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FDI-ENVIRONMENTAL QUALITY NEXUS: SOUTHEAST ASIAN TIGER CUB ECONOMIES

Yong Sze Wei♣
Faculty of Business and Management, Universiti Teknologi MARA, 94300 Kota Samarahan, Sarawak, Malaysia

Jerome Kueh Swee Hui
Faculty of Economics and Business, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

ABSTRACT

Foreign Direct Investment (FDI) is a crucial catalyst for economic growth in countries, especially in the Southeast Asian Tiger Cub economies, including Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. Nonetheless, the impact of foreign direct investment on environmental quality may differ by region. This study aims to investigate the impact of the FDI on carbon dioxide emission among Tiger Cub economies. Panel Autoregressive Distributed Lag (ARDL) and quadratic estimation methods are adopted in the study to estimate the relationship between FDI and carbon dioxide emission from 1995 to 2022, in view of linearity and non-linearity aspects. Empirical findings indicate that there is a negative relationship between FDI and carbon dioxide emission in the long run under the linearity model and supported the Pollution Halo Hypothesis (PHH). Furthermore, the non-linearity results show that existence on inverted U-Shaped relationship between FDI and carbon dioxide emission. There is a positive impact of FDI on carbon dioxide emission when FDI is below the threshold level, while there is a negative impact of FDI on carbon dioxide emission when FDI is above the threshold level. The government should encourage green investment by offering business incentives or carbon credits, with a focus on high-value sectors such as advanced manufacturing, technology, renewable energy and research and development, as well as promoting technology transfer and innovation to attract foreign direct investment and stimulate economic growth, all while reducing environmental degradation.

***Keywords**:* Foreign Direct Investment (FDI), carbon dioxide emissions, ARDL, non-linear

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1. INTRODUCTION

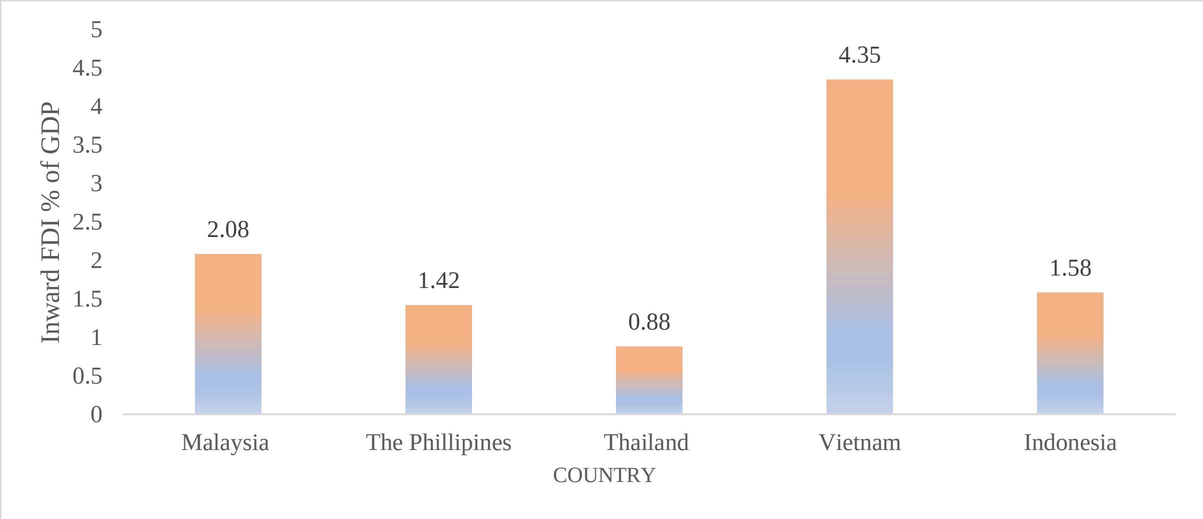
The "Tiger Cub Economies" of Southeast Asia, including Indonesia, Malaysia, the Philippines, Thailand, and Vietnam, have demonstrated remarkable economic growth due to export-driven strategies and technological advancements. Recent studies show that economic growth in these countries has been significantly influenced by key macroeconomic indicators, particularly export value and manufacturing value added, which have positively impacted growth over the past two decades (Nguyen, 2018). However, this growth has also exacerbated environmental degradation, with studies highlighting that economic development in Southeast Asia has not been accompanied by adequate environmental safeguards. For example, increased financial development and economic growth in the region have been associated with higher ecological footprints, underscoring the need for enhanced renewable energy generation and environmentally friendly growth policies (Zeraibi et al., 2021). Despite these insights, there remains a lack of focused studies such as Foreign Direct Investment (FDI) on the environmental implications of economic growth in the Tiger Cub economies, pointing to a critical research gap that needs to be addressed.

Foreign Direct Investment (FDI) has played a critical role in the economic development of the ASEAN-5 countries-Indonesia, Malaysia, the Philippines, Thailand, and Vietnam contributing significantly to their GDP growth. Between 1970 and 2013, FDI positively impacted economic growth in Malaysia, Thailand, and Indonesia, with Gross Domestic Investment (GDI) also playing a major role. However, the effects of FDI is vary across the

♣ Corresponding author: Yong Sze Wei, Faculty of Business and Management, Universiti Teknologi MARA, 94300 Kota Samarahan, Sarawak, Malaysia. Email: yongszewei@uitm.edu.my

region; for example, Singapore did not exhibit long-run cointegration with FDI but still benefited from short-run effects (Ridzuan et al., 2018). Comparative analyses reveal that while FDI has driven growth in ASEAN, it also poses risks to natural resource abundance, suggesting that unchecked FDI could lead to environmental degradation (Ridzuan et al., 2021). This dual nature of FDI promoting economic growth while risking environmental harm highlights the need for policies that balance economic benefits with sustainable development in the region. The inward FDI of Tiger-Cub Economies for the year 2023 is shown in Figure 1 below.

Figure 1: Inwards FDI for Tiger-Cub Economies in 2023



Source: UNCTAD, based on FDI/MNE database (www.unctad.org). Retrieve from https://unctadstat.unctad.org/datacentre/

Based on the Figure 1, the inward foreign direct investment (FDI) of the five Tiger Cub economies demonstrates significant disparity, with Vietnam at the forefront, accounting for 4.34% of its GDP. This is indicative of Vietnam's increasing status as a manufacturing hub and a primary attraction for foreign investors. A diverse array of high-tech and natural resource-oriented investments is attracted to Malaysia, which is ranked at 2.08%. Indonesia's considerable domestic market and resource abundance attract moderate foreign investment, with an FDI rate of 1.58%. However, its full potential may be impeded by infrastructure and regulatory obstacles. Despite its strong performance in industries such as business process outsourcing (BPO), the Philippines experiences a decrease in foreign direct investment levels, which currently stands at 1.42%. Meanwhile, Thailand has the lowest FDI share at 0.88%, which is likely due to economic and political concerns. The inward FDI of a country is indicative of its economic dynamics and appeal to foreign investors.

Tiger Cub economies of Southeast Asia, particularly Vietnam, Myanmar, the Philippines, and Thailand, faces significant environmental vulnerabilities exacerbated by climate change and rapid economic growth. Recent studies reveal that economic growth and urbanization in these countries have led to increased carbon emissions, with Indonesia having the largest urban population and Malaysia having the highest rate of urbanization and carbon emissions per capita among ASEAN countries (Tan & Hong, 2020). Additionally, the impacts of climate change, such as rising temperatures and erratic rainfall patterns, have adversely affected agriculture in Myanmar, leading to crop failures and reduced productivity in the dry zone, where climate change has severely impacted farm households (Oo et al., 2020). Comparative analyses show that while economic growth drives development, it also exacerbates environmental degradation, highlighting the need for sustainable policies that mitigate these impacts (Nasir et al., 2019). However, there remains a critical gap in research focusing specifically on the dual nature of FDI in influencing both economic growth and environmental degradation in the region, particularly in the context of Southeast Asia.

There are studies in Southeast Asia provide mixed evidence for the Pollution Haven Hypothesis (PHH) and the Pollution Halo Hypothesis (PHL). The Pollution Haven Hypothesis suggests that international trade and FDI can lead to increased global emissions by relocating polluting industries to countries with less stringent environmental regulations. This theory posits that developed countries' stringent environmental policies push pollution-intensive industries to developing nations, thereby increasing pollution in these host countries. Supporting evidence for this hypothesis indicates that foreign industries often exacerbate environmental degradation in nations with lax regulations. In contrast, the Pollution Halo Hypothesis argues that FDI can enhance environmental quality by introducing advanced technologies and innovative practices, which lead to cleaner production processes. This divergence in perspectives creates a policy dilemma for developing countries: they must choose between accepting FDI inflows that might boost economic productivity but harm the environment or prioritizing environmental protection at the expense of economic growth. To reconcile economic growth with sustainability, the Tiger Cub economies of Southeast Asia have implemented diverse foreign direct investment and environmental regulations. For instance, Malaysia actively encourages FDI by offering tax incentives and establishing designated economic zones, especially in the industrial, technology, and renewable energy sectors. Meanwhile, Vietnam promotes FDI by amending its investment legislation and prioritising areas such as manufacturing, information and communication technology, and renewable energy. In Thailand, government FDI via the Board of Investment (BOI), which offers tax advantages and non-fiscal benefits, especially for high-tech enterprises, the digital economy, and renewable energy sectors.

An examination of four ASEAN countries (Malaysia, the Philippines, Singapore, and Thailand) over the period from 1971 to 2014 found that while the PHH was supported in the Philippines, suggesting that weaker environmental regulations attract polluting industries, the PHL was more applicable in Malaysia and Singapore, where FDI has been associated with cleaner technologies and reduced emissions (Kisswani & Zaitouni, 2021). Another study covering ASEAN-5 countries confirmed the validity of the PHH, demonstrating that increased FDI contributes to environmental degradation, with a significant rise in CO2 emissions linked to FDI inflows (Guzel & Okumuş, 2020). However, the ongoing debate about FDI's environmental impact remains unresolved, with some studies suggesting the need for stronger policies to balance economic growth with environmental protection (Singhania & Saini, 2020).

Given the ongoing debate, this study aims to empirically assess the impact of FDI on environmental quality in the Tiger Cub economies. The relationship between FDI and environmental quality remains ambiguous and highly context-dependent. This study seeks to determine whether FDI in these economies exacerbates environmental degradation or contributes to sustainable development, thereby addressing a critical gap in the existing literature. The findings of this research will have significant policy implications. If FDI is found to primarily contribute to environmental harm, it may necessitate stricter environmental regulations and the promotion of more sustainable investment practices. Conversely, if FDI is shown to promote cleaner technologies and sustainable growth, it could reinforce the importance of attracting foreign investment while advancing environmental protection initiatives. Thus, understanding this dynamic is crucial for policymakers in the Tiger Cub economies as they strive to achieve sustainable economic development in an increasingly globalized world.

Following this introduction, the next section provides a comprehensive literature review, capturing previous studies and theoretical foundations relevant to our research topic. The third section details the methodology employed and describes the data used in the analysis. The fourth section presents the empirical results, followed by a thorough discussion in the fifth section that interprets the findings, draws out broader implications, and policy formulation.

2. LITERATURE REVIEW

The relationship between Foreign Direct Investment (FDI) and environmental quality has garnered significant academic attention, with studies producing varying conclusions depending on the regional context and methodological approaches employed. Some scholars have posited that FDI does not substantially affect environmental quality, a perspective supported by Sun et al. (2022), Nyeadi (2023), and Famanta et al. (2024). For instance, Sun et al. (2022) explored the impact of FDI on ecological footprints across the G11 nations, revealing that while FDI might not affect ecological footprints in the short term, it holds potential for improving air quality in the long run. This finding aligns with Nyeadi's (2023) study of 44 sub-Saharan African countries, which highlighted a complex relationship between FDI, carbon emissions, and clean energy consumption, particularly when disaggregated by income levels. In a similar vein, Famanta et al. (2024) investigated green FDI in 34 less-developed countries and found that it generally enhances environmental quality, with environmental costs associated with economic growth being mitigated.

Conversely, another body of research, including works by Abdul-Mumuni et al. (2022), Khan et al. (2023), and Fortune Ganda (2024), suggests that FDI can have a detrimental impact on environmental quality, particularly in contexts where institutional frameworks are weak. Abdul-Mumuni et al. (2022) examined the asymmetric effects of FDI on carbon emissions in sub-Saharan Africa, concluding that positive shocks in FDI tend to increase carbon emissions in the long term. Similarly, Khan et al. (2023) identified a positive correlation between FDI and pollution in developing countries, particularly those with lower levels of education, thus validating the Pollution Haven Hypothesis (PHH). Furthermore, Fortune Ganda (2024) confirmed the PHH in sub-Saharan Africa, where

FDI was found to be associated with environmental degradation, particularly in the presence of inadequate regulatory frameworks.

The ongoing debate surrounding the impact of FDI on environmental quality underscores the importance of considering contextual factors such as governance, institutional quality, and technological innovation. For instance, Uddin et al. (2024) demonstrated that the interaction between FDI and economic growth could reduce CO_2 emissions, particularly in low and lower-middle-income countries. This finding emphasizes the potential for FDI to contribute to sustainable development when coupled with strong institutional support and technological advancements. The relationship between economic growth and environmental degradation in Southeast Asia is complex. While economic growth is often seen as a pathway to development, it frequently comes at the cost of environmental quality. For example, industrialization and foreign direct investment (FDI) have been linked to increased environmental degradation, as these activities typically exploit natural resources without adequate environmental safeguards (Ahmed et al., 2022; Iswari & Kusuma, 2022). The influx of FDI in the Asia-Pacific region, which accounted for 45% of global inflows in 2018, raises concerns about its environmental implications, as many investments are associated with resource-intensive industries (Ahmed et al., 2022). This dynamic is particularly pronounced in Southeast Asia, where rapid economic growth has led to significant environmental challenges, including pollution and habitat destruction (Ahmed et al., 2022; Arfanuzzaman & Dahiya, 2019).

Comparatively, Southeast Asia's environmental vulnerabilities can be contrasted with those of other developing regions. Studies indicate that while FDI can stimulate economic growth, it also poses risks to environmental sustainability, particularly in regions with weaker regulatory frameworks (Ahmed et al., 2022; King & Du, 2022). The environmental impacts of FDI in Southeast Asia are similar to those observed in other developing areas, where economic activities often lead to significant ecological footprints (Ahmed et al., 2022; Rauf et al., 2018). This suggests a need for a more nuanced understanding of how FDI influences environmental quality, emphasizing the importance of robust environmental policies to mitigate degradation while promoting economic development (Ahmed et al., 2022; Nguyen et al., 2022). Empirical studies have demonstrated that Foreign Direct Investment (FDI) has a complex impact on environmental quality within the Tiger Cub economies, often following the Environmental Kuznets Curve (EKC) framework. A recent analysis covering Asian countries, including the ASEAN-5, reveals that FDI inflows significantly contribute to environmental degradation, as evidenced by increased CO_2 emissions (To et al., 2019). The study confirms the EKC hypothesis, indicating that while economic growth initially exacerbates environmental harm, a turning point is reached where further growth leads to environmental improvements. Comparative analyses further highlight that the Pollution Haven effect is prominent in developing regions, where weaker environmental regulations allow FDI to drive significant environmental degradation (Singhania & Saini, 2020).

The nature of foreign direct investment (FDI) also affects its environmental consequences. Chen et al. (2022) stated that the impacts of foreign direct investment (FDI) on environmental pollution can be classified into scale, structure and technology effects, with the latter two potentially resulting in emissions reductions when FDI is allocated to cleaner technologies. This is congruent with the findings of Fan et al. (2022) that while foreign direct investment (FDI) may enhance production activities and emissions, it can also promote technology transfer that alleviates environmental impacts, especially when the host country possesses the absorptive capacity to adopt such technologies. Despite these findings, there is still a need for more targeted research on the policy implications of FDI's environmental impact, particularly in promoting sustainable investment practices in the Southeast Asian Tiger Cub economies.

3. DATA AND METHODOLOGY

This study utilized annual panel data from 1995 to 2022 for Indonesia, Malaysia, Philippines, Thailand and Vietnam. All variables' data are extracted from The World Bank. Table 1 shows the data description of variables used in the study.

Table 1: Data Description of Variables

Variables	Description	Source
CO2	Carbon Dioxide Emissions (metric tons per capita)	World Development Indicator (WDI), World Bank
FDI	Foreign Direct Investment (US$)	
GDPPC	Gross Domestic Product Per Capita (US$)	
PO	Population (total)	
E	Export (US$)	

This study employs a linear model to analyze the impact of FDI on carbon emissions. The linear model measures the long-run and short-run aspects. This study further investigates the relationship between carbon emissions and FDI from the non-linear perspective. The model serves as to identify the turning point of FDI and subsequently examine the impact of FDI on carbon emissions when the FDI is above or below the threshold level. The model setup is based on the Kuznet curve model where fundamentally examine the association between environmental degradation and per capita income.

The linear model is specified as follows:

$$LCO2_{it} = \alpha_0 + \alpha_1 LFDI_{it} + \alpha_2 LGDPPC_{it} + \alpha_3 LPOP_{it} + \alpha_4 LE_{it} + \varepsilon_{it} \qquad (1)$$

where;

$LCO2$	=	logarithm of carbon dioxide emissions
$LFDI$	=	logarithm of foreign direct investment
$LGDPPC$	=	logarithm of gross domestic product per capita
$LPOP$	=	logarithm of population
LE	=	logarithm of export
α_i	=	coefficients of parameters of interest
ε	=	error term

The non-linear model is specified as follow:

$$LCO2_{it} = \beta_0 + \beta_1 LFDI_{it} + \beta_2 LFDI_{it}^2 + \beta_3 LGDPPC_{it} + \beta_4 LPOP_{it} + \beta_5 LE_{it} + \varepsilon_{it} \qquad (2)$$

where;

$LCO2$	=	logarithm of carbon dioxide emissions
$LFDI$	=	logarithm of foreign direct investment
$LGDPPC$	=	logarithm of gross domestic product per capita
$LPOP$	=	logarithm of population
LE	=	logarithm of export
β_i	=	coefficients of parameters of interest
ε	=	error term

3.1 Empirical Testing Procedures

3.1.1 Panel Unit Root Tests

This study applied the Levin, Lin and Chu (LLC) and Im, Pesaran and Shin (IPS) unit root tests to examine the stationarity of the variables. The LLC test, developed by Levin et al. (2002), assumes that the autoregressive (AR) dynamics are consistent across all members of the panel. It specifically suggests that each panel member shares the same AR(1) coefficient, while also accounting for individual-specific effects, time-related effects, and the possibility of a time trend. The model allows for differences only in the intercept and can be expressed as follows:

$$\Delta Y_{it} = \alpha_i + \gamma Y_{it-1} + \sum_{j=1}^{Pi} \beta_j \Delta Y_{it-j} + \varepsilon_{it} \qquad (3)$$

where ΔY_{it} represents the panel series for country i over time period t ($i = 1, 2, 3, \dots, N; t = 1, 2, 3, \dots, T$), P_i denotes the number of lags in the ADF regression and ε_{it} is the error term, which is assumed to be an independent and normally distributed random variable with a mean of zero and a finite heterogeneous variance across all *i* and *t*. The hypothesis of LLC unit root test is as follow:

$$H_0: \gamma = 0$$
$$H_1: \gamma < 0$$

The null hypothesis asserts that each series in the panel contains a unit root, while the alternative hypothesis indicates that all individual series in the panel are stationary. The null hypothesis will be rejected if the *p*-value is smaller than the 1%, 5%, or 10% significance level.

The IPS test, proposed by Im et al. (2003), is less restrictive compared to the LLC unit root test. The IPS test allows for heterogeneous coefficients, accommodating individual effects, time trends, and common time effects. As a result, the IPS test is considered to have greater power than other unit root tests. The model for the IPS unit root test is presented as follows:

$$\Delta Y_{it} = \alpha_i + \gamma_i Y_{it-1} + \sum_{j=1}^{Pi} \beta_{ij} \Delta Y_{it-j} + \varepsilon_{it} \qquad (4)$$

where ΔY_{it} represents the panel series for country iii over the time period t $(i = 1, 2, 3, \ldots, N; t = 1, 2, 3, \ldots, T)$, P_i denotes the number of lags in the ADF regression and ε_{it} is the error term, which is assumed to be an independent and normally distributed random variable with a mean of zero and a finite, heterogeneous variance across all i and t. The hypotheses for the IPS unit root test are as follows:

$$H_0: \gamma_i = 0$$
$$H_1: \gamma_i < 0 \text{ for all } i$$

The null hypothesis suggests that the panel is not stationary, while the alternative hypothesis indicates that at least one of the individual series in the panel is stationary. The null hypothesis will be rejected if the p-value is smaller than the 1%, 5%, or 10% significance level.

3.1.2 Panel Cointegration Test

This study employs the Pedroni cointegration test, developed by Pedroni (1999), to investigate the long-run equilibrium relationship between the variables. The Pedroni cointegration test includes seven different statistics, which are categorized into within-dimension (*panel v-statistic, panel rho-statistic, panel PP-statistic, panel ADF-statistic*) and between-dimension (*group rho-statistic, group PP-statistic, group ADF-statistic*). These seven statistics can be constructed as follow:

Panel *v*-statistic:

$$Z_v = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{\varepsilon}_{it-1}^2\right)^{-1}$$

Panel *rho*-statistic:

$$Z_\rho = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{\varepsilon}_{it-1}^2\right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{\varepsilon}_{it-1} \Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i\right)$$

Panel *PP*-statistic:

$$Z_t = \left(\hat{\sigma}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{\varepsilon}_{it-1}^2\right)^{-\frac{1}{2}} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{\varepsilon}_{it-1} \Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i\right)$$

Panel *ADF*-statistic:

$$Z_t^* = \left(\hat{s}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{\varepsilon}_{it-1}^{*2}\right)^{-\frac{1}{2}} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{\varepsilon}_{it-1}^{*} \Delta\hat{\varepsilon}_{it}^{*}$$

Group *rho*-statistic:

$$\tilde{Z}_\rho = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{\varepsilon}_{it-1}^2\right)^{-1} \sum_{t=1}^{T} \left(\hat{\varepsilon}_{it-1} \Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i\right)$$

Group *PP*-statistic:

$$\tilde{Z}_t = \sum_{i=1}^{N} \left(\hat{\sigma}^2 \sum_{t=1}^{T} \hat{\varepsilon}_{it-1}^2\right)^{-\frac{1}{2}} \sum_{t=1}^{T} \left(\hat{\varepsilon}_{it-1} \Delta\hat{\varepsilon}_{it} - \hat{\lambda}_i\right)$$

Group *ADF*-statistic:

$$\tilde{Z}_t^* = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{s}_i^{*2} \hat{\varepsilon}_{it-1}^{*2}\right)^{-\frac{1}{2}} \sum_{t=1}^{T} \hat{\varepsilon}_{it-1}^{*} \Delta\hat{\varepsilon}_{it}^{*}$$

where ε_{it} denotes the estimated residual, $\hat{L}_{11i}^{-2}$ denotes the estimated long-run covariance matrix for $\Delta\hat{\varepsilon}_{it}$, $\hat{\sigma}^2$, $\hat{s}^{*2}$ and $\hat{s}_i^{*2}$ indicate individual contemporaneous and long-run variances for individual i.

3.1.3 Panel ARDL Estimation

This study adopts the panel ARDL estimation method developed by Shin and Pesaran (1999) and Pesaran et al. (2001) to estimate the long-run cointegration relationships between the variables. There are several assumptions under Panel ARDL. First, the model can accommodates variables with varying integration levels *I*(0) and *I*(1). Secondly, it allows panel units to exhibit short-run dynamics and it assumes homogeneous long-run coefficients across panel units. Thirdly, the model incorporates an Error Correction term (ECT) to capture the speed from the short-term departures from long-run equilibrium. According to Pesaran et al. (2001), the panel ARDL estimation provides consistent estimates of the long-run coefficients, which are asymptotically normal, regardless of whether the variables are significant at *I*(0), *I*(1), or a mix of both in panel unit root tests. The general long-run model is presented as follows:

$$Y_{it} = \mu_i + \beta_i' X_{it} + \varepsilon_{it} \qquad (5)$$

where Y_{it} denotes dependent variable that country i over time period t $(i = 1, 2, 3, \ldots, N; t = 1, 2, 3, \ldots, T)$, μ_i denotes country-specific intercept term, β_i refers to the vector of coefficients vary across countries, X_{it} refers as vector of independent variables and ε_{it} is error term. The ARDL for bound test is shown as follow:

$$Y_{it} = \mu_i + \sum_{i=1}^{k} \delta_{ij} Y_{j,t-i} + \sum_{i=0}^{q} \beta_{it}' X_{j,t-i} + \varepsilon_{it} \qquad (6)$$

The Equation 3.13 is then reparametrized as follow:

$$\begin{aligned}\Delta LCO2_{it} = {} & \beta_1 + \sum_{i=1}^{k} \delta_{ij} \Delta LCO2_{j,t-i} + \sum_{i=0}^{k} \alpha_{ij} \Delta LFDI_{j,t-i} + \sum_{i=0}^{k} \partial_{ij} \Delta LFDI_{j,t-i}^2 \\ & + \sum_{i=0}^{k} \vartheta_{ij} \Delta LGDPPC_{j,t-i} + \sum_{i=0}^{k} \emptyset_{ij} \Delta LPOP_{j,t-i} + \sum_{i=0}^{k} \sigma_{ij} \Delta LE_{j,t-i} \\ & + \theta_1 LCO2_{j,t-i} + \theta_2 LFDI_{j,t-i} + \theta_3 LFDI_{j,t-i}^2 + \theta_4 LGDPPC_{j,t-i} \\ & + \theta_5 LPOP_{j,t-i} + \theta_6 LE_{j,t-i} + \varepsilon_{it} \qquad (7)\end{aligned}$$

where i denotes countries, t denotes time, Δ is first variation factors, k is ideal lag length.

The hypothesis of panel ARDL estimation is shown as follow:

$$H_0: \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta_6 = \theta_7 = \theta_8$$
$$H_1: \theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq \theta_6 \neq \theta_7 \neq \theta_8$$

The null hypothesis suggests that there is no cointegration, while the alternative hypothesis indicates the presence of cointegration between the variables. The null hypothesis of no cointegration will be rejected if the p-value is smaller than the 1%, 5%, or 10% significance level. Once the long-run correlation between the variables is established, the long-run model will be examined, as specified below:

$$LCO2_{it} = \beta_2 + \sum_{i=1}^{k} \delta_{i2} LCO2_{j,t-i} + \sum_{i=0}^{k} \alpha_{i2} LFDI_{j,t-i} + \sum_{i=0}^{k} \partial_{i2} LFDI_{j,t-i}^2 + \sum_{i=0}^{k} \vartheta_{i2} LGDPPC_{j,t-i} + \sum_{i=0}^{k} \emptyset_{i2} LPOP_{j,t-i} + \sum_{i=0}^{k} \sigma_{i2} LE_{j,t-i} + \varepsilon_{it2} \quad (8)$$

3.1.4. Turning Point Estimation

The study investigates the relationship between FDI and carbon emission in 4 ASEAN cub from the non-linear perspective. The relationship between FDI and carbon emission is expected to have an inverted U-shaped curvature. Hence, the turning point estimation by differential calculus approach is employed in the non-linear model with the aim to identify the turning point of FDI and how FDI impact on the carbon emission based on the threshold aspect. The real quadratic function is shown as follow:

$$f(x) = ax^2 + bx + c \quad (9)$$

where a, b, and c are real numbers and $a \neq 0$. Then, the tuning point can be capture by taking the first derivative in the Equation 3.16 and equalize to zero. The equations are shown as follow:

$$f'(x) = 2ax + b \quad (10)$$
$$x^* = \frac{-b}{2a} \quad (11)$$

The Equation (11) is then rewritten as follow:

$$LFDI^* = \frac{-\beta_1}{2\beta_2} \quad (12)$$

where $LFDI^*$ is the turning point of *LFDI*, β_1 and β_2 are the coefficients of the linear and quadratic term of *LFDI*, respectively.

4. RESULT AND DISCUSSION

4.1 Panel Unit Root Tests

Table 2 presents the panel unit root tests' results. Based on the results of the LLC unit root test, at level *I*(0), LCO2 and LFDI are stationary with trend and intercept, while LPOP and LE are stationary with intercept. LGDPPC is not stationary at *I*(0). After first difference *I*(1), all the variables are stationary, except LPOP. Based on the results of IPS unit root test, at *I*(0), LCO2 is stationary with trend and intercept, LPOP is stationary with intercept, while LFDI is stationary with both trend and intercept and intercept. Only LGDPPC and LE are not stationary. At *I*(1), all variables are stationary, except LPOP. In short, the findings of both unit root tests indicate that there is a mix results among the variables, which mean all variables are stationary at *I*(0), *I*(1) or both.

Table 2: Panel Unit Root Tests Results

Variables	LLC Unit Root Test [At Level]		IPS Unit Root Test [At Level]	
	Trend and Intercept	**Intercept**	**Trend and Intercept**	**Intercept**
LCO2	-1.7394** (0.0410)	-0.8947 (0.1855)	-2.1466** (0.0159)	1.9457 (0.9742)
LFDI	-3.6227*** (0.0001)	-0.74518 (0.2281)	-4.1508*** (0.0000)	-1.5765* (0.0574)
LGDPPC	-0.5545 (0.2896)	-0.1339 (0.4467)	-0.6791 (0.2485)	3.5772 (0.9998)
LPOP	2.0126 (0.9779)	-4.4071*** (0.0000)	4.7539 (1.0000)	-1.4483* (0.0738)
LE	-1.2146 (0.1122)	-4.0760*** (0.0000)	0.0065 (0.5026)	-0.0795 (0.4683)
Variables	**LLC Unit Root Test [First Difference]**		**IPS Unit Root Test [First Difference]**	
LCO2	-6.1608*** (0.0000)	-7.5371*** (0.0000)	-8.7145*** (0.0000)	-8.5123*** (0.0000)
LFDI	-5.9712*** (0.0000)	-8.2351*** (0.0000)	-7.7172*** (0.0000)	-9.4720*** (0.0000)
LGDPPC	-8.6071*** (0.0000)	-9.6703*** (0.0000)	7.3739*** (0.0000)	-8.5891*** (0.0000)
LPOP	1.9595 (0.9750)	-0.1579 (0.4373)	-0.7118 (0.2383)	1.5402 (0.9382)
LE	-7.8209*** (0.0000)	-8.6538*** (0.0000)	-6.6123*** (0.0000)	-7.6626*** (0.0000)

Notes: Asterisk ***, ** and * denotes as rejection at 1%, 5% and 10% significant level. LLC refers to Levin, Lin & Chu; IPS refers to Im, Pesaran & Shin. Values in parentheses refer to probability.

4.2 Pedroni Residual Cointegration Test

The results of Pedroni cointegration test are shown in Table 3. The null hypothesis of no cointegration will be rejected and indicates the variables have long-run equilibrium relationship if there are more than or equal to 4 out of 7 cointegration test statistics are statistically significant.

Table 3: Pedroni Cointegration Test's Results

	Statistic	**Standard Error**
Within-dimension:		
Panel *v*-Statistic	0.0488	0.4805
Panel *rho*-Statistic	0.5731	0.7167
Panel *PP*-Statistic	-1.9419**	0.0261
Panel *ADF*-Statistic	-2.9792***	0.0014
Between-dimension:		
Group *rho*-Statistic	1.1559	0.8761
Group *PP*-Statistic	-2.0223**	0.0216
Group *ADF*-Statistic	-2.7401***	0.0031

Notes: Asterisk ***, ** and * denotes as rejection at 1%, 5% and 10% significant level.

Based on the results in Table 3, there are 4 out of 7 cointegration test statistics are statistically significant. This includes 2 out of 4 within dimension cointegration test statistics are statistically significant at 5% and 1% level, respectively and there are 2 out of 3 between dimension cointegration test statistics are statistically significant at 5% and 1% level, respectively. Therefore, there is long-run equilibrium relationship between the parameters of interest.

4.3 Panel ARDL Estimation: Linear and Non-Linear Estimations

The findings of panel ARDL estimation and turning point estimation are exhibited in Table 4. The columns Linearity A and Non-Linearity B indicate the results for linear model and non-linear model, respectively, under Panel ARDL estimations. Column Non-Linearity C indicates the result of the Panel Dynamic Least Squares (DOLS), which act as robustness checking. Under the long-run linearity results, LFDI has a negative impact on LCO2 with coefficient of 0.0374 at 5% significant level. This outcome is consistent with the finding of Sun et al. (2022) and Famanta et al. (2024) where their studies supported the finding the FDI will improve the environmental quality in long run. The is due to the adoption of advanced technology via the FDI when the income of the country surge. These advanced technologies may have been more efficient and environmentally friendly. As a result, this,

this will cause the carbon emission decline in the long run upon rise of the FDI. The results also indicate that there is a positive relationship between LGDPPC, LPOP and LE with LCO2. In the short-run, only LGDPPC has a positive relationship with LCO2.

Under the long-run non-linearity results as shown in column Non-Linearity B, there is a turning point where FDI acts as the threshold variable in the model. FDI is selected as the threshold variable to examine the impact of FDI on carbon dioxide emissions when the FDI is above or below the threshold level by adopting the Quadratic form. The findings indicate that there is an inverted U-shaped relationship between FDI and carbon dioxide emission. The turning point of FDI level is 1.0253. The empirical results show that there is a positive relationship between FDI and carbon dioxide emission when FDI is below the threshold level, with the value of 1.0253 and statistically significant at 5% level. Intuitively, this indicates that increase in the FDI will lead to increase of the carbon dioxide emission, initially, when the FDI is below the threshold level. This indicates that the increment of the FDI level will cause carbon dioxide emission to increase initially. However, when the FDI is beyond the threshold level, there is a negative relationship between FDI and carbon dioxide emission with a coefficient of 0.0233. This indicates that increase in the FDI will cause the carbon dioxide emission to decline when the FDI is above the threshold level. This result is consistent with findings of Chen et al. (2022) and Fan et al. (2022). The intuition is that FDI has the potential to improve production activities and emissions. Nevertheless, it can facilitate technology transfer that mitigates environmental impacts, particularly when the host country has the absorptive capacity to implement such technologies.

The ECT under both linear and non-linear estimation results indicate that both are statistically significant at 1% and 5%, respectively and exhibit negative sign and less than 1. The ECT coefficient under the linearity model is 0.6777, which indicates the speed of adjustment is approximately 67.77% converging to long-run equilibrium upon short-run deviation. Meanwhile, the ECT coefficient under the non-linearity model is 0.6453, signifies approximately 64.53% of the speed of adjustment converging to long-run equilibrium. The Panel Dynamic Least Squares (DOLS) result serve as robustness checking purpose in the study. The results of the Panel DOLS show that there is a non-linearity relationship between carbon dioxide emission and FDI. The existence of non-linearity result is consistent with the Panel ARDL estimation results.

Table 4: Linear and Non-Linear Estimation Results

	Panel ARDL Estimation				**Panel Dynamic Least Squares (DOLS)**	
	Linearity (A)		**Non-Linearity (B)**		**Non-Linearity (C)**	
	Statistic	**Standard Error**	**Statistic**	**Standard Error**	**Statistic**	**Standard Error**
Long-run:						
LFDI	-0.0374**	0.0193	1.0749**	0.4887	0.5973***	0.1475
LFDI2	-	-	-0.0233**	0.0104	-0.0140***	0.0029
LGDPPC	1.1326***	0.0312	1.1617***	0.0354	1.0214***	0.1033
LPOP	0.2264*	0.1150	0.2211***	0.0467	-0.2094**	0.0997
LE	0.1974***	0.0094	0.1805***	0.0083	0.2633***	0.0208
Constant	0.2119	1.8029	-12.5877**	5.7311	-	-
Short-run:						
LFDI	-0.0288	0.0562	-2.5325	2.1427	-	-
LFDI2	-	-	-0.0189	0.0592	-	-
LGDPPC	0.5802***	0.1176	0.5651**	0.2212	-	-
LPOP	-12.1501	25.4261	-0.3306	15.8550	-	-
LE	-0.1000	0.07427	-0.0488	0.0444	-	-
ECT	-0.6777***	0.2376	-0.6453**	0.2664	-	-
Threshold (FDI)	-	-	1.0253	-	-	-

Notes: Asterisk ***, ** and * denotes as rejection at 1%, 5% and 10% significant level. ECT refers to Error-Correction Term. Dependent variable is Carbon dioxide emission. The threshold value of 1.0253 is antilog of the estimated threshold level.

5. CONCLUSION

FDI is a critical factor in the stimulation of economic development in countries, particularly in the Southeast Asia Tiger Cubs economies, which include Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. However, the environmental quality may differ across various regions as a result of FDI. The environmental quality of a country is influenced by FDI in two distinct ways: Pollution Haven Hypothesis (PHH) and the Pollution Halo Hypothesis

(PHL). The main objective of this study is to examine the impact of the FDI on carbon dioxide emission among Southeast Asia Tiger Cubs from 1955 to 2022. The adoption of Panel Autoregressive Distributed Lag (ARDL) and quadratic estimation methods in this study to estimate the relationship between FDI and carbon dioxide emission from the linearity and non-linearity aspects. Empirical findings of this study support the Pollution Halo Hypothesis and indicate that there is a negative relationship between FDI and carbon dioxide emission in the long run under the linearity model. Meanwhile, the non-linearity results show that existence on inverted U-Shaped between FDI and carbon dioxide emission nexus. There is a positive impact of FDI on carbon dioxide emission when FDI is below the threshold level, while there is a negative impact of FDI on carbon dioxide emission when FDI is above the threshold level.

It is essential for policymakers to implement measures that encourage foreign direct investment by advocating for sustainability and green FDI. In light of the growing global focus on sustainability, governments ought to establish laws that incentivise foreign direct investment in eco-friendly sectors. By offering green incentives or carbon credits to companies that invest in sustainable projects, countries can promote economic development and mitigate environmental degradation. Secondly, policymakers should prioritise the attraction of foreign direct investment in high-value industries, including advanced manufacturing, technology, renewable energy, and research and development. This enhances economic growth while promoting innovation and skill development to attract green foreign direct investment (FDI). Tax incentives or subsidies may be provided to foreign investors in several sectors. Thirdly, government must encourage the transmission of knowledge and technology from foreign investors to domestic enterprises in order to increase inward foreign direct investment (FDI). This can be achieved by nurturing an environment that is conducive to cooperation between foreign and domestic companies, incentivising foreign companies to establish R&D centres, and engaging in collaborative research efforts. In conclusion, the interaction between FDI and environmental degradation in Southeast Asia requires a comprehensive strategy that promotes sustainable practices and considers the implications of FDI. Policymakers must prioritize environmental health to ensure that economic development does not come at the expense of ecological integrity.

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