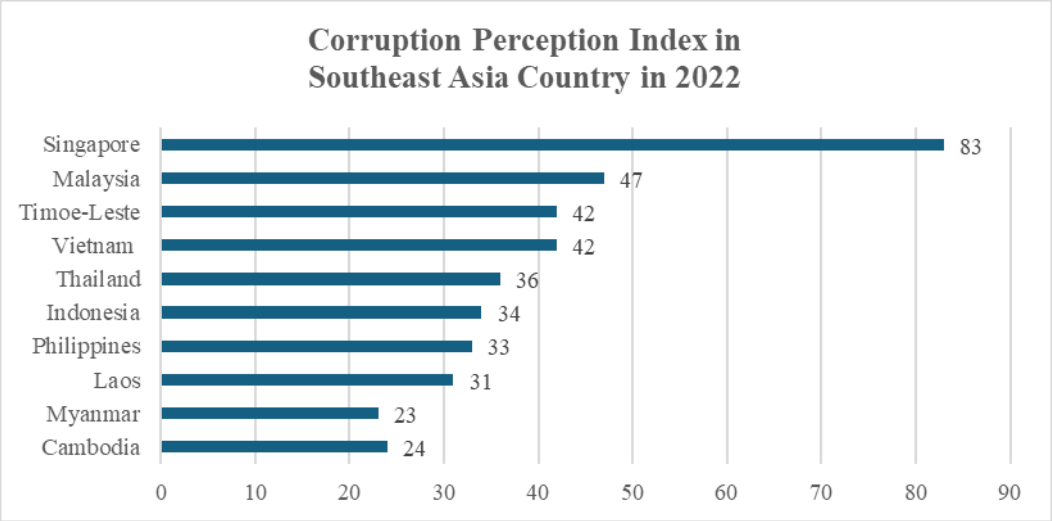

Figure 1. Corruption Perception Index (Statista, 2023)

In an effort to reduce the level of corruption, developing countries have long faced the problem of income inequality or economic disparities. Poor financial governance undoubtedly exacerbates income inequality (Houssou and Alinsato, 2023). On the other hand, in today's climate issue circumstance, Income Inequality and Economic Growth play a crucial role in promoting Sustainable Development Goals (SDGs), which are mainly aimed at enhancing environmental quality. The relationship between economic growth and environmental degradation is often depicted by the Environmental Kuznets Curve (EKC) hypothesis. The EKC suggests that environmental degradation increases in the early stages

of economic growth, reaches a peak, and then declines at a certain point as income continues to rise. When per capita income goes up, pollution levels can go down and eventually become negative. This can happen because of things like changes in the types of outputs, the introduction of cleaner production technology, and more public pressure for tighter controls on emissions (Grossman and Krueger, 1995).

As income is key factor, income inequality remains the biggest problem in establishing sustainable development. According to the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) in its 2021 SDGs report: "The region did not achieve the milestones of the 2030 agenda in 2020. The region must reverse the trend of regression and increase progress to achieve the goals and ambitious targets by 2030." The report suggests that the Association of Southeast Asian Nations (ASEAN) needs to optimize efforts in joint regional performance to achieve Sustainable Development Goal 10, reducing inequality. According to the latest International Monetary Fund (IMF) World Economic Prospects Update, ASEAN's estimated growth for the current year is 3.1 percent, with an expected estimate of 5.6 percent in 2022. Rising inequality will lead to increased poverty. Forecasts suggest that increasing the GINI in each country by 1 percent by 2020 would worsen the number of poor people by around 15 percent, estimated at 152 million people.

Further, in ASEAN countries, the interplay between corruption, economic growth, income inequality and environmental quality is particularly complex. Most countries are characterized by rapid industrialization, significant income inequality, and varying levels of institutional quality (Oanh and Ha, 2023). The EKC hypothesis initiated by provides a framework to explore how these factors interact over time, particularly in the presence of corruption, which can exacerbate income inequality and impede environmental protection efforts. Thus, studies on this topic attract many scholars, especially the recent climate change issues and environmental attention.

Initially, the Environmental Kuznets Curve (EKC) hypothesizes that there is a dependency between economic development and environmental quality. The EKC curve shows an inverted U-shaped relationship between income and CO2, it suggests that the early stages of economic development are initially environmentally detrimental, while society will generally interact with the environment in an attempt to decrease the rate of environmental degradation under certain conditions of economic growth. Eventually, it will reach a point where development reduces carbon emissions. However, since this is not included in policy prevention, the application of the EKC hypothesis is crucial for understanding a turning point negative CO2 emissions as a result of economic growth. This concept was later explored by many scholars (Chan et al., 2024; Shaharuddin et al., 2023; Khan et al., 2023; Öndes and Kızılgöl, 2024). Reinforcing the issue of climate risk, the EKC hypothesis increasingly underscores the direct impact between economic growth and environmental quality (Oanh and Ha, 2023; Khan et al., 2022; Kusumawardani and Dewi, 2020; Tanchangya and Ayoungman, 2022).

Several other studies have incorporated additional factors into the EKC framework, with diverse conclusions. In reaching a turning point on this hypothesis, the governance aspect becomes crucial for green funding allocation to be more targeted and highly prioritized. While financial governance has a direct impact on economic aspects, income

inequality is also prominent in affecting good environmental quality. Within the framework of this study, income inequality functions not just as a contributor to environmental deterioration but also as a pathway through which other structural factors (GDP, corruption, financial development and Trade Openness) influence environmental outcomes. Inequality is a consequence of the effectiveness of GDP and governance frameworks. This mediating role elucidates why similar rates of growth and other economic indicators provide varied environmental outcomes among nations.

GDP and Income Inequality

According to the initial concept of the EKC hypothesis, previous studies have confirmed that economic growth is the main factor in the formation of the EKC Hypothesis. The non-linear relationship between the two is predicted using economic growth and the square of economic growth. More specifically, the positive relationship between economic growth and the environment must be followed by a negative relationship between the square of economic growth and environmental quality (Grossman and Krueger, 1995). However, to reach the turning point that forms a non-linear relationship, economic growth must have implications for welfare (Grossman and Krueger, 1995) and income distribution (Handayani et al., 2022; Tabash et al., 2024; Xu et al., 2021). This is because improving environmental quality requires support from all sectors through the concentration of wealth and capital, access to education, and the enhancement of efficiency and profit (Abbas et al., 2023; Adams & Klobodu, 2019; Agustin et al., 2025).

Research conducted by Ridzuan et al., (2021) in Indonesia, Malaysia, the Philippines and Thailand, states that economic growth measured by Growth Domestic Product (GDP) has a significant positive effect on income distribution in Malaysia and Indonesia, but this is not the case in Thailand and the Philippines. This research also shows that in the long-term analysis the Inverted U-shaped Financial Kuznetz Hypothesis was detected in Malaysia and Thailand, while U-shaped Financial Kuznet Curves were found in Indonesia and the Philippines. This indicates that financial institutions in Malaysia and Thailand have helped reduce the trend of income inequality, while the opposite effect is felt by Indonesia and Thailand. Adams and Klobodu (2019) stated that GDP has a positive significant effect on income inequality. Research conducted by Khan et al., (2023) shows that GDP significantly reduces income inequality.

Research by Amri and Nazamuddin (2018) shows that GDP has a significant negative effect on long-term income inequality. Handayani et al., (2022) conducted a study that shows the relationship between GDP and income distribution, finding that GDP has a significant negative effect on income distribution. Statistically, a 1% increase in GDP will decrease income inequality by 0.342%. Based on economic theory, an increase in economic growth will lead to a reduction in income inequality, while additional value in various sectors will create higher economic growth, thus reducing income inequality. Better economic growth will absorb new labor and other activities in various sectors, so that income equality can be realized.

$\mathbf{H_1}$: Economic Growth (GDP) significantly affects the income inequality

Corruption Index and Income Inequality

Houssou and Alinsato (2023) revealed that corruption has a positive and significant effect on the GINI index, which represents the income inequality indicator. It can be interpreted that an increased level of corruption will lead to increased income inequality. Therefore, the greater the perception of business people on the level of corruption, the greater the income gap will be. Abbas et al., (2023) conducted a study that showed corruption has a significant positive impact on income inequality. This suggests that higher levels of corruption in a country are related to an increase in income inequality. This indicates that the presence of corruption can counter the potential benefits of good institutional quality in reducing income inequality. Dwiputri et al., (2018)) investigated the relationship between corruption and income inequality, the findings indicate that corruption has a strong and significant influence on income inequality in Asia. The study concluded that lower levels of corruption trigger lower levels of income inequality. In other words, greater corruption levels may lead to greater income inequality.

Meanwhile research by Handayani et al., (2022) confirmed that the corruption index is negatively related to income inequality in Indonesia. Higher levels of corruption in the country increase the problem of income inequality by 0.11%, Corrupt practices can provide opportunities for individuals or other officials to obtain public benefits or a larger share than they should get, paying a smaller share than they should pay. Conditions where large groups get the opportunity to benefit more because regulations are weak will greatly reduce income equality. High levels of corruption, however, can distort the government's role in resource allocation. Another research conducted by S. Wang et al., (2021) stated that corruption worsen the income inequality at least at the 10% level, indicating that official corruption affects the impact of population income inequality. These results highlight that the corruption significantly contributes to income inequality by distorting economic systems and undermining equitable resource distribution (Khalfaoui et al., 2023; Li et al., 2023; Li et al., 2024).

H_2: Corruption index significantly reduces the income inequality

Trade Openness and Income Inequality

Referring to (Tabash et al., 2024) the open trade borders reduce inequality, as the coefficient on trade is significant and negative. This result supports the existing literature that trade decreases inequality in higher economic growth countries. This study revealed a statistically significant negative relationship between income inequality and the square of GDP per capita growth when fitting the estimated model. This indicates that GDP growth decreases income inequality. Apriani and Perwithosuci (2023) confirmed trade openness has a negative and significant considerable influence on income inequality. Research by Mitra et al., (2018) found that the long-term effect is positively significant, but short-term effect of trade openness has significantly negative effect.

Adams and Klobodu (2019) indicate that trade openness have positive effects on income inequality. Xu et al. (2021) shows that, the estimated coefficient for trade openness indicates a positive effect on inequality. This means that as trade openness rises, inequality also tends to grow. Khan et al., (2021) show that significant effects on income inequality. The relationship between openness and income inequality suggests that initially, greater

openness will increase income inequality, but over time, openness will eventually reduce inequality.

Based on the explanation above, it is evident that trade openness has the potential to either increase or decrease income inequality. However, in the current era of globalization, trade openness is fully supported by technological advancement and regional policies that favor all sectors (Azmeh, 2025). Thus, trade openness will create greater opportunities to increase income through the ease of import-export (Xu et al., 2021), foreign direct investment (Khan et al., 2021) and support from governance mechanisms. Based on this, the third hypothesis in this study is as follows:

H_3: Trade openness significantly reduces income inequality

Financial Development and Income Inequality

Research by Shaharuddin et al., (2023) revealed that financial development has a positive effect on income inequality. Khan et al., (2023) show that financial development stability raises income inequality in developing countries. Meanwhile, in higher-income countries, financial development increases income inequality. Evident from newly industrialized countries,Öndes and Kızılgöl (2024) found that financial development deteriorates the income distribution in the short run, but then reduces income inequality in the long run .

Ridzuan et al., (2021) show that Financial development in Malaysia, Indonesia and Thailand has been successful in reducing income inequality, but the Philippines has had a different impact, where income distribution has worsened. Nittayakamolphun et al., (2024) show that income inequality will decrease if it reaches a certain limit in the early period of financialization, but income inequality will increase after financial system development is carried out.

In light of the above explanation, financial development can worsen the income inequality in the short run, but it will turn to reduce the income inequality in the long run which is in line with modernization theory. However, since this study examines the relationship between financial development and income inequality in a linear relationship, thus we proposed the hypothesis as follows:

H_4: Financial Development significantly reduces income inequality

Income Inequality and CO2 Emissions

Oanh and Ha (2023) conducted a study that showed income inequality is significantly positively related to environmental damage at the 1% significance level. Due to increasing income inequality, the gap between the rich and the poor is widening. Individuals who have low income are not required to contribute to the cost of reducing climate change. Changing to green energy for a country that is currently undergoing development will be difficult, as money is spent on development or social security rather than on changing the energy used. The unequal impacts and effects of climate change can be reduced by reducing emissions, but reducing risks does not eliminate the environmental impacts of inequality. H. Khan et al., (2022) explained that income inequality has a significant direct impact on carbon emissions. This research shows that if the income inequality gap is reduced, then there will be equality, and most of the people can achieve educational equality, and everyone can get awareness through education because people with low income cannot get educational

equality as people with high income can get the same standard of living, and thus can improve environmental quality.

Research by Kusumawardani and Dewi (2020)) shows that Income Inequality has a significant negative relationship with increasing CO2 Emissions, indicating that a decrease in Income Inequality leads to an increase in CO2 emissions. Other researcher Tanchangya and Ayoungman (2022) revealed that Income Inequality has a positive relationship with CO2 emission in Bangladesh. A study by ,S. Wang et al. (2021) Income Inequality has a negative significant relationship to CO2 emissions. Income inequality can be mitigated through appropriate awareness and campaigns in low-income societies where excessive emissions from various activities, such as fossil fuel combustion and deforestation, cause environmental degradation.

H_5: Income inequality significantly increases CO2 emissions

GDP on CO2 Enissions Mediated by Income Inequality

A recent study by Ridzuan et al., (2021), Adams and Klobodu (2019), Khan et al., (2023), found that GDP significantly reduced the income inequality. Meanwhile, other studies conducted by Amri and Nazamuddin (2018) and Handayani et al., (2022) found that GDP has a significant effect on income distribution.

According to research by Oanh and Ha (2023) H. Khan et al., (2022), Tanchangya and Ayoungman (2022) revealed that income inequality has worsened the level of CO2 emissions. Meanwhile research by Y. Wang et al., (2021), Kusumawardani and Dewi (2020) shows that Income Inequality has significant impact on environmental degradation measured by CO2 Emissions. Therefore, from previous research, it can be assumed that income inequality can mediate the relationship between GDP and CO2 Emissions.

H_6: Income inequality has a significant mediating effect between GDP and CO2 Emissions

Corruption Index on Environmental Degradation Mediated by income Inequality

Handayani et al. (2022) and Wang et al., (2021) shows that corruption significant effect on worsening the income inequality. Meanwhile research conducted by Houssou and Alinsato (2023), Abbas et al. (2023), Dwiputri et al. (2018) revealed that corruption distorts public expenditure intended for other purposes, such as poverty and income inequality alleviation which led to higher income inequality.

According to research by Oanh and Ha (2023), Khan et al. (2022), Tanchangya and Ayoungman (2022) revealed that income inequality reduces environmental regulations' strictness and makes energy policies inefficient which led to an increase in the level of CO2 emissions. This is supported with research by Kusumawardani Dewi (2020) shows that Income Inequality has a significant impact on environmental degradation. Therefore, from previous research, it can be assumed that income inequality can mediate the relationship between GDP and Environmental Quality.

H_7: Income inequality has a significant mediating effect between corruption and CO2 emissions.

Trade Openness on Environmental Degradation Mediated by Income Inequality

Research conducted by Tabash et al. (2024), Apriani & Perwithosuci (2023) concluded that trade openness has significantly reduced income inequality. Mitra et al. (2018) find that in the short run trade openness shows significantly negative relationship with income inequality but long run is significantly positive. Meanwhile Adams and Klobodu (2019), Xu et al. (2021) confirmed that trade openness has significant positive effect on income inequality. Khan et al. (2021) have argued that the impact of openness in the initial level increased income inequality but later reduced it.

According to research by Oanh and Ha (2023), Khan et al. (2022) Tanchangya and Ayoungman (2022) revealed that income inequality has a positive relationship with CO2 emissions. Meanwhile research by Wang et al. (2021) Kusumawardani and Dewi (2020) shows that Income Inequality has a significant negative relationship with increasing CO2 Emissions. Therefore, from previous research, it can be assumed that income inequality can mediate the relationship between GDP and CO2 emissions.

H_8: Income inequality has a significant mediating effect between trade openness and CO2 emissions.

Financial Development on Environmental Degradation Mediated by Income Inequality

Shaharuddin et al. (2023), Khan et al. (2023), Öndes and Kızılgöl (2024) revealed that financial development has a significant positive effect meaning it increased income inequality. Meanwhile research by Ridzuan et al. (2021) Nittayakamolphun et al. (2024) finds that financial development will reduce income inequality in some countries to and certain limit.

According to research by Oanh and Ha (2023), Khan et al. (2022), Tanchangya and Ayoungman (2022) revealed that income inequality has a positive relationship with CO2 emissions. Meanwhile research by Wang et al. (2021), Kusumawardani and Dewi (2020) shows that Income Inequality has a significant negative relationship with increasing CO2 Emissions. Therefore, from previous research, it can be assumed that income inequality can mediate the relationship between GDP and CO2 emissions.

H_9: Income inequality has a significant mediating effect between financial development and CO2 emissions.

In light of the explanation above, this study aimed to revisit the EKC hypothesis in the ASEAN-5 countries by examining the role of corruption and income inequality in influencing environmental quality, measured by CO2 Emissions. This study contributes to the recent literatures at least two fold. First, while many studies are examining the interaction between corruption and income inequality (Houssou & Alinsato, 2023; Abbas et al. (2023); Wang et al. (2021) this study provide an indirect influence between corruption and environment with income inequality serves as mediating variables. Second, the factors contributing to environmental degradation vary between developed and emerging nations. In industrialized countries, the primary factors contributing to environmental deterioration are frequently linked to consumption patterns, including energy utilization and transportation. In emerging nations, the primary catalysts of environmental deterioration are frequently linked to production activities like industrialization and urbanization (Li et

al., 2021). Third, policy responses in advanced economies frequently emphasize market-oriented methods such as carbon pricing and emissions trading systems. In emerging economies, policy responses frequently emphasize command-and-control strategies, including pollution legislation and environmental costs. Understanding these dynamics is expected to provide insight into policy interventions that can enhance environmental sustainability and reduce inequality.

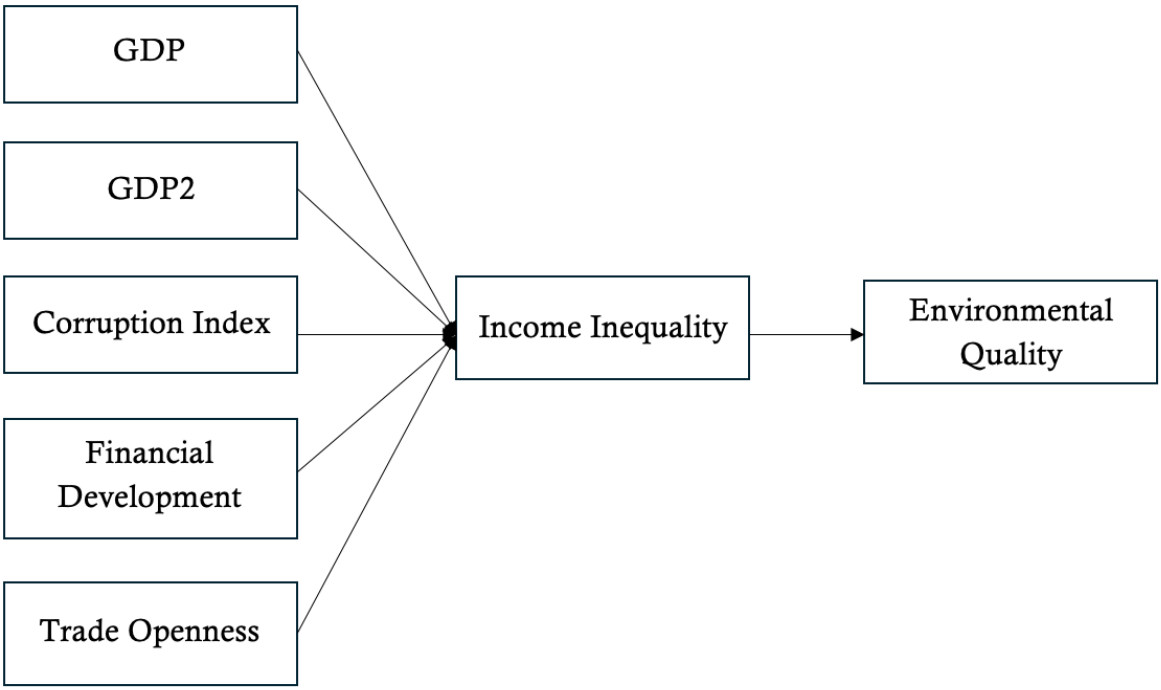

Figure 2. Research Model

METHOD

Considering the starting point of global financialization, this study uses panel data from 1990-2022 from five ASEAN countries : Indonesia, Malaysia, Thailand, Philippines, and Vietnam. The study uses environment quality which is measured by CO2 Emissions as a dependent variable, while economic growth, Trade Openness, and corruption index are the independent variables, and income inequality as a mediating variable. The detailed explanation of the data description are provided in Table 1.

According to the variables included and the research framework, the model specification for this study are as follows.

$$GINI_t = \emptyset + \alpha_1 GDP_t + , \alpha_2 GDP^2 t + \alpha_3 COR_t + \alpha_4 TO_t + \alpha_5 FD_t + e_t \quad \text{(Eq. 1)}$$

$$CO2 = \emptyset + \alpha_5 GINI_t + e_t \quad \text{(Eq. 2)}$$

Where, CO2 refers to CO2 Emissions; GDP is a Growth Domestic Product as an economic growth measurement, GDP^2 is a square of GDP, COR is corruption index, TO is trade openness, FD is Financial Development,and GINI is a measure of Income Inequality.

Equation 1 reflects the relationship between Independent Variables to Income Inequality (Ridzuan et al., 2021; Adams and Klobodu 2019; H. Khan et al., 2023; Amri and Nazamuddin 2018; Handayani et al., 2022; S. Wang et al., 2021; Houssou and Alinsato 2023; Abbas et al., 2023; Dwiputri et al., 2018; Tabash et al., 2024; Apriani and Perwithosuci 2023; Mitra et al., 2018; Xu et al., 2021; I. Khan et al., 2021; Shaharuddin et al., 2023; H. Khan et al., 2023; Öndes and Kızılgöl 2024; Nittayakamolphun et al., 2024).

Equation 2 depicts the Income Inequality and CO2 Emission nexus (Oanh and Ha 2023; H. Khan et al., 2022; Tanchangya and Ayoungman 2022; Y. Wang et al., 2021; Kusumawardani and Dewi 2020).

Variable	Definition	Sources
CO2 Emissions	Environmental conditions that can provide optimal carrying capacity for human survival in an area.	Our World in Data (https://ourworldindata.org/co2-emissions)
Economic Growth (GDP)	The concept of measuring national income is used to see a country's economic growth. GDP calculates the production or income of all citizens in the country, whether Indonesian citizens or foreign citizens.	WDI – World Bank (https://data.worldbank.org/indicator/NY.GDP.PCAP.KD)
Corruption Index	Measures the level of corruption in a country. or GPA ranges from 0 (highly corrupt) to 100 (highly clean). The higher the GPA score, the cleaner the perception of corruption in a country.	Transparency International https://www.transparency.org/en/cpi/2022)
Trade Openness	The proportion of total goods and services exported to and imported from other countries, represented as a percentage of Gross Domestic Product (GDP).	WDI – World Bank https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS
Financial Development	measures the amount of money in circulation in an economy. It is defined as the most inclusive method of calculating the money supply in a country, and includes narrow money along with other assets that can be easily converted into cash to purchase goods and services.	WDI – World Bank https://data.worldbank.org/indicator/FM.LBL.BMNY.GD.ZS
Income Inequality (GINI Index)	Measurement of income distribution in a country or region from an equal distribution of income. The Gini Ratio index ranges from 0 to 1, where 0 indicates an equal distribution of income, while 1 indicates a very unequal distribution of income.	WDI – World Bank (https://data.worldbank.org/indicator/SI.POV.GINI)

Table 1. *Variable Description and Data Measurement*

The data analysis is as follows:

1) Descriptive Statistics : to describes the whole performance of each variables included.
2) Stationary Tests: Initial procedure for time series data to check whether data are stationary on level I(0) or in the first difference I(1). This study use Panel Unit Root Test with some criteria namely (Levin, Lin, and Chu, Im, Pesaran and Shin W-stat, ADF - Fisher Chi-square, PP – Fisher Chi-square) to test the stationary properties of the variables.
3) Autoregressive Distributed Lag (ARDL)
   The method applied in this study is Autoregressive Distributed Lag (ARDL) to evaluate the relationship between the interested variables. The ARDL approach developed by (Pesaran et al., 2001) is particularly advantageous for this study as it can handle variables with different orders of integration, I(0) and I(1), without requiring pre-testing for cointegration. This flexibility is crucial given the potential non-stationarity of the variables and the limited time-series data availability for some of the ASEAN-5 emerging countries. Additionally, the ARDL approach allows for variable lag lengths, providing more flexibility in capturing the dynamic relationships between the variables.

   While the Johansen approach is unsuitable for this study due to its handling of small sample time arrangements, ARDL is expected to provide robust results even with limited samples. Pesaran and Shin (1995) prove advantageous given the availability of imbalanced income data only at an annual frequency and the restricted time periods for many emerging economies like Indonesia and Malaysia. Additionally, ARDL allows for variable lag lengths to vary, providing more flexibility, whereas the Johansen approach requires all variables in the model to share the same number of lags. The selection of optimal lag lengths for the ARDL model in this study was determined using the Akaike Information Criterion (AIC). In analyzing the time series data, ARDL are able to capture the short-run and long-run relationships which are crucial to explain the nature of each relationship.
4) Mediation Analysis

   As this study use Income Inequality as Mediation Variables, the mediation analysis used is the sobel test Sobel (1982) an explicit procedures focused on the significance assesment of the indirect impact. Sobel test evaluates whether this mediation effect is statistically significant by calculating the indirect effect and its standard error, then comparing it to a normal distribution to determine significance.

   The Sobel test evaluates the strength of the indirect impact of X on Y through Z. This indirect impact is determined by multiplying the path from X to Z (a) by the path from Z to Y (b), also represented as path ab. Thus, the coefficient ab equals (c' - c), where c represents the effect of X on Y without accounting for Z, and c' represents the effect of X on Y after accounting for Z. The standard errors for coefficients a and b are denoted as Sa and Sb, respectively, and the combined standard error of the indirect effect, Sab, is computed utilizing a particular formula:

$$S_{ab} = \sqrt{b^2\, sa^2 + a^2\, sb^2 + sa^2\, sb^2}$$

Table 2. *Sobel Test Description*

Components	Description
S_{ab}	Represent the standard error of mediation effect
Sa	The standard error associated with coefficient a
Sb	The standard error associated with coefficient b
b	The coefficient representing the mediating variable
a	The coefficient representing the independent variable

After obtaining the standard error of the mediation effect, we can conclude the significance of each indirect effect. If the result shows significance below 0.05, it means that variable Z successfully mediates the relationship between X and Y.

FINDING AND DISCUSSION

Descriptive Statistics

Table 3. shows descriptive statistical data from Indonesia, Malaysia, Thailand, Philippines, and Vietnam. The table shows the value of each variable with measurements of mean, median, maximum, minimum standard deviation, and so on. The data shows the average amount of CO2 Emission is 0.234312, with a maximum value of 0.369761 and a minimum value of 0.128698. The standard deviation value for CO2 emissions is 0.063221. The corruption variable shows an average value of 34.38667, with a maximum value of 53.20000 and a minimum value of 33.0000. This shows that the level of corruption in the 5 ASEAN countries is still high when compared to developed countries such as Singapore. GINI has an average value of 40.69152 with a maximum value of 49.1 and a minimum value of 40.7, indicating that income inequality still occurs in 5 developing countries in ASEAN.

Table 3. *Descriptive Statistics*

	CO_2	GINI	GDP	GDP^2	FD	COR	TO
Mean	0.234312	40.69152	3795.285	20505168	81.27338	34.38667	104.8608
Median	0.226945	40.70000	3130.911	9802601.	78.37215	33.00000	97.00125
Maximum	0.369761	49.10000	11399.40	1.30E+08	148.8354	53.20000	220.4068
Minimum	0.128698	29.50000	673.3855	453448.0	19.56649	17.00000	32.97218
Std. Dev.	0.063221	5.197530	2477.536	27223646	37.12397	9.860184	47.62737
Skewness	0.326807	0.034806	1.217388	2.187937	0.089202	0.452767	0.500206
Kurtosis	2.152611	1.744866	3.864206	7.497717	1.613807	2.227503	2.290139
Jarque-Bera	7.873803	10.86393	45.89056	270.7219	13.42934	9.740119	10.34500
Probability	0.019509	0.004374	0.000000	0.000000	0.001213	0.007673	0.005670
Sum	38.66147	6714.100	626222.0	3.38E+09	13410.11	5673.800	17302.03
Sum Sq. Dev.	0.655481	4430.348	1.01E+09	1.22E+17	226023.0	15944.61	372012.0
Observations	165	165	165	165	165	165	165

Panel Unit Root Test

Table 4 shows the data results using the Panel Unit Root Test to determine whether the data used is stationary or not. The analysis utilizes the calculation tools Levin, Lin, and Chu, Im Pesaran, and Shin W-Stat, ADF - Fisher Chi-Square, and PP - Fisher Chi-square. The findings show that at the level there is one variable, financial development, which shows the data is stationary. This indicates that financial development data has a predictable data trend or I(0). Other variables in this case are not found in stationary data so it can be concluded that other variables do not have trends for prediction. Furthermore, the First Difference test was carried out and the results showed that all variables showed significance so that the data as a whole became stationary. The results of the analysis using First Difference show that each variable has significance at the 1% level. This shows that after using the First Difference analysis, each variable is stationary so that it has a predictable trend I(1). Stationary data results indicate that the data under study has consistent or constant statistics over time. This will support more precise statistical analysis and produce more valid conclusions, thus supporting better decision-making based on the research results.

Table 4. Results from Panel Unit Root Test

Test	Variables	Level	First Difference
Levin, Lin, and Chu	CO2 Emission	0.52843	-3.25458***
	Income Inequality	1.19302	-5.50333***
	GDP	4.56545	-6.08749***
	GDP2	6.19423	-4.55472***
	Corruption Index	0.71722	-6.77458***
	Financial Development	-1.76839**	-4.91726***
	Trade Openness	-0.64018	-3.83613***
Im, Pesaran and Shin W-stat	CO2 Emissions	1.31565	-4.49857***
	Income Inequality	1.68545	-7.41965***
	GDP	6.00836	-5.36360***
	GDP2	7.62160	-4.77334***
	Corruption Index	1.05646	-6.46252***
	Financial Development	-1.72961**	-5.60044***
	Trade Openness	0.07177	-6.46156***
ADF - Fisher Chi-square	CO2 Emissions	3.69755	40.4864***
	Income Inequality	10.9189	68.5609***
	GDP	0.49641	48.9462***
	GDP2	0.15836	46.7497***
	Corruption Index	11.6556	58.8826***
	Financial Development	29.3263***	49.8719***
	Trade Openness	7.79845	58.9621***
PP - Fisher Chi-square	CO2 Emissions	4.24466	78.1973***
	Income Inequality	7.25465	112.384***
	GDP	0.52232	61.8769***
	GDP2	0.09739	57.8448***
	Corruption Index	9.99198	123.504***
	Financial Development	22.5628**	78.6290***
	Trade Openness	9.61391	94.9099***

Notes: Standard errors in parentheses, ***, **, and * indicated statistically significant at 1%, 5%, and 10%, respectively.

Cointegration Test

Table 5 shows the results of the Predoni Residual Cointegration Test analysis. The analysis was conducted by testing cointegration in this study to see the significance between variables. Using the Panel PP-Statistic method in the data test process and the results show that the error correction parameter is at a significant level of 1%. The results of the analysis show that the cointegration test rejects the null hypothesis, and shows the existence of cointegration in the long run and short run.

Table 5. Predoni Residual Cointegration Test

Test Statistic	t-Statistic	Prob.
Panel PP-Statistic	-2.0066117	(0.0194)

Notes: Standard errors in parentheses, ***, **, and * indicated statistically significant at 1%, 5%, and 10%, respectively

Autoregressive Distributed Lag (ARDL)

Table 6 shows the relationship between the independent and mediating variables. In the long run, GDP has a positive significant relationship with income inequality, indicating that higher economic activity in a country will lead to an increase in income inequality. This is consistent with research by Ridzuan et al. (2021); Adams and Klobodu (2019); Khan et al. (2023). Corruption has a positive significant relationship with income inequality, indicating that the higher the level of corruption in a country has an impact on increasing income inequality. This result is in line with research Houssou and Alinsato (2023); Abbas et al. (2023); Dwiputri et al. (2018). Trade Openness has a significant negative relationship with income inequality, indicating that the higher the number of export and import activities in a country will have an impact on reducing income inequality. This is in accordance with research Tabash et al. (2024); Apriani and Perwithosuci (2023); Mitra et al. (2018). Financial Development has a positive significant relationship with income inequality, indicating that higher financial development has an impact on reducing income inequality. This result supports the research conducted by Shaharuddin et al. (2023); Khan et al. (2023); Öndes and Kızılgöl (2024). Meanwhile, in the short term, each variable does not show a significant relationship. It can be concluded that in the long run the variables will affect income inequality while in the short run, no effect will be found.

Table 7 shows the relationship between income inequality and environmental quality as measured by CO2 emissions. The results of the analysis show a positive significant effect on CO2 Emissions. This means that it is in accordance with the existing hypothesis, namely that the higher the income inequality, the higher the impact on increasing the amount of CO2 Emissions. This is in line with research Oanh and Ha (2023); Khan et al. (2022); Tanchangya and Ayoungman (2022).

Table 6. ARDL Model for Independent on Income Inequality

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Long Run Equation				
GDP	0.038741***	0.012121	3.196139	0.0024
GDP^2	-4.63E-06***	1.29E-06	-3.596891	0.0007
Corruption Index	1.778499***	0.362837	4.901648	0.0000
Trade Openess	-0.406595***	0.091403	-4.448355	0.0000
Financial Development	0.145571***	0.036730	3.963239	0.0002
Short Run Equation				
Cointeq01	-0.128136	0.136614	-0.937938	0.3528
D(GDP)	0.013151*	0.007402	1.776680	0.0817
D(GDP(-1))	-0.008506	0.005488	-1.550016	0.1274
D(GDP(-2))	0.004816	0.009508	0.506506	0.6147
D(GDP(-3))	-0.021696*	0.011327	-1.915434	0.0612
D(GDP2)	-1.42E-06	1.01E-06	-1.406556	0.1657
D(GDP2(-1))	8.38E-07	5.68E-07	1.474899	0.1465
D(GDP2(-2))	-9.59E-07	1.43E-06	-0.670558	0.5056
D(GDP2(-3))	3.54E-06*	2.02E-06	1.749946	0.0863
D(Corruption Index)	-0.290897	0.238381	-1.220306	0.2281
D(Corruption Index(-1))	-0.228805	0.207208	-1.104227	0.2748
D(Corruption Index(-2))	-0.073661	0.218493	-0.337130	0.7374
D(Corruption Index(-3))	-0.100995	0.113029	-0.893532	0.3759
D(Trade Openess)	0.047304	0.060212	0.785620	0.4358
D(Trade Openess(-1))	0.014816	0.046604	0.317916	0.7519
D(Trade Openess(-2))	0.046783**	0.021586	2.167246	0.0350
D(Trade Openess(-3))	-0.009370	0.021016	-0.445840	0.6576
D(Financial Development)	0.049409	0.067236	0.734866	0.4659
D(Financial Development(-1))	-0.002385	0.045423	-0.052502	0.9583
D(Financial Development(-2))	0.001387	0.014765	0.093970	0.9255
D(Financialdevelopment(-3))	-0.013572	0.025165	-0.539320	0.5921
C	-8.857921	9.006502	-0.983503	0.3301
Root MSE	0.359843	Mean dependent var		-0.141379
S.D. dependent var	1.060109	S.E. of regression		0.653687
Akaike info criterion	1.893047	Sum squared resid		21.36532
Schwarz criterion	4.057796	Log likelihood		-41.17634
Hannan-Quinn criter.	2.771794			

Notes: ***, **, and * indicated statistically significant at 1%, 5%, and 10%, respectively.

Table 7. ARDL Model for Mediation on Dependent Variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run Equation				
Income Inequality	0.010270***	0.003033	3.386274	0.0009

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Short Run Equation				
COINTEQ01	-0.070796*	0.040488	-1.748578	0.0824
D(Income Inequality)	-0.000306	0.001471	-0.208182	0.8354
C	-0.011751	0.007422	-1.583366	0.1155
Root MSE	0.009629			
S.D. dependent var	0.011034			
Akaike info criterion	-6.086042			
Schwarz criterion	-5.784860			
Hannan-Quinn criter.	-5.963782			
Mean dependent var	0.001268			
S.E. of regression	0.010132			
Sum squared resid	0.015297			
Log likelihood	518.0985			

Notes: ***, **, and * indicated statistically significant at 1%, 5%, and 10%, respectively.

Mediation Analysis

The calculation using the Sobel test method aims to see whether the mediating variable successfully mediates the relationship between the independent and dependent variables.

Table 8. Sobel Test Results

Indirect relationship	T-Statistics	Std Error	P-Value
GDP-> GINI-> CO2 Emission	2.32428156	0.00017118	0.02011041**
GDP2-> GINI -> CO2 Emission	-2.46298404	2e-8	0.0137786**
Corr -> GINI -> CO2	2.78597057	0.00655613	0.00533677***
TO -> GINI -> CO2	-2.69432092	0.00154983	0.00705322***
FD -> GINI -> CO2	2.57443716	0.00058071	0.01004033**

Table 8 explains the results of the mediation using Sobel test results indicating that income inequality successfully mediates the relationship between corruption and environmental quality (p-value < 0.05). This finding supports the hypothesis that corruption exacerbates income inequality, which in turn negatively impacts environmental quality through increased CO2 emissions. Similarly, income inequality mediates the relationships between economic growth, trade openness, financial development, and environmental quality, highlighting the crucial role of income distribution in shaping the environmental outcomes of these factors.

Furthermore, the negative t-statistics on the GDP variable re-confirm the existence of the EKC hypothesis, where the squared GDP depicts a U-shaped relationship with the dependent variable. This indicates that high economic growth will indirectly improve environmental quality (reduce CO2 emissions) through increased income distribution. Theoretically, these results support the Kuznets Curve theory for the environment and the Financial Kuznets Curve.

Discussion

Based on the analysis results in Tables 5, 6, and 7, overall, the existence of the EKC hypothesis in ASEAN countries is proven. The significance of the relationship between GDP and GDP2 on Income Inequality confirms the U- Inverse shaped of EKC model (Adams and Klobodu, 2019; Tabash et al. 2024; Xu et al. 2021). However, the significance of this relationship is seen in the long run, which indicates that ASEAN countries need more time to realize it. Meanwhile, in the short term, the relationship between variables does not show significance, which means that in ASEAN countries, the effect will not be felt in a short period of time (Agustin et al. 2025; Handayani et al. 2022; Amri and Nazamuddin, 2018).

Corruption index is proven to be able to cause an increase in social inequality in ASEAN countries. Corruption can benefit some groups who get the opportunity to gain more. Corruption will make officials and private individuals richer because they get a bigger share of the benefits that should be given to the public (Wang et al. 2021). If rules or regulations related to corruption are weak, it will encourage these parties to commit acts of corruption, and obtain greater profits and income so that income distribution becomes lower. This will enrich a few groups and will harm those who would have received public benefits if there was no corruption. The higher the level of corruption, the lower the allocation of resources to be distributed, leading to higher income inequality. This result in line with studies by Khalfaoui et al. (2023); Li et al. (2023); Li et al. (2024).

The finding revealed the significant relationship between Trade openness and Income Inequality. Trade openness is a step to increase export and import activities in a country. If a country increases trade openness then the country will open up employment opportunities for many people to get a job. The new jobs will encourage production activities and also encourage employment. The unemployment rate will decrease along with the increase in labor absorption due to new jobs. Because of the absorption of labor, it will increase the individual income of each person, increase the standard of living and the opportunity to achieve a better life. A declining unemployment rate can reduce the level of income inequality so that it will affect income distribution in a country that has increased trade openness. Then it will have an impact on the income distribution of a country, the higher the trade openness carried out, the income distribution can increase so that income inequality can decrease (Apriani and Perwithosuci, 2023; Mitra et al. 2018; Tabash et al. 2024).

Moreover, the result posits that financial development significantly increases income inequality, which is not in line with theoretical expectations and prior literatures (Shaharuddin et al. 2023; Khan et al. 2023; Öndes and Kızılgöl, 2024). As access to financial resources from financial institutions increases, it becomes easier to access and utilize financial services. However, in the developing countries like ASEAN, financial development does not always benefit all groups equally. Wealthier individuals and large firms are often the first to access and benefit from expanded financial services, credit markets, and capital investment (Ridzuan et al. 2021). As a result, financial development reinforces existing inequalities by expanding opportunities only for the already advantaged.

Based on the results of mediation analysis, Income inequality has been shown to mediate the relationship between economic growth, Corruption, Trade Openness, and

Financial Development. This shows the significant role of income inequality in enhancing environmental quality. In a highly unbalanced society, wealth is concentrated in the hands of a few people. In many developing and transitional economies like ASEAN countries, GDP growth is frequently inequitably allocated. Economic growth may disproportionately advantage high-income groups and urban elites, while low-income and rural populations get limited enhancement (Khan et al. 2023). Affluent demographics exhibit significantly greater carbon footprints owing to their energy-intensive consumption patterns, whereas economically disadvantaged people frequently depend on less expensive, polluting fuels (such as coal and biomass) and possess restricted access to clean technologies. Inequality diminishes collective political engagement: in unequal societies, environmental preservation is often deprioritized as the affluent can insulate themselves from pollution, while the impoverished lack the agency or resources to advocate for cleaner air and water (Khan et al. 2022; Oanh and Ha 2023; Tanchangya and Ayoungman 2022).

This condition is exacerbated by the presence of corrupt governance. Corruption facilitates the appropriation of public resources by elites, resulting In the concentration of wealth among politically connected parties. Corruption indirectly contributes to elevated CO_2 emissions by intensifying income disparity, which subsequently undermines environmental governance and amplifies emissions through disproportionate consumption and the marginalization of environmental issues (Wang et al. 2021).

CONCLUSION

This study contributes to the understanding of the complex interplay between corruption, economic development, income inequality, and environmental quality in ASEAN-5 emerging countries. By examining the mediating role of income inequality, the findings underscore the detrimental impact of corruption on exacerbating income disparities, which in turn adversely affects environmental quality through increased CO2 emissions.

The analysis confirms the existence of the U-shaped Environmental Kuznets Curve (EKC) hypothesis, suggesting that while economic growth initially leads to environmental degradation, it ultimately results in improvements at higher income levels. However, the presence of corruption and income inequality can impede this transition towards environmental sustainability.

The study highlights the significant impact of trade openness and financial development on income inequality and environmental quality in the long run. Open trade policies and well-developed financial systems can help reducing income disparities and promoting environmental protection, but their effectiveness may be hindered by corruption and inequality. However, according to the result, financial development in ASEAN countries is not sufficiently reducing the income inequality.

To enhance environmental sustainability and achieve a balance between economic development and environmental protection, policymakers in ASEAN emerging countries should prioritize efforts to combat corruption and address income inequality. Implementing strong anti-corruption measures, promoting transparent governance, and fostering equitable distribution of resources are crucial steps in mitigating the negative consequences of corruption and inequality on the environment.

Future research could explore the specific mechanisms through which corruption and income inequality influence environmental outcomes, as well as the potential interactions with other factors such as technological advancements, renewable energy adoption, and institutional quality. Additionally, comparative studies across different regions or country groups could provide further insights into the generalizability of the findings and the variations in the relationships between the examined variable.

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