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Unveiling the triangular causality between FDI, GDP, and CO2 emissions: Insights from ASEAN-5 countries

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Abstract

This study investigates the dynamic relationships between FDI, GDP, and CO2 emissions in the ASEAN-5 countries. Using data from 1970 to 2023, the findings of the Toda-Yamamoto non-causality test reveal consistent bidirectional causality between FDI and GDP across the region, highlighting the mutual dependence of foreign investment and economic growth. On the other hand, unidirectional causality from FDI to CO2 emissions in most countries (except Singapore) supports the pollution haven hypothesis, emphasizing the environmental costs associated with FDI inflows. Furthermore, the unidirectional causality from GDP to CO2 emissions in Malaysia and the bidirectional causality observed in the Philippines underscores the need for Malaysia to prioritize decarbonizing its industrial base and adopting cleaner technologies while the Philippines must address the feedback effects by integrating sustainable practices into its growth strategies to ensure that environmental challenges do not hinder long-term economic development. Overall, the findings underscore the importance of aligning foreign investment policies with environmental sustainability goals to achieve balanced economic growth.

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1. Introduction

The interplay between Foreign Direct Investment (FDI), economic growth, and environmental sustainability has become a critical research focus in recent decades (Danso and Boateng, 2020; Kongsirikorn et al., 2023). Notably, FDI is often regarded as a key driver of economic growth, particularly in developing and emerging economies, as it brings capital inflows, technology transfer, and employment opportunities (Borensztein et al., 1998; Gaikwad, 2013; Ruranga et al., 2014; Albur, 2019). However, the environmental consequences of FDI, especially in terms of Carbon Dioxide (CO2) emissions, have raised significant concerns, highlighting the potential trade-offs between economic progress and environmental sustainability (Xu et al., 2015; Yang et al., 2022). Therefore, understanding the dynamics between these factors is crucial for shaping policies that balance economic development with environmental stewardship.

The Environmental Kuznets Curve (EKC) hypothesis, which posits that environmental degradation initially increases with economic growth but eventually declines as income levels rise, has been widely used to explain the relationship between Gross Domestic Product (GDP) and CO2 emissions (Adebayo et al., 2021). However, the role of FDI in this framework remains contested. While some studies suggest that FDI exacerbates CO2 emissions by enabling pollution-intensive activities (pollution haven hypothesis), others argue that it fosters cleaner technologies and environmental standards (FDI halo effect) (Tamazian and Rao, 2010; Tang et al., 2016). Thus, the mixed evidence highlights the need for region-specific analyses that account for varying economic structures, industrial policies, and environmental regulations.

The ASEAN-5 countries, which consist of Indonesia, Malaysia, the Philippines, Singapore, and Thailand, offer a unique context for examining this nexus. These economies are among the top FDI recipients in Asia, driven by their strategic location, abundant natural resources, and expanding industrial base. As members of the ASEAN Economic Community (AEC), these countries are committed to regional economic integration and sustainable development, making the analysis of FDI, GDP, and CO2 emissions particularly relevant. Hence, this study aims to examine the causal relationships among FDI, GDP, and CO2 emissions in the ASEAN-5 countries, using robust econometric techniques to uncover both short- and long-term dynamics. Accordingly, the findings will provide critical insights into the interplay between economic growth and environmental sustainability in the region, offering valuable guidance for policymakers.

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature. Section 3 outlines the methodology employed in the analysis. Section 4 presents the empirical findings, including the unit root tests, cointegration analysis, and causality results. Finally, Section 5 concludes the study and offers suggestions for future research.

2. Literature Review

In analyzing the literature related to FDI, GDP and CO2 emissions, a systematic search was conducted on the Scopus database on 1st January 2025 with the keywords "foreign direct investment" OR "FDI" AND "gross domestic product" OR "GDP" AND "carbon" OR "CO_2" in article titles yielded 14 main documents. These studies provide valuable insights into the dynamics of FDI, economic performance, and carbon emissions, offering a foundation for evaluating their complex interrelationships.

An early work by Pao and Tsai (2011) examined the interactions between CO2 emissions, energy consumption, GDP, and FDI in the leading BRICS countries, namely Brazil,

Russia, India, and China. Notably, the study uncovered bidirectional causality between FDI and CO2 emissions, as well as unidirectional causality from GDP to FDI. In particular, these findings highlight the importance of integrating environmental considerations into FDI policies to mitigate the adverse effects of economic growth.

In China, Zhang and Zhang (2018) have assessed the impacts of GDP, trade structure, exchange rates, and FDI inflows on CO2 emissions. The study validated the EKC hypothesis while revealing a positive relationship between FDI inflows and emissions. These findings also emphasize the need for environmentally sustainable trade and investment policies to address the challenges posed by rapid economic growth.

In the context of India, Rai et al. (2019) have explored the causal relationships among CO2 emissions, energy consumption, FDI, GDP, and economic openness. The study identified a long-run relationship among the variables and reported strong unidirectional causality from energy consumption, FDI, GDP, and openness to CO2 emissions. Furthermore, the findings underscored a cyclical relationship where economic growth driven by FDI and energy use exacerbates emissions. The study also highlighted the need for policies promoting energy efficiency and technological advancements to mitigate emissions without hindering economic growth.

Similarly, a study by Muthusamy and Rani (2019) empirically analyzed the relationship between FDI, GDP, and CO2 emissions in India using Autoregressive Distributed Lag (ARDL) bound testing and Granger causality. The study discovered unidirectional long-run causality from GDP and CO2 emissions to FDI, highlighting how economic growth and environmental factors drive foreign investment. In addition, the results confirmed a long-run equilibrium relationship among the variables, emphasizing the need for sustainable economic policies to balance FDI attraction and environmental impact.

Moreover, Kim (2019) has explored the causal relationships among CO2 emissions, energy consumption, GDP, and FDI in 57 developing countries. Using a panel Vector Error Correction Model (VECM), the study identified a long-run cointegrated relationship among these variables, supporting the EKC hypothesis. However, the elasticity of FDI on CO2 emissions was minimal, challenging the pollution haven hypothesis. These findings emphasized the limited role of FDI in influencing environmental outcomes in the short run, particularly in developing economies.

Shifting the focus to Vietnam, Do and Dinh (2020) have examined the short- and long-term effects of GDP, energy consumption, FDI, and trade openness on CO2 emissions. The results indicated that while GDP growth per capita negatively influences emissions in the long run, FDI contributes positively to emissions. This highlighted the need for policies that promote green investments to balance economic growth with environmental sustainability.

In addition, Ngoc et al. (2024) studies in Vietnam highlighted significant positive correlations between FDI inflows and GDP growth while identifying the environmental challenges posed by urbanization and internal migration. To address these challenges, the authors advocated for comprehensive policies integrating green technologies, sustainable urban development, and international collaboration.

Adding to the diversity of regional analyses, Zubair et al. (2020) have investigated the interplay between FDI, GDP, trade integration, and CO2 emissions in Nigeria. Notably, employing ARDL and Vector Autoregressive (VAR) methodologies, the study discovered that increased FDI inflows, GDP, and capital investment contributed to reducing CO2 emissions. These findings challenge conventional assumptions about the environmental risks associated with FDI, suggesting climate-friendly policies can align economic growth with environmental sustainability.

On the other hand, Mohsin et al. (2022) have examined the relationship between FDI, GDP, energy consumption, and CO2 emissions in European and Central Asian countries using

the ARDL approach. The study reported that FDI and energy consumption Granger-cause CO2 emissions in the short run, while CO2 emissions negatively influence GDP in the long run. These findings highlighted the environmental costs of economic growth and FDI, emphasizing the need for green energy policies to mitigate long-term environmental deterioration.

In contrast, Nur Mozahid et al. (2022) analyzed the causal dynamics among CO2 emissions, energy consumption, GDP, and FDI in five South Asian countries. Using ARDL models and Granger causality tests, the study confirmed the EKC hypothesis for Pakistan and Sri Lanka while presenting mixed evidence for the pollution haven and FDI halo hypotheses. This regional perspective underscored the variability in FDI's environmental impact, driven by country-specific economic and policy frameworks.

Using data from Southeast Asian countries, Mai (2023) investigated the impacts of FDI, GDP, and CO2 emissions on renewable energy consumption. The study discovered that FDI positively influences the renewable energy sector, while GDP and CO2 emissions have negative impacts. These results underscored the role of FDI in promoting sustainable energy initiatives. They provided a foundation for policies to expand renewable energy activities to balance economic growth and environmental sustainability in the region.

In contrast, a study by Bunnag (2023) in Thailand using ARDL, VECM, and Granger causality tests discovered no long-run cointegration but confirmed short-run relationships. Bidirectional causality was identified between energy consumption and GDP as well as GDP^2. Accordingly, unidirectional causality suggested that FDI influences CO2 emissions, energy consumption, and GDP. The findings also emphasized the need for policies promoting renewable energy and green investments to mitigate emissions while sustaining economic growth.

Extending the regional focus to Sub-Saharan Africa, Kwablah (2023) has conducted a sector-specific analysis of FDI's impact on CO2 emissions in 36 countries. The study noted that industrial FDI increases emissions, validating the pollution haven hypothesis, while agricultural and services sector FDI reduce emissions. These findings suggested the need for policies strategically directing FDI toward cleaner sectors to harness its potential for positive environmental outcomes.

A broader perspective is provided by Wang et al. (2023), who examined the threshold effects of per capita GDP on the FDI-CO2 relationship across 67 countries. Their findings demonstrated a shift from a positive to a negative relationship as income levels rise, emphasizing the role of economic development in enabling countries to leverage FDI for environmental benefits. This income-dependent dynamic highlighted the significance of fostering higher income levels to fully capitalize on the emission reduction potential of FDI.

While significant research has been conducted on the relationship between FDI, GDP, and CO2 emissions, existing studies predominantly focus on broader regional blocs, such as developing countries (Kim, 2019) or South Asia (Nur Mozahid et al., 2022) or single-country analyses like Vietnam (Do and Dinh, 2020; Ngoc et al., 2024) and China (Zhang and Zhang, 2018). However, the ASEAN-5 countries represent a unique and vital context for such analysis, as they are among the top recipients of FDI in Asia and exhibit rapid economic growth and industrialization. Despite their shared regional policies and economic integration under ASEAN frameworks, the environmental implications of FDI inflows and GDP growth in these countries remain underexplored. Investigating the dynamic interrelationships among FDI, GDP, and CO2 emissions in the ASEAN-5 not only fills a critical gap in the literature but also provides valuable insights to inform sustainable development policies in one of the most economically vibrant regions of the world.

3. Methodology

This study adopts a comprehensive econometric framework to investigate the triangular causality among FDI, GDP, and CO2 emissions in the ASEAN-5 countries. To capture the country-specific dynamics, this study employs a pure time series framework, whereby each model is estimated individually. This approach helps minimize issues related to cross-sectional dependence, which commonly occur in panel data analyses.

The methodology is structured into several key phases to ensure robustness and accuracy in the findings. Initial analysis will begin with descriptive statistics to provide an overview of the data's characteristics. As a preliminary test, stationarity tests will be conducted using the Augmented Dickey-Fuller (ADF) test as follows:

$$\Delta y_t = \beta_1 + \beta_{2t} + \delta y_{t-1} + \alpha_i \sum \Delta y_{t-1} + v_t \quad (1)$$

Whereby y_t is the variable of interest, Δ is the differencing operator, t is the time trend, and v is the residual. $\beta 1$, $\beta 2$, δ, and α_i are the set of parameters to be estimated.

If the ADF confirmed that all variables are stationary at the first difference, I(1), the study proceeded with the Johansen cointegration test proposed by Johansen and Juselius (1990) to determine whether a long-run relationship exists among the variables. The null hypothesis of the test indicates that there is no cointegrating vector.

Once a cointegration relationship is established, the study examines the causality among the variables using the Toda and Yamamoto (1995) non-causality test to determine the direction of causality among FDI, GDP, and CO2 emissions as follows:

$$GDP_t = \alpha_0 + \sum_{i=1}^{p+dmax} \alpha_{1i} GDP_{t-i} + \sum_{i=1}^{p+dmax} \alpha_{2i} FDI_{t-i} + \mu_i \quad (2)$$

$$CO2_t = \alpha_0 + \sum_{i=1}^{p+dmax} \alpha_{1i} CO2_{t-i} + \sum_{i=1}^{p+dmax} \alpha_{2i} FDI_{t-i} + \mu_i \quad (3)$$

$$CO2_t = \alpha_0 + \sum_{i=1}^{p+dmax} \alpha_{1i} CO2_{t-i} + \sum_{i=1}^{p+dmax} \alpha_{2i} GDP_{t-i} + \mu_i \quad (4)$$

Where p is the optimal lag length selected based on the Akaike Information Criteria (AIC), and dmax is the highest order of integration among the variables. One key advantage of the Toda-Yamamoto non-causality test is its ability to produce stable results even in the presence of structural breaks, as it does not require pre-testing for stationarity or cointegration (Daly et al, 2024; Jaber et al., 2025; Zapata, and Rambaldi, 2008). Although structural breaks often distort the outcomes of conventional unit root and cointegration tests, leading to biased or misleading inferences, the Toda-Yamamoto approach addresses this issue by estimating the VAR model in levels and incorporating additional lags to account for the maximum order of integration. This makes it a more robust and reliable framework for identifying causal relationships in time series data that may be influenced by economic shocks, policy changes, or other structural shifts.

This study utilizes time series data from 1971 to 2023 to analyze the relationship between FDI, GDP and CO2 emissions. The data for FDI and GDP were gathered from the World Development Indicator (WDI), while the CO2 emissions data were obtained from Our World in Data (OWID). Accordingly, the findings from the analysis will provide insights into how FDI impacts economic growth and environmental outcomes in the context of ASEAN-5 countries.

4. Findings and Discussion

This section presents the empirical results obtained from the econometric analysis of the relationships among FDI, GDP, and CO2 emissions within the ASEAN-5 countries. The analysis follows a methodical approach, beginning with descriptive statistics, tests for stationarity, and cointegration testing to causality analysis. Each step is designed to uncover the intricate dynamics and causal interactions between FDI, GDP and CO2 emissions.

4.1 Descriptive Statistics

Table I summarizes the descriptive statistics for FDI, GDP and CO2 emissions across the ASEAN-5 countries. Based on the information, Indonesia exhibits an average FDI of $6,390 million, ranging from a minimum of -$4,550 million to a maximum of $25,100 million, indicating volatile investment patterns. Notably, the GDP averages $459,000 million, with the economic output fluctuating between $82,600 million and $1,180,000 million. This reflects periods of significant economic expansion and contraction. Meanwhile, the environmental impact, as measured by CO2 emissions, averages 291.20 million tons, with a minimum of 38.95 million tons and a peak of 737.07 million tons, highlighting significant variability in emissions.

In Malaysia, the data indicates an average FDI of $4,750 million, ranging from $100 million to $20,200 million. The GDP in Malaysia averages $154,000 million, with a notable range from $20,800 million to $401,000 million. At the same time, CO2 emissions average 123.81 million tons, ranging from 16.66 million to 288.82 million tons.

In the Philippines, FDI averages $2,400 million, ranging from -$106 million to $12,000 million. The GDP averages $172,000 million, stretching from $53,500 million to $430,000 million. CO2 emissions are consistently low, averaging 67.65 million tons, ranging from 26.40 million to 154.57 million tons.

Singapore boasts the highest average FDI among the group at $30,100 million, with investment reaching up to $175,000 million and dipping as low as $116 million. The average GDP is $150,000 million, fluctuating from $16,300 million to $387,000 million. Note that Singapore also has the lowest environmental impact, with CO2 emissions averaging 39.86 million tons, ranging from 16.27 million to 60.08 million tons.

Finally, Thailand's FDI averages $4,180 million, ranging from -$4,290 million to $15,900 million. The GDP averages $223,000 million, substantially ranging from $36,600 million to $460,000 million. CO2 emissions average 149.36 million tons, with a minimum of 19.21 million tons and a maximum of 288.30 million tons, reflecting variability in industrial and environmental conditions.

Based on the data, it can be concluded that Singapore stands out with the highest average FDI and substantial economic performance peaks, coupled with the lowest CO2 emissions. This reflects Singapore's robust economic infrastructure and effective environmental policies, positioning it as a leader in sustainable management among the ASEAN-5 countries.

Table I: Descriptive statistics

Variables	Obs	Unit	Mean	Median	Max	Min	Std. Dev.
Indonesia							
FDI	53	US$ million	6390	1480	25100	-4550	9020
GDP	53	US$ million	459000	381000	1180000	82600	319000
CO2	53	million tonnes	291.20	253.06	737.07	38.95	200.85
Malaysia							
FDI	53	US$ million	4750	3900	20200	100	4740
GDP	53	US$ million	154000	129000	401000	20800	115000
CO2	53	million tonnes	123.81	109.78	288.82	16.66	91.15
Philippines							
FDI	53	US$ million	2400	1220	12000	-106	3260
GDP	53	US$ million	172000	132000	430000	53500	107000
CO2	53	million tonnes	67.65	66.27	154.57	26.40	37.07
Singapore							
FDI	53	US$ million	30100	11400	175000	116	42200
GDP	53	US$ million	150000	122000	387000	16300	119000
CO2	53	million tonnes	39.86	40.80	60.08	16.27	9.79
Thailand							
FDI	53	US$ million	4180	2440	15900	-4290	4700
GDP	53	US$ million	223000	214000	460000	36600	142000
CO2	53	million tonnes	149.36	167.23	288.30	19.21	96.83

4.2 Unit Root Test

Table II reports the results of the Augmented Dickey-Fuller (ADF) unit root test for each dataset from the ASEAN-5 countries.

Table II: Augmented Dicky-Fuller (ADF) unit root test

Variable		Level		1st difference	
		Intercept	Intercept & trend	Intercept	Intercept & trend
Indonesia	FDI	-0.708572	-2.880251	-9.310144***	-9.303637***
	GDP	5.347620	0.654775	-3.928255***	-5.586103***
	CO2	3.531205	0.038167	-2.771681*	-4.635501***
Malaysia	FDI	1.861435	-0.428799	-2.694303*	-3.503803*
	GDP	1.108989	-0.422436	-5.505480***	-7.233579***
	CO2	1.171544	-2.474216	-6.127239***	-6.664578***
Philippines	FDI	1.404320	-0.131698	-3.185169**	-3.911714**
	GDP	2.576947	0.596920	-5.408660***	-6.776482***
	CO2	2.327771	-0.409861	-5.689443***	-4.520505***
Singapore	FDI	5.000288	4.957045	-4.956485***	-6.195151 ***
	GDP	0.546043	-1.158905	-4.678055***	-6.889964***
	CO2	-1.751602	-2.263650	-7.163175***	-7.251633***
Thailand	FDI	-1.134099	-2.455232	-11.37189***	-11.25807***
	GDP	0.946223	-2.719309	-4.454989***	-4.528262***
	CO2	-0.796735	-0.805318	-4.873212***	-4.846178***

The value in parentheses represents the p-value of the test. ***, ** and * indicate the significance level at 1%, 5% and 10% respectively.

The result revealed that for all five countries, the variables FDI, GDP, and CO2 emissions are non-stationary at levels, as the test statistics failed to reject the null hypothesis of a unit root. However, after first differencing, all variables became stationary. This confirms that all variables are integrated into order one, *I(1)*. Hence, the study can proceed with Johansen's cointegration test to examine the existence of long-term equilibrium relationships among the variables.

4.3 Cointegration Test

To examine the presence of long-term equilibrium relationships among FDI, GDP, and CO2 emissions, Johansen's cointegration test was conducted. The test results, summarized in Table III, are based on the Trace statistic, and the calculated values are compared against the critical value at the 5% significance level. In addition, the null hypothesis indicates no cointegration among the variables (H_0: r = 0).

Table III. Johansen's cointegration test

Country	Variable	No. of CE(s)	Trace statistic	Critical value (5%)	Decision
Indonesia	GDP-FDI	None*	23.5630	15.49471	Reject H0
		At most 1*	6.8635	3.841465	Reject H0
	CO2-FDI	None*	17.9091	15.49471	Reject H0
		At most 1	3.5034	3.841465	Do not reject
	CO2-GDP	None*	17.9646	15.49471	Reject H0
		At most 1*	6.7834	3.841465	Reject H0
Malaysia	GDP-FDI	None*	31.9971	15.49471	Reject H0
		At most 1*	8.7038	3.841465	Reject H0
	CO2-FDI	None*	35.5433	15.49471	Reject H0
		At most 1	1.6922	3.841465	Do not reject
	CO2-GDP	None*	21.4947	15.49471	Reject H0
		At most 1	3.8415	3.841465	Do not reject
Philippines	GDP-FDI	None*	22.3389	15.49471	Reject H0
		At most 1*	4.4149	3.841465	Reject H0
	CO2-FDI	None	5.9576	15.49471	Do not reject
		At most 1	0.7093	3.841465	Do not reject
	CO2-GDP	None*	15.6267	15.49471	Reject H0
		At most 1*	3.9841	3.841465	Reject H0
Singapore	GDP-FDI	None*	33.3575	15.49471	Reject H0
		At most 1*	6.8164	3.841465	Reject H0
	CO2-FDI	None*	23.7550	15.49471	Reject H0
		At most 1*	4.8505	3.841465	Reject H0
	CO2-GDP	None*	18.1510	15.49471	Reject H0
		At most 1	2.5226	3.841465	Do not reject
Thailand	GDP-FDI	None*	30.1655	15.49471	Reject H0
		At most 1	0.2343	3.841465	Do not reject
	CO2-FDI	None*	16.9739	15.49471	Reject H0
		At most 1	0.6980	3.841465	Do not reject
	CO2-GDP	None	6.0274	15.49471	Do not reject
		At most 1	0.5103	3.841465	Do not reject

* denotes rejection of the null hypothesis of no cointegration at 5% significance level.

In Indonesia, the GDP-FDI relationship exhibits evidence of two cointegrating equations, as the null hypothesis of no cointegration ($r = 0$) and, at most, one cointegration relationship ($r \leq 1$) were both rejected. For CO2-FDI, the null hypothesis of no cointegration ($r = 0$) was rejected. Nonetheless, at most, one cointegration relationship ($r \leq 1$) could not be rejected, indicating one cointegrating relationship. Similarly, CO2-GDP revealed two cointegrating relationships, as both null hypotheses were rejected.

In Malaysia, both GDP-FDI and CO2-GDP relationships exhibit two cointegrating equations, as the null hypotheses of no cointegration and, at most, one cointegration relationship were rejected. For CO2-FDI, one cointegrating relationship was identified. For the Philippines, GDP-FDI and CO2-GDP each presented two cointegrating equations, as both null hypotheses were rejected in these cases. However, for CO2-FDI, the null hypothesis of no cointegration could not be rejected. This indicates no cointegrating relationships.

In Singapore, the result indicated that GDP-FDI and CO2-FDI exhibit two cointegrating equations, indicating strong long-term equilibrium relationships among the variables. However, for CO2-FDI, one cointegrating relationship was identified. Lastly, in Thailand, GDP-FDI and CO2-FDI each have one cointegrating relationship, as the null hypothesis of no cointegration ($r = 0$) was rejected. However, the null for at most one ($r \leq 1$) could not be rejected. Despite that, for CO2-GDP, neither null hypothesis was rejected, indicating no cointegration between these variables.

In conclusion, The Johansen cointegration test results reveal varying levels of long-term relationships across countries and variable pairs. Indonesia, Malaysia, and Singapore exhibit stronger evidence of interconnectedness among FDI, GDP, and CO2 emissions, with multiple cointegrating relationships, compared to the Philippines and Thailand. Accordingly, these findings highlight the diverse dynamics of economic and environmental linkages among the ASEAN-5 countries.

4.4 Toda-Yamamoto non-causality Test

The Toda-Yamamoto non-causality test examined the short-run causal relationships between FDI, GDP, and CO2 emissions in the ASEAN-5 countries. The findings reported in Table IV reveal nuanced interdependencies among the variables, shedding light on the dynamics of FDI, GDP and CO2 emissions in these economies.

First, the result of the causal relationship between FDI and GDP reveals bidirectional causality between FDI and GDP across the ASEAN-5 countries, which underscores the mutual reinforcement of FDI and economic growth. Moreover, this robust relationship reflects the strategic significance of foreign investment as a catalyst for economic progress in the ASEAN-5 economies. This result is consistent with Pao and Tsai (2011), who highlighted the interdependence between FDI and GDP in driving economic development in emerging markets.

Examining the relationship between FDI and CO2 emissions, a unidirectional causality from FDI to CO2 emissions was identified in Indonesia, Malaysia, the Philippines, and Thailand. This finding supports the pollution haven hypothesis in these countries, suggesting that foreign investment may contribute to increased emissions, particularly in sectors reliant on energy-intensive. As supported by Kbawlah (2023), based on a study in Sub-Saharan Africa, FDI inflows may lead to increased emissions, particularly in sectors reliant on fossil fuels or energy-intensive activities.

In contrast, the absence of causality between FDI and CO2 emissions in Singapore indicates a divergence from this pattern. Similar to findings by Wang et al. (2023), which suggested that higher-income countries are better positioned to decouple economic growth

from environmental degradation, Singapore's advanced environmental regulations and green investment policies likely mitigate the environmental impact of FDI.

Table IV. Toda-Yamamoto non-causality test

Country	Null hypothesis	Chi-square	p-value	Decision
Indonesia	FDI does not Granger cause GDP	36.74653***	0.0002	Reject H_0
	GDP does not Granger cause FDI	22.90355**	0.0286	Reject H_0
	FDI does not Granger cause CO2	33.34494***	0.0009	Reject H_0
	CO2 does not Granger cause FDI	17.31234	0.1382	Do not reject
	GDP does not Granger cause CO2	15.55562	0.2124	Do not reject
	CO2 does not Granger cause GDP	8.705561	0.7279	Do not reject
Malaysia	FDI does not Granger cause GDP	36.46612***	0.0003	Reject H_0
	GDP does not Granger cause FDI	23.03841**	0.0274	Reject H_0
	FDI does not Granger cause CO2	81.12475***	0.0000	Reject H_0
	CO2 does not Granger cause FDI	14.86772	0.2488	Do not reject
	GDP does not Granger cause CO2	27.14567***	0.0074	Reject H_0
	CO2 does not Granger cause GDP	11.36076	0.4983	Do not reject
Philippines	FDI does not Granger cause GDP	22.53016**	0.0320	Reject H_0
	GDP does not Granger cause FDI	59.98700***	0.0000	Reject H_0
	FDI does not Granger cause CO2	9.570453**	0.0483	Reject H_0
	CO2 does not Granger cause FDI	6.383676	0.1723	Do not reject
	GDP does not Granger cause CO2	28.46216***	0.0027	Reject H_0
	CO2 does not Granger cause GDP	20.39832**	0.0403	Reject H_0
Singapore	FDI does not Granger cause GDP	146.4907***	0.0000	Reject H_0
	GDP does not Granger cause FDI	45.37191***	0.0000	Reject H_0
	FDI does not Granger cause CO2	6.281910	0.9012	Do not reject
	CO2 does not Granger cause FDI	2.034820	0.9994	Do not reject
	GDP does not Granger cause CO2	3.450345	0.9914	Do not reject
	CO2 does not Granger cause GDP	7.537097	0.8202	Do not reject
Thailand	FDI does not Granger cause GDP	70.83955***	0.0000	Reject H_0
	GDP does not Granger cause FDI	31.45191***	0.0017	Reject H_0
	FDI does not Granger cause CO2	46.20807***	0.0000	Reject H_0
	CO2 does not Granger cause FDI	9.883314	0.6262	Do not reject
	GDP does not Granger cause CO2	14.87631	0.2483	Do not reject
	CO2 does not Granger cause GDP	12.21171	0.4288	Do not reject

*** and ** indicates the rejection of the null hypothesis at 1% and 5%, significance level.

Moving further to the relationship between GDP and CO2 emissions, the absence of causality between GDP and CO2 emissions in Indonesia, Singapore, and Thailand provides an interesting insight into the decoupling of economic growth from environmental degradation in

these countries. These findings contrasted with those in other regions, such as in South Asia (Nur Mozahid et al., 2022) and China (Zhang and Zhang, 2018), indicating that economic growth in these countries may not be directly linked to carbon emissions in the short run.

In the case of Singapore, stringent environmental regulations, advanced technologies, and a shift toward cleaner energy sources have likely mitigated the impact of GDP growth on emissions. Meanwhile, the lack of causality for Indonesia and Thailand could indicate that emissions are driven more by specific industrial sectors rather than aggregate economic activity. In addition, these results suggest that targeted, sector-specific interventions and continued investments in sustainable practices could further enhance sustainability while maintaining economic progress.

On the other hand, the results suggest a unidirectional causality running from GDP to CO2 emissions in Malaysia, while a bidirectional causality was observed in the case of the Philippines. The unidirectional relationship in Malaysia indicates that economic growth is a significant driver of carbon emissions, likely due to industrialization and energy consumption patterns associated with GDP expansion. This aligns with findings in similar developing economies where industrial growth and reliance on fossil fuels primarily contribute to emissions (Nur Mozahid et al., 2022).

In contrast, the bidirectional causality in the Philippines highlights a cyclical relationship. That is, GDP growth contributes to CO2 emissions, and environmental degradation may also provide feedback into economic activities, possibly through increased costs or reduced productivity in pollution-sensitive sectors. This aligns with the cyclical relationships identified in studies such as Rai et al. (2019), emphasizing the complex interplay between economic activities and environmental outcomes.

These findings provide valuable insights for policymakers, underscoring the importance of tailored approaches to sustainable development. For ASEAN-5 countries, policies should focus on attracting green FDI, decarbonizing growth-driving industries, and fostering technological innovation to balance economic progress with environmental sustainability. Nevertheless, by addressing these challenges, this study contributes to the broader discourse on sustainable economic development, offering actionable guidance for one of the most dynamic and rapidly growing regions in the world.

5. Concluding Remarks

This study examined the relationships between FDI, GDP, and CO2 emissions across the ASEAN-5 countries. The bidirectional causality between FDI and GDP found in this study underscores the critical role of foreign investment in driving economic growth in the region. However, the unidirectional causality from FDI to CO2 emissions observed in most countries (except Singapore) raises concerns about the environmental costs associated with FDI inflows, supporting the pollution haven hypothesis in these countries. Furthermore, the significant causality observed between GDP and CO2 emissions in Malaysia and the Philippines emphasizes the ongoing environmental challenges tied to economic expansion.

The findings of this study have significant implications for policymakers. The bidirectional causality between FDI and GDP emphasizes the importance of foreign investment in driving economic growth, while economic expansion, in turn, attracts more foreign capital. Governments should focus on creating investment-friendly environments that leverage FDI for sustainable development.

On the other hand, the unidirectional causality from FDI to CO2 emissions in all countries except for Singapore highlights the environmental challenges associated with foreign

investment, which supports the pollution haven hypothesis in these countries. Hence, policymakers should focus on attracting green FDI by offering incentives for environmentally friendly investments and ensuring that regulatory frameworks prioritize sustainability.

Finally, for countries like Malaysia and the Philippines, where GDP growth significantly drives CO2 emissions, efforts should prioritize transitioning to renewable energy, enhancing energy efficiency, and decarbonizing high-emission industries. Notably, Singapore's success in decoupling economic growth from CO2 emissions provides a model for implementing sustainable practices that other ASEAN countries can adopt. Moreover, regional collaboration within ASEAN could help facilitate sharing best practices, technology transfers, and joint initiatives to address the shared challenges of economic growth and environmental sustainability.

Future research can build on this study in several important ways. First, future studies may consider incorporating structural breaks or applying break-adjusted cointegration techniques, such as the Gregory-Hansen test, to assess whether the long-run and short-run relationships between FDI, GDP, and CO2 emissions vary across economic regimes. Second, while this study adopts a country-specific time series approach, future research could employ panel data techniques to capture regional dynamics and potential cross-country interdependencies within the ASEAN-5 countries. Lastly, future studies could explore nonlinear causality relationships to better capture the complex interactions between economic activity and environmental outcomes over time.

References

Adebayo, T. S., Awosusi, A. A., Kırıkkaleli, D., Akinsola, G. D., & Mwamba, M. N. (2021). Can CO2 emissions and energy consumption determine the economic performance of South Korea? A time series analysis. *Environmental Science and Pollution Research*, 28, 38969-38984.https://doi.org/10.1007/s11356-021-13498-1

Albur, M. (2019). The impact of domestic and direct foreign investment on the economic growth in Sudan: Evidence from granger causality and VAR framework. *Journal of Economics and Development Studies*, 7(4), 101-109. https://doi.org/10.15640/jeds.v7n4a9

Borensztein, E., De Gregorio, J., & Lee, J. W. (1998). How does foreign direct investment affect economic growth? *Journal of International Economics*, 45(1), 115–135. https://doi.org/10.1016/S0022-1996(97)00033-0

Bunnag, T. (2023). Analyzing short-run and long-run causality relationship among CO2 emission, energy consumption, GDP, square of GDP, and foreign direct investment in Environmental Kuznets Curve for Thailand. *International Journal of Energy Economics and Policy*, *13*(2), 341-348. https://doi.org/10.32479/ijeep.14088

Daly, H., Abdulrahman, B. M. A., Ahmed, S. A. K., Abdallah, A. E. Y., Elkarim, S. H. E. H., Sahal, M. S. G., ... & Elshaabany, M. M. (2024). The dynamic relationships between oil products consumption and economic growth in Saudi Arabia: Using ARDL cointegration and Toda-Yamamoto Granger causality analysis. *Energy Strategy Reviews*, 54, 101470. https://doi.org/10.1016/j.esr.2024.101470

Danso, E. I. and Boateng, E. K. (2020). Impact of Income Inequality on Economic Growth – Evidence from the Ten (10) Biggest Economies in Africa. *Journal of Economics and Sustainable Development*, 10(14), 57-62.

Do, T. V. T., & Dinh, H. L. (2020). Short-and long-term effects of GDP, energy consumption, FDI, and trade openness on CO2 emissions. *Accounting*, 6(3), 365-372.

Gaikwad, P. (2013). The impact of Foreign Direct Investment (FDI) on Gross Domestic Production (GDP) in Indian economy. *Information Management and Business Review*, 5(8), 411-416. https://doi.org/10.22610/imbr.v5i8.1069

Jaber, M. M., Szép, T., El-Naqa, A. R., & Abusmier, S. A. (2025). Energy consumption, economic growth, and climate change nexus in Jordan: insights from the Toda Yamamoto causality test. *Resources*, 14(3), 36. https://doi.org/10.3390/resources14030036

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with appucations to the demand for money. *Oxford Bulletin of Economics and Statistics*, *52*(2), 169-210.

Kim, S. (2019). CO2 emissions, Foreign Direct Investments, energy consumption, and GDP in developing countries: A more comprehensive study using panel vector error correction model. *The Korean Economic Review*, 35(1), 5-24.

Kongsirikorn, K., Chaiboonsri, C., and Saosaovaphak, A. (2023). Dependent Structure of Gross Domestic Product and Inflow of Foreign Direct Investment from China in Asean Member Countries Using Varma-Garch Copula Approach. *Journal of Economic Research & Review*, 3(4), 304-337.

Kwablah, E. (2023). Foreign direct investment, gross domestic product and carbon dioxide emission in sub-Saharan Africa: a disaggregated analysis. *Transnational Corporations Review*, 15(4), 59-68. https://doi.org/10.1016/j.tncr.2023.01.001

Mai, T. N. (2023). Renewable Energy, GDP (Gross Domestic Product), FDI (Foreign Direct Investment) and CO2 Emissions in Southeast Asia Countries. *International Journal of Energy Economics and Policy*, 13(2), 284-289. https://doi.org/10.32479/ijeep.14022

Mohsin, M., Naseem, S., Sarfraz, M., & Azam, T. (2022). Assessing the effects of fuel energy consumption, foreign direct investment and GDP on CO2 emission: New data science evidence from Europe & Central Asia. *Fuel*, 314, 123098. H ttps://doi.org/10.1016/j.fuel.2021.123098

Muthusamy, A., & Rani, P. J. (2019). FDI, GDP, and CO2 emission: ARDL bound cointegration relationship examination. *International Journal of Recent Technology and Engineering (IJRTE)*, 8(2S10), 132-138.

Ngoc, N. B., Xuan, V. N., & Huong, L. M. (2024). Nexus between carbon dioxide emissions, population, migration, foreign direct investment, and gross domestic product: New evidence in the context of Vietnam. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(2), 100281. https://doi.org/10.1016/j.joitmc.2024.100281

Nur Mozahid, M., Akter, S., & Hafiz Iqbal, M. (2022). Causality analysis of CO2 emissions, foreign direct investment, gross domestic product, and energy consumption: empirical evidence from South Asian Association for Regional Cooperation (SAARC) countries. *Environmental Science and Pollution Research*, 29, 65684-65698. https://doi.org/10.1007/s11356-022-20362-3

Pao, H., & Tsai, C. (2011). Multivariate Granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. *Energy*, 36(1), 685-693. https://doi.org/10.1016/j.energy.2010.09.041

Rai, S. K., Bembey, A. M., & Sarfare, D. (2019). Empirical verification of causality between CO2 emissions, energy consumption, foreign direct investment, gross domestic product, and openness of the economy: Evidence from India. *International Journal of Sustainable Economy*, 11(3), 237-257. https://doi.org/10.1504/IJSE.2019.100679

Ruranga, C., Ocaya, B., & Kaberuka, W., & (2014). Var analysis of economic growth, domestic investment, foreign direct investment, domestic savings and trade in Rwanda. *Greener Journal of Economics and Accountancy*, 3(2), 030-041.

Tamazian, A., & Rao, B. B. (2010). Do economic, financial, and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Economics*, 32(1),137–145. https://doi.org/10.1016/j.eneco.2009.04.004

Tang, C. F., Tan, B. W., & Ozturk, I. (2016). Energy consumption and economic growth in Vietnam. *Renewable and Sustainable Energy Reviews*, 54, 1506–1514. https://doi.org/10.1016/j.rser.2015.10.083

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, 66(1-2), 225-250. https://doi.org/10.1016/0304-4076(94)01616-8

Wang, Q., Yang, T., Li, R., & Wang, X. (2023). Reexamining the impact of foreign direct investment on carbon emissions: does per capita GDP matter? *Humanities and Social Sciences Communications*, 10, 406. https://doi.org/10.1057/s41599-023-01895-5

Xu, S., He, Z., Long, R., Shen, W., Ji, S., & Chen, Q. (2015). Impacts of economic growth and urbanization on co2 emissions: regional differences in China based on panel estimation. *Regional Environmental Change*, 16(, 777-787. https://doi.org/10.1007/s10113-015-0795-0

Yang, Z., Cai, J., Lu, Y., & Zhang, B. (2022). The impact of economic growth, industrial transition, and energy intensity on carbon dioxide emissions in China. *Sustainability*, 14(9), 4884. https://doi.org/10.3390/su14094884

Zapata, H. O., & Rambaldi, A. N. (2008). Monte Carlo evidence on cointegration and causation. *Oxford Bulletin of Economics and Statistics*, 59(2), 285-298. https://doi.org/10.1111/1468-0084.00065

Zhang, Y., & Zhang, S. (2018). The impacts of GDP, trade structure, exchange rate and FDI inflows on China's carbon emissions. *Energy Policy*, 120, 347-353. https://doi.org/10.1016/j.enpol.2018.05.056

Zubair, A. O., Samad, A. A., & Dankumo, A. M. (2020). Does gross domestic income, trade integration, FDI inflows, GDP, and capital reduces CO2 emissions? An empirical evidence from Nigeria. *Current Research in Environmental Sustainability*, 2, 100009. https://doi.org/10.1016/j.crsust.2020.100009