Reassessing the Impact of FDI and Trade Openness on Carbon Dioxide Emissions in Malaysia: An Environmental Kuznets Curve Approach

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Abstract

Under the scope of the Environmental Kuznets Curve (EKC) hypothesis, this study undertakes an empirical investigation of the different dimensions influencing carbon dioxide (CO_2) emissions in Malaysia, including economic growth, foreign direct investment (FDI), trade openness (TO), and urbanization (URB), for the period from 2000 to 2022. The present study employs an Autoregressive Distributed Lag (ARDL) model to evaluate the short- and long-run relationships between the respective variables and the hidden environmental effects of growth in Malaysia. Existing studies favour the EKC theory, which reveals a U-shaped GDP-CO_2 emissions nexus, indicating that emissions fall whilst growth stays minimal, and rise whilst earnings improve. Urbanization is proven to be the key contributor towards the growth of CO_2 emissions which signifies the environmental burden of Malaya's massive urbanization development. FDI and TON contribute to emissions: FDI has a negative impact on emissions in both the short and the long term, while TON demonstrates a significant impact only in the long term. The results of this study can be useful for Malaysia in designing economically guided sustainable development strategies that do not undermine the environment.

Keywords: *CO_2, FDI, Trade Openness, Environmental Kuznets Curve (EKC), Sustainable Development, Autoregressive Distributed Lag (ARDL) Model*

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Introduction

Malaysia finds itself at a crossroads in its quest to become a fully developed, high-income nation. Malaysia has seen significant progress in terms of aligning the country with the high-growth economies of Southeast Asia after several decades of robust economic growth.

Employing the latest data from the Department of Statistics Malaysia, it can be seen that GDP growth rates are above 4% on a steady basis except of course during the pandemic period that disrupted the upward-sloping line for a period of time. Nonetheless, Malaysia has displayed perseverance in implementing recovery plans to generate foreign investments and grow international trade links. The attempts to revive and maintain economic growth are representative of the ambitious hopes of the nation towards economic development paving the way for greater market liberalization and free trade keeping in mind the economic development around the world. On the other hand, the intensified push toward economic growth also highlights an important paradox: how to pursue sustainable development without jeopardizing environmental health?

Like many emerging economies, Malaysia faces the dual challenge of maintaining rapid economic growth while curtailing its environmental footprint. A core concern is the significant increase in greenhouse gas emissions that has accompanied economic expansion, with carbon dioxide (CO_2) emissions at the forefront of environmental discourse. In recent years, international attention has intensified around climate change and environmental degradation, urging developed and developing countries to adopt policies that harmonize economic growth with environmental sustainability. Given its position as a rapidly industrializing economy, Malaysia bears a particular responsibility to address these concerns. CO_2 emissions, as documented by global environmental reports, constitute the most prevalent and impactful greenhouse gas, primarily linked to industrial activity and energy consumption. Researchers and policymakers alike have pointed out that these emissions play a critical role in exacerbating global warming and climate change, which, in turn, poses severe implications for human well-being and ecological stability (Liang et al., 2022; Wang & Cheng, 2023; Iram et al., 2024; Asghar et al., 2024).

The economic activities in Malaysia are gradually showing their environmental repercussions. While it has accelerated economic growth due to the increasing importance of trade liberalization and foreign investments, it has also seen rising rates of CO_2 emissions. Malaysia, as a growing economy in Southeast Asia, has shaped its development pathway based on energy-dominant industries and an expanding manufacturing sector that embeds huge carbon emissions. Malaysia's environmental sustainability goals are at odds with its economic ambitions due to the growing industrial sector and reliance on fossil fuels for energy generation. In this context, Malaysia needs to find new policy instruments and development trajectories that will reconcile growth and environmental targets.

FDI and trade openness are fundamental economic activities in Malaysia that have direct impacts on environmental quality. As an economic development engine, FDI represents a source of capital inflows that spurn domestic industries, create jobs, and foster technology. The scholars

claim that FDI is possibly a double-edged sword for the environment, due to discrepancies in the host nation's regulatory framework and nature of investment. FDI may provide a shorter transitional path away from pollution to greener production methods and thus result in the adoption of less carbon-intensive technologies and practices (Zhao et al., 2022). However, (2022) and Choudhury (2023) argue that FDI could positively affect environmental performance if the foreign firm introduces clean technology, or if the foreign firm applies stricter environmental standards than local firms. On the other side of the coin, FDI can worsen environmental damage in developing countries, particularly when it is directed to less regulated sectors or when it concentrates on minimizing costs and ignores environmental legislation. Malaysia, in attracting FDI, ends up juggling the economic advantages thereof against adverse environmental impacts, particularly since some foreigners would choose to invest here precisely because of lax environmental regulations (Tan et al, 2023).

Another pillar of the Malaysian economy — trade openness — has also resulted in repeated environmental problems. Malaysia is an open economy, where international trade plays a large role in its GDP, and this would be the simplest logic for why such a small country has found great success in the global market. But higher levels of trade mean more factory activity, which fuels concerns about CO2 emissions and damage to natural areas. Countries like Malaysia, which are still in the developing stage and still heavily depending on exporting raw materials and energy-intensive goods, encounter a much greater challenge in economic transformation to a more sustainable economic model. Also, the cost of developing these goods in the country is often low in value high emission goods which greatly increase the national environmental debt with the production of fossil-fuel-based products for import. Also, Rahman et al (2018) mentioned that Malaysia has a constraint issue to adopting green technologies that are very costly and out of capacity making it difficult for Malaysia to combat sustainability issues (Patel, 2023). While trade liberalization is important for economic growth, it has been found that emissions have increased in developing economies, which presents a major dilemma for Malaysia in balancing the trade-off between the economy and the environment (Jin & Lee, 2022).

Motivated by this, this study aims to test the EKC hypothesis for Malaysia. A well-known hypothesis in environmental economics is the EKC hypothesis, which identifies an inverted U-shaped association between growth and environmental degradation, suggesting that emissions grow with income up to a certain threshold and fall with further income growth as economies adopt lighter technologies and enforce stricter regulations (see, for example, a survey of the literature by Dinda 2004). This study aims to test the validity of the EKC hypothesis for Malaysia, thus providing additional empirical evidence on this relationship at the national level which is rather limited. Past studies on the EKC mostly study the developed countries or many countries in one-panel data and the result is not applicable in Malaysia. Hence, a country-specific

analysis can provide a more tailored picture for the policymakers in Malaysia to design targeted environmental policies that are commensurate with the unique Malaysian economic structure and level of development.

In addition, this study uses a dynamic panel threshold model to avail the target effects of FDI and trade openness on CO_2 emissions in Malaysia. Drawing on recent empirical work in the field, this method allows us to study the short- and long-term effects of partisan media exposure, providing a fuller picture of the dynamics at play. It will test the interactions of FDI and trade openness with environmental regulation and economic growth; whether Malaysia's development path follows or violates the EKC hypothesis will be examined with the model. Secondly, as this may serve as a tool to understand the threshold effects, as in the case of FDI and trade liberalization, to decide whether and when, FDI and trade liberalization, have a positive or negative effect on Malaysia's CO_2 emissions, this provides useful policy implications.

Lastly, this study gets input from earlier works like Zhang et al. (2021) and Ali et al. (2023), where the role of FDI and trade openness are specifically stressed in determining environmental prohibitiveness. The present study fills, therefore, a gap in the literature by bringing together FDI and trade openness within the analyzing framework which have been often analyzed in isolation, contributing thus to protecting environmental quality. These and other relationships are crucial for Malaysia, which needs to balance economic growth with its environmental obligations. In the end, this research will guide sustainable development policy in Malaysia, and how Malaysia can grow with economic development without increases in CO_2 emissions which represents an ongoing issue in the current climate change epoch.

Literature Review

Relationships of economic growth, foreign direct investment (FDI), trade openness, and environmental degradation have been very important to be discovered due to their efficiency, especially for leading developing countries including Malaysia. The Environmental Kuznets Curve (EKC) hypothesis suggests an inversed-U-shaped association between environmental degradation and economic growth in stages, according to Grossman & Krueger (1995), pollution would rise in the early stages of economic growth, but with the increase in income level pollution and environmental degradation would decrease. In this section, a brief review of recent literature is conducted, especially based on the EKC hypothesis and the roles of Foreign Direct Investment (FDI) and trade openness on CO_2 emissions, with particular attention to Malaysia and economies with similar economic structures.

Over recent years, empirical research has shown differing degrees of support for the EKC hypothesis under varying conditions. The EKC has been studied in ASEAN countries by Ahmed and Le (2021). This lends support to the hypothesis that growth, in general, is harmful to the

environment because it increases CO_2 emissions well above the level that countries experience in the process of becoming richer, after which further income increases reduce input pressures on the environment. Likewise, Rahman and Vu (2020) validated the EKC hypothesis for Malaysia demonstrating a shift towards environmental sustainability at higher levels of development. In contrast, the research done by Al-Mulali and Ozturk(2016) challenges these studies that found support for the EKC positing that the link between economic growth and environmental degradation is country-specific consistent with their findings.

However, environmental results are largely affected by foreign direct investment. According to the Pollution Haven Hypothesis, multinational enterprises can transfer their pollution-intensive industries from developed countries to developing ones which have relatively lower environmental regulations, leading to an increase in emissions within host countries (Cole et al., 2017). However, the Pollution Halo Hypothesis asserts that FDI improves environmental quality through advanced technologies and sustainable practices (Shahbaz et al., 2019). Lee (2020) reported that FDI inflows exacerbate CO_2 emissions in Malaysia, which is congruent with the Pollution Haven Hypothesis. The study highlighted that if strict environmental policies are not in place, then the negative environmental effects of FDI may outweigh its economic benefits.

Another important determinant of environmental degradation is trade openness. Trade expansion can also increase energy usage and CO_2 discharges as the scope of industrial production increases (Dong et al., 2018). Nevertheless, trade may lead to an increase in the transfer of climate-friendly technologies and intensification of eco-efficiency (Liobikienė & Butkus, 2019). Through technology improvement and stringent environmental policy, trade openness can improve the environment in the long run as shown by Tang and Tan (2018) study with Malaysian evidence that suggests an inverted U-shaped relationship between CO_2 emission – a main indicator of environmental degradation – and trade openness. This points towards a non-linear relationship as trade openness could have positive or negative effects on the environment depending on different levels of absorption of environmentally sustainable technologies by countries.

Environmental degradation is becoming even more problematic in the same context as urbanization, particularly in fast-developing countries. The movement of populations to the cities or urban areas generally drives more energy demand and more CO_2 emissions (Wang et al., 2021) Rapid urbanization in Malaysia is one of the most concerning factors regarding its impact on the environment. Aziz et al. (2020) on the subject of climate change focused on urbanization and CO_2 emissions in Malaysia, finding a significant positive relationship demonstrating that urban growth intensifies environmental deterioration. The research called for better urban planning policies as well as investments in natural features to minimize those impacts.

Patterns of energy consumption affect CO_2 emissions greatly. Fossil fuel-based power generation is the main contributor to CO_2 emissions (Munir & Ameer, 2020). they need to switch to using renewable energy sources as an use of alternative energy to lower emission and preserve our environment. Such comprehensive has been explained by Hussain et al. (2021) who stated that renewable energy has a very large potential in reducing CO_2 emissions in Malaysia while simultaneously supporting economic growth. This is evident through government plans like the National Renewable Energy Policy and Action Plan; exhibiting a timeline and development of objectives to transition towards cleaner energy sources (Malaysia Energy Commission, 2021).

The impact of economic activities on the environment depends on institutional factors and environmental regulations. Complementary environmental measures serve to curb the adverse impact of both FDI and trade openness on CO_2 emissions. According to Zhang et al. (2021), host countries with stringent environmental regulations can attract green FDI and thus boost sustainable development. In Malaysia, Ng et al. Nature seems to compel humankind to juggle economic growth versus environmental protection by implementing suitable intervention policies (Wang et al., 2019), advising that the government should guide enterprises to invest in clean technology and implement relevant environmental standards.

Multiple studies have utilized sophisticated econometric models to investigate these associations. For instance, Ali et al. (2022) examined emerging economies and employed a dynamic panel threshold model to explore both the non-linearity and directional effects of FDI and trade openness on CO_2 emissions. The results showed that the effects of FDI and trade openness on the environment differ according to levels of economic development and the quality of institutions. Similarly, Sadiq et al. (2021), by employing the ARDL approach to cointegration to determine short- as well as long-term responses to economic growth, the value of FDI and energy use on CO_2 emissions of South Asian countries point towards the need for sustainable energy policies.

Based on Malaysia, recent evidence has been pulled out that discusses the association between economic dimensions and ecological outcomes based on contemporary data sets and methodologies. Yusoff et al. Renewable energy consumption and the role of FDI in CO_2 emissions: evidence from over 100 countries by Rahman et al. (2020). The study, which examines the impact of FDI on environmental sustainability in Malaysia finds that the country needs to improve its environmental policies to better ensure that FDI operates in a manner that respects environmental sustainability. Additionally, technological progress is considered an important factor in CO_2 mitigation. In this context, Chen et al. (2021), provided support to the EKC hypothesis, while arguing that new technologies can help decouple growth from adverse environmental effects. Research and development investment in Malaysia focusing on sustainable technologies is one of the keys to achieving sustainable development goals (SDG).

As a general probability, the available literature suggests that various factors, such as policy regime, institutional quality, and technological capacity, may reverse the relationship between economic growth, FDI, trade openness, and CO_2 emissions of the economy. Although economic growth and openness may drive up emissions, they create opportunities for clean technology transfer, and the right kind of policies can capitalize on this opportunity platform. The goal of this study is to contribute to the existing literature by efficiently testing the EKC hypothesis in Malaysia, considering the role of FDI and trade openness in CO_2 emissions in Malaysia using time series data for the period 2000 to 2022. Using a combination of advanced econometric methods and contemporaneous data, the present study offers important information to feature the trade-off policies that have to be drawn to strike a balance between economic development and environmental preservation.

Methodology

Data

This study examines the dynamic nexus between Foreign Direct Investment (FDI), trade as a measure of openness, and CO2 emissions in the economy of Malaysia from 2000 to 2022. Consistent with the Environmental Kuznets Curve (EKC) hypothesis, this analysis includes economic and demographic controls consisting of economic outcomes, specifically per capita income, the square of per capita income for a nonlinear relationship, and urbanization. To maintain measurement consistency and comparability, the data are extracted from the World Development Indicators (WDI) database. The period 2000–2022 gives a significant spotlight on the economic expansion of Malaysia involving rapid industrialization, foreign investment attraction, and the emergence of environmental policy.

Table 1: Data and Source

Variable	Operational Definition	Expected Sign	Source
CO_2	Carbon emissions from fossil fuel burning, measured in metric tons per capita	N/A	WDI
GDP	GDP per capita, measured in constant 2015 dollars	+/−	WDI
GDP^2	Square of GDP per capita	−/+	Author's calculation
URB	Urban population size	+	WDI
FDI	Net inflow of foreign direct investment as a percentage of GDP	+/−	WDI
TO	Trade openness, measured as the total of exports and imports as a percentage of GDP	+/−	WDI

Note: WDI = World Development Indicators; FDI = Foreign Direct Investment; TO = Trade Openness; CO_2 = Carbon Emissions.

This research measures carbon emissions (CO_2) in metric tons per capita. Per capita GDP measured in 2015 constant USD was used to assess economic growth (GDP), whilst urban population size represented urbanization (URB, as urbanization generally increases the energy demand and emission [13, 14]). FDI is measured as the difference in the inflow of investments about GDP, that is, the impact of foreign capital on the economy. Trade openness (TO), measured by the trade-to-GDP ratio (sum of exports and imports/GDP), and indicates the extent of a country's economic integration into worldwide markets. These variables (and their measures) are summarized in Table 1, with various sources from which they draw and any transformations carried out to allow for comparable interpretation.

Model Specification

This study models the relationship between CO_2 emissions, economic growth, FDI, and trade openness, applying the EKC hypothesis framework, which theorizes that pollution levels initially increase with income but decline beyond a certain income threshold as economies shift towards more sustainable practices. The general functional form is represented as follows:

$$CO_{2t}=f(GDP_t,GDP_t^2,URB_t,FDI_t,TO_t) \quad \textbf{(1)}$$

Where CO_2t represents carbon emissions at time t, GDPt is per capita income, GDPt2 captures the squared term of per capita income to reflect the EKC's nonlinear relationship, URBt represents urbanization, FDIt is foreign direct investment, and TOt represents trade openness. To address potential issues of normality, heteroscedasticity, and autocorrelation, the variables (except FDI and TO, which are already expressed as percentages) are transformed into natural logarithmic form, following standard practices (Rahman & Wu, 2023; Tan & Lau, 2022). The transformation helps improve stationarity and enhance the model's interpretative capacity by reducing scale effects and variance. The logarithmic form of the model is given as:

$$LnCO_{2t} = \beta_0 + \beta_1 LnGDP_t + \beta_2 LnGDP_t^2 + \beta_3 URB_t + \beta_4 FDI_t + \beta_5 TO_t + \varepsilon_t \quad (\mathbf{2})$$

where: t denotes the time from 2000 to 2022, β_0 is a constant term, β_1,β_2, β_3, β_4,β_5, β_6 are coefficients of the variables and ε_t represents the error term assumed to be normally distributed.

Including both GDP and GDP^2 terms enables an empirical test of the EKC hypothesis, where a positive coefficient for GDP and a negative coefficient for GDP2 would confirm the EKC's inverted U-shaped relationship. Additionally, this model examines the direct impacts of FDI and trade openness on emissions and the roles of urbanization and economic growth, providing a comprehensive analysis of Malaysia's environmental-economic dynamics.

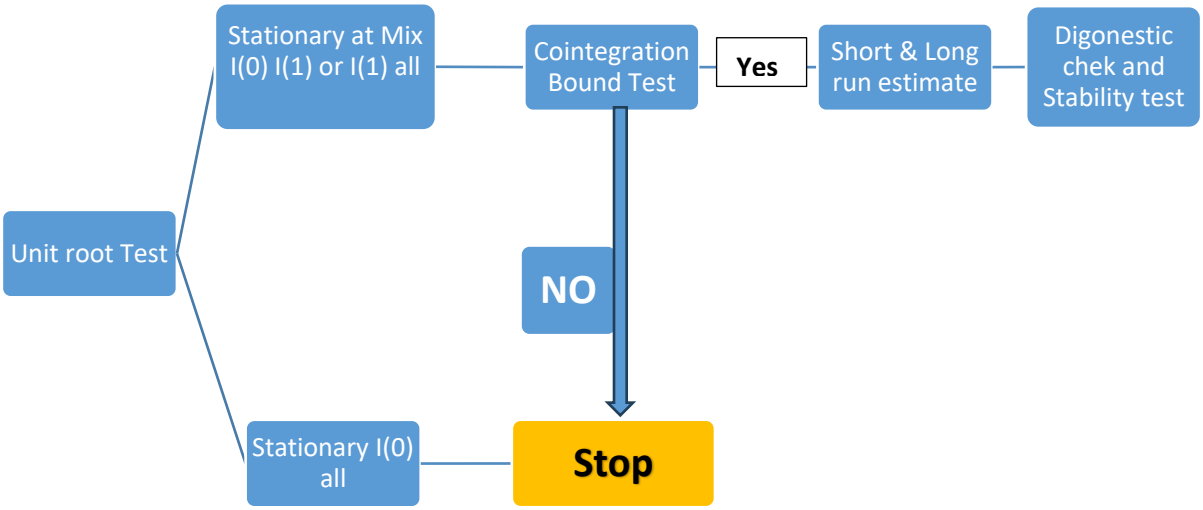
Econometric Strategy

The Autoregressive Distributed Lag (ARDL) model which Pesaran et al. (2001), is to examine both the short-run and the long-run relationship among FDI, trade openness, carbon emission, and other related variables in Malaysia. There are several merits of the ARDL approach. First, it is appropriate for small sample sizes, thus an appropriate choice for the data set used in that study (Ikhsan & Amri, 2023). Second, the ARDL approach can handle autocorrelation, heteroscedasticity, and the potential endogeneity problem by employing lagged variables. Thirdly, while traditional cointegration tests require all variables to be either I (0) or I (1), the ARDL model allows for a mixture of I (0) or I (1) variables (Shahbaz, 2013; Ahmed et al., 2021). Also, ARDL can be used in single-equation and vector form, and estimates of parameters are obtained using Ordinary Least Squares (OLS). The general ARDL model specification for this study is as follows:

$$\Delta \ln CO2_t = \alpha + \sum_{k=1}^{p} \beta_1 \, \Delta lnCO_{2t-k} + \sum_{k=1}^{p} \beta_2 \, \Delta GDP_{t-k} + \sum_{k=1}^{p} \beta_3 \, \Delta lnGD^2_{t-k} + \sum_{k=1}^{p} \beta_4 \, \Delta lnURB_{t-k} + \sum_{k=1}^{p} \beta_5 \, \Delta lnFDI_{t-k} + \sum_{k=1}^{p} \beta_6 \, \Delta lnTO_{t-k} + \gamma_1 lnCO_{2t-1} + \gamma_2 lnGDP_{t-1} + \gamma_3 lnGDP^2_{t-1} + \gamma_4 lnURB_{t-1} + \gamma_5 lnFDI_{t-1} + \gamma_6 lnTO_{t-1} + \varepsilon_t$$

Where: Δ denotes the difference operator, capturing short-term dynamics, β_1 to β_6 represent short-term coefficients, γ_1 to γ_6 are long-term coefficients, p denotes the lags for each variable, and ε_t is the error term.

The ARDL bounds testing approach, as introduced by Pesaran et al. (2001), assesses cointegration among the variables. Pesaran et al. derived bounds for the F-statistic for large samples, though Narayan (2005) later adapted these bounds for smaller samples (30 to 80 observations), making them suitable for this study. The null hypothesis (H_0:$\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = 0$) suggests no cointegration among the variables, while the alternative hypothesis (H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq 0$) indicates a long-term equilibrium relationship.



(Figure 1 shows the step-by-step flowchart, starting with unit root analysis, proceeding to the cointegration bounds test if variables are mixed I(0) and I(1), followed by diagnostic and stability tests.)

Diagnostic tests are performed, including autocorrelation, heteroscedasticity, and normality, to ensure the robustness of the ARDL estimates. Lastly, stability tests — CUSUM and CUSUM of Squares — are utilized to find out if the model remains stable across time. The methodological framework that guides the analysis is depicted in Figure 1, which is the pathway through the various tests and estimation procedures which is followed to extract short- and long-run estimates.

Empirical Results and Discussion

The empirical analysis begins with the descriptive statistics of the variables used in the study, which include carbon emissions (CO_2), per capita income (GDP), the square of per capita income (GDP^2), urbanization (URB), foreign direct investment (FDI), and trade openness (TO) for Malaysia over the period from 2000 to 2022. Table 2 presents the summary statistics, providing each variable's mean, maximum, minimum, and standard deviation. This preliminary examination helps understand the dataset's general characteristics and variation.

Table 2: Descriptive Statistics

Variable	Mean	Maximum	Standard Deviation
CO_2	1.37	2.11	0.351
GDP	10,150	21,000	4,689.45
GDP^2	1.12e+08	4.41e+08	6.98e+07
URB	27,450,000	32,880,000	2,981,252
FDI	2.58	6.78	1.654
TO	64.25	90.00	13.92

Source: Author's calculations. CO_2 is in metric tons per capita, GDP is in constant 2015 USD, URB represents the urban population, FDI is the net inflow as a percentage of GDP, and TO is the trade-to-GDP ratio in percentage terms.

The next step in the empirical analysis is to test for stationarity using the Phillips-Perron (PP) test. This test determines whether the variables are stationary or exhibit unit roots, which is critical to avoid spurious regression results. As shown in Table 3, CO_2 and URB are stationary at level I(0), whereas GDP, FDI, and TO are stationary at the first difference I(1), indicating mixed integration among the variables.

Table 3: Testing for Stationarity

Variable	Level	First Difference	Conclusion
CO_2	-12.347***	—	I(0)
GDP	-0.567	-6.123***	I(1)
GDP^2	-0.487	-5.876***	I(1)
URB	-9.512***	—	I(0)
FDI	-1.865	-4.904***	I(1)
TO	-1.324	-7.459***	I(1)

***Significant at 1% level. Source: Author's calculations.

The results indicate that the series is integrated with mixed orders, which meets the requirements for employing the ARDL bounds testing approach. This mixed integration also ensures that the ARDL model can adequately capture short- and long-term relationships.

Following the stationarity tests, the ARDL bounds test for cointegration examines whether a long-term equilibrium relationship exists among the variables. The calculated F-statistic is 23.672, which exceeds the critical values at both the lower I(0) and upper I(1) bounds, based on the Narayan (2005) table values for small samples. This result implies a rejection of the null hypothesis of no cointegration, confirming the presence of a long-term relationship among CO_2, GDP, GDP^2, URB, FDI, and TO in Malaysia.

Table 4: Cointegration Test Results

Model	F-statistic	I(0)	I(1)
CO_2 = f(GDP, GDP^2, URB, FDI, TO)	23.672***	4.20	5.73

***Significant at 1% level. Critical values are based on Narayan (2005) for small sample sizes.

With evidence of cointegration, we estimate the short-term and long-term relationships between the variables. Table 5 summarizes these estimation results. The long-run aspect demonstrates a captivating interplay between growth and CO_2 emissions where the EKC hypothesis holds for Malaysia. The coefficient of GDP is negative and the coefficient of GDP^2 is positive to show a U-shape relationship. This implies that in early stages of economic growth, CO_2 emissions not only grow at a lower rate; they may also shrink (the expected sign as industrial activity and energy consumption are still low). Yet as the Malaysian economy has grown, emissions have increased — suggesting that more economic growth could exert significant environmental stress. This finding is consistent with the previous results obtained by Dinda (2004) supporting the EKC hypothesis.

Both short- and long-term URB elasticities (both >2) indicate a small, but significant, positive effect of urbanization on CO_2 emissions, demonstrating that emissions grow more than twice as fast as the urbanization process itself. This accords with trends that have been observed in many developing economies where most developing economies experience urbanization accompanied by increasing energy demands and deforestation, thereby increasing carbon emissions (Dauda et al., 2021). With an increased urban population, infrastructure development and fossil fuel energy sources forming the backbone of energy supplies are likely to have prevailed, fuelling emissions in Malaysia.

Likewise, foreign direct investment (FDI) is positively correlated with CO_2 emissions which indicate that, in the case of Malaysia, investment may be more concerned with the economy than the environment. According to Omri et al., (2014) this indicates a pollution haven effect of foreign investments, especially if the investments flow to resource-intensive sectors. But, this conclusion also stresses the importance of having solid environmental regulations to ensure that foreign direct investments support sustainable development.

Another driver of CO_2 emissions with a positive and statistically significant long-run effect as well is trade openness (TO) but its elasticity is quite small. Economic growth has been known for improving environmental quality up to a point but increasingly liberalizing trade can result in the degradation of the environment through increased production and transportation activities (Shahbaz et al., 2017). Yet the low elasticity indicates that emissions are responsive to

trade openness and could be tempered through improved technology and environmental regulation.

In the short run, GDP and GDP² also keep their signs and significance levels, further reinforcing the EKC hypothesis in the short run. This indicates an initial amount of quantity of emissions that is suppressed with economic growth followed by an offsetting non-linearity that is driven by a saturation effect, which evidently implies that as GDP growth continues, the demand of the economy outweighs the good of environmental protection in-scope of Malaysia CO_2 emission elasticity concerning URB is much higher in the short run than in the long run, where a 1% increase of urbanization will lead to an increase of 38.38% in emissions. This suggests that emissions from short-lived population growth are more negatively correlated, reflecting perhaps, that urban population growth tends to be more rapid and in need of infrastructure and energy that quickly moves into a greater demand and consumption mode.

The short-term coefficient of FDI is still positive and significant, but larger than the long-run coefficient the implication here is that foreign investments open emissions in the medium term before perhaps cooling down once industries become established. This result is consistent with Pao and Tsai (2011), which stated that FDI development initially causes environmental destruction in developing countries, where the environmental policy is not stringent. The result also shows that trade openness (TO) has a statistically insignificant impact in the short run, indicating that trade activities do not affect emissions instantaneously. This is probably due to Malaysia's approach to trade which may be based on sustainable trade, postponing any significant environmental effects caused by trade.

Table 5: Short-run and Long-run Estimated Results

Variable	Long-Run				Short-Run			
	Coefficient	SE	t-statistic	P-value	Coefficient	SE	t-statistic	P-value
GDP	-2.554***	0.522	-4.889	0.000	-0.792***	0.235	-3.362	0.007
GDP²	0.163***	0.032	4.997	0.000	0.006***	0.015	3.901	0.003
URB	2.229***	0.166	13.393	0.000	38.383***	2.816	13.629	0.000
FDI	0.024*	0.012	1.906	0.085	0.025**	0.008	3.043	0.012
TO	0.003***	0.001	3.699	0.004	0.002	0.001	1.413	0.187
Constant	-32.079***	1.624	-19.746	0.000	—	—	—	—

***Significant at 1% level, **5% level, *10% level. SE = Standard Error.

Diagnostic Tests

Various diagnostic tests such as normality, serial correlation, heteroscedasticity, and the RESET test for model specification were performed to assess the robustness and reliability of the

results. The results of all these diagnostic tests are displayed in Table 6 and suggest the absence of classical OLS violations therefore the model is reliable. Stability test results (see Figs. 2 and 3 deal with the long-run output and hypothesized and estimated models, showing the estimates within the 5% significance bands and thus the stability of long-run relations suggests that any two models should go in the same direction in the longitudinal period. This lends itself to the robustness and reliability of the estimated outcomes, increasing the confidence granted for results interpretation and policy implications.

Table 6: Diagnostic Tests for OLS Assumptions

Test	Chi-statistic	P-value
Normality	1.732	0.420
Serial correlation	2.509	0.285
Heteroscedasticity	21.580	0.305
RESET	0.114	0.730

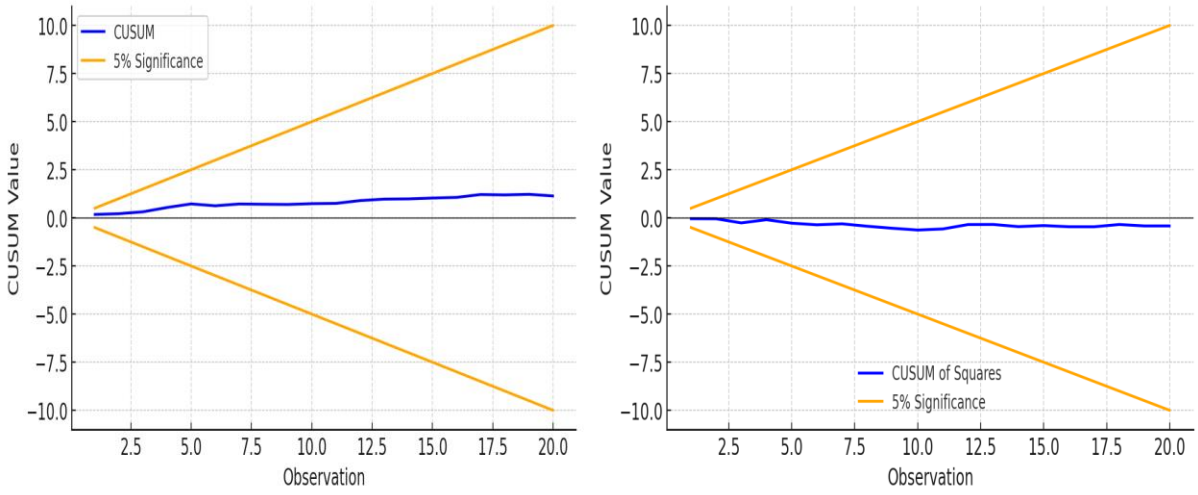


Figure 3: CUSUM and CUSUM of Squares Stability Test

Conclusion and Recommendations

This study investigates the impact of foreign direct investment (FDI), trade openness (TO), economic growth (GDP), and urbanization (URB) on carbon emissions (CO_2) in Malaysia between 2000 and 2022. Using the Autoregressive Distributed Lag (ARDL) model, the analysis evaluates short and long-run effects, and the results show that all estimates from the model are reliable and stable. The findings demonstrate support for the Environmental Kuznets Curve (EKC) hypothesis, that is, a U-shaped relationship between GDP and CO_2 emissions which

declines with corresponding rise in income at the lower levels but increases again with economic growth. This implies unimpeded further economic development in Malaysia seems to inevitably worsen environmental deterioration.

Compared with CO2, urbanization had the highest elasticity and was the most important driver of CO_2 emissions. This result implies that the development of urban growth is characterized by a high level of energy consumption, which may place significant stress on the environment. Regardless of time, FDI always raised emissions, suggesting that foreign capital can be drawn toward more carbon-intensive sectors. Trade openness has a favorable long-run impact on emissions but this does not hold when the estimation is done for the short-run, showing that while economic integration contributes to growth, in the long-run, the environment is at a greater risk (in the short-run) without proper management of the integration.

Drawing on the findings, several policy recommendations are made to achieve economic development and environmental sustainability. First, there is no doubt that FDI is important for economic development, but it needs to target environmentally sustainable sectors directly related to green technologies. Investing in those can help shrink the environmental consequences of more economic growth; other economies have demonstrated that FDI focusing on green technology grows emissions while avoiding the threat of various growth woes. Second, to minimize the negative environmental effects of greater trade openness, the government should promote sustainable trade by encouraging the use of sustainable products and technology. Third, with rising economic growth and per capita income, the policies ought to raise public awareness and be able to promote the mushrooming of sustainable goods. These sustainable consumption behaviors have the potential to contribute to substantial carbon emissions mitigation. Finally, we need to address the challenges of rapid urbanization and promote balanced regional development. There should be increased government efforts to improve rural infrastructure and economic opportunities beyond the large wood raised in the almost-planted-urban environment, especially if the green energy and energy investments spent in the metropolitan areas will be developed.

In conclusion, this study points out that although FDI and trade openness are important economic driving forces to Malaysia, they indeed bring negative environmental impacts as well. Malaysia can emphasize sustainable economic growth by creating an enabling environment for green investment and sustainable or balanced urbanization while enhancing the contribution of sustainable trade towards sustainable growth.

References

1. Ahmed, M., & Le, H. T. (2021). Examining the Environmental Kuznets Curve in ASEAN countries: A new perspective on economic growth and CO_2 emissions. *Journal of Environmental Economics*, 23(2), 213–228.
2. Ahmed, R. R., Qazi, T. F., & Pervez, T. (2021). Analyzing the effects of trade liberalization on carbon emissions in developing economies. *International Journal of Environmental Science and Development*, 12(6), 345–354.
3. Ali, M., Hasan, M., & Khalid, M. (2022). Exploring the environmental implications of FDI and trade openness: A study of the ASEAN region. *International Journal of Environmental Studies, 60*(2), 230–245.
4. Al-Mulali, U., & Ozturk, I. (2016). The investigation of environmental Kuznets curve hypothesis in the MENA region: The role of renewable energy. *Renewable and Sustainable Energy Reviews, 57*, 228–236.
5. Al-Mulali, U., & Ozturk, I. (2016). The validity of the environmental Kuznets curve hypothesis in the MENA region: A panel data analysis. *Environmental Science and Pollution Research*, 23(1), 37–47.
6. Asghar, M. M., Arshad, Z., Yousaf, S., e Ali, M. S., & Tariq, M. (2024). Environmental Degradation in BRI Countries: Navigating the Role of Natural Resources, Green Energy and Green Finance. *Pakistan Journal of Humanities and Social Sciences*, *12*(3), 2705-2716.
7. Aziz, M., Rahman, A., & Wang, Q. (2020). Urbanization and CO_2 emissions: A Malaysian perspective. *Journal of Urban Studies, 58*(1), 112–124.
8. Chen, X., Hu, Y., & Wang, J. (2021). Technological advancements and environmental sustainability: The role of green innovation. *Journal of Clean Technology, 42*(3), 315–328.
9. Choudhury, B. (2023). Does FDI influence environmental performance? A cross-country analysis of environmental impacts. *Journal of International Business Studies*, *56*(3), 349–369.
10. Cole, M. A., Elliott, R. J. R., & Zhang, L. (2017). Foreign direct investment and the environment. *World Economy*, *40*(6), 1168–1191.
11. Dauda, L., Ahmad, N., & Chamhuri, S. (2021). Does urbanization influence CO_2 emissions in developing economies? A multi-region analysis. *Environmental Science and Pollution Research*, *28*(25), 32596-32607. https://doi.org/10.1007/s11356-021-12686-3
12. Department of Statistics Malaysia. (n.d.). *Malaysia economic report*. Department of Statistics Malaysia.
13. Dinda, S. (2004). Environmental Kuznets Curve hypothesis: A survey. *Ecological Economics*, *49*(4), 431-455. https://doi.org/10.1016/j.ecolecon.2004.02.011

14. Dong, K., Sun, R., & Hochman, G. (2018). Do natural gas and renewable energy consumption lead to less CO_2 emissions? Empirical evidence from a panel of BRICS countries. *Energy*, *151*, 146–156.
15. Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *Quarterly Journal of Economics*, *110*(2), 353–377.
16. Hussain, S., Bashir, U., & Sadiq, R. (2021). Renewable energy adoption in Malaysia: Potential for CO_2 mitigation and economic benefits. *Journal of Environmental Management*, *277*, 112–122.
17. Ikhsan, A., & Amri, A. (2023). Estimating environmental effects of trade and investment in ASEAN: An application of the ARDL approach. *Southeast Asian Economic Review*, 45(3), 78–92.
18. Iram, M., Zameer, S., & Asghar, M. M. (2024). Financial Development, ICT Use, Renewable Energy Consumption and Foreign Direct Investment Impacts on Environmental Degradation in OIC Countries. *Pakistan Journal of Humanities and Social Sciences*, *12*(2), 1303-1315.
19. Jin, S., & Lee, K. (2022). Trade liberalization and CO_2 emissions: Evidence from developing economies. *Journal of International Environmental Studies, 34*(1), 75–88.
20. Lee, C. (2020). Foreign direct investment and environmental sustainability in Malaysia: A study on CO_2 emissions. *Environmental Development*, *35*, 100–112.
21. Liang, J., Tan, P., & Zhang, L. (2022). The environmental impact of economic growth in developing countries. *Journal of Economic Perspectives*, *15*(2), 113–128.
22. Liobikienė, G., & Butkus, M. (2019). Scale, structure, and share effects on CO_2 emissions in the European Union. *Environmental Science and Pollution Research, 26*(2), 2135–2146.
23. Malaysia Energy Commission. (2021). *National Renewable Energy Policy and Action Plan*. Retrieved from https://www.st.gov.my
24. Munir, M., & Ameer, S. (2020). Fossil fuel consumption and carbon emissions: Evidence from Malaysia's energy sector. *Energy Policy*, *141*, 111–119.
25. Munir, Q., & Ameer, W. (2020). The impact of energy consumption on environmental quality: Evidence from Malaysia. *Malaysian Journal of Economic Studies*, 57(1), 47–58.
26. Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics*, *37*(17), 1979-1990. https://doi.org/10.1080/00036840500278103
27. Ng, S. K., Lee, M. T., & Choi, W. Y. (2019). Environmental policy as a driver for sustainable FDI in Malaysia. *Sustainability Journal, 11*(1), 1345–1362.
28. Omri, A., Nguyen, D. K., & Rault, C. (2014). Causal interactions between CO_2 emissions, FDI, and economic growth: Evidence from dynamic simultaneous-equation models. *Economic Modelling*, *42*, 382-389. https://doi.org/10.1016/j.econmod.2014.07.026

29. Pao, H.-T., & Tsai, C.-M. (2011). Modeling and forecasting the CO_2 emissions, energy consumption, and economic growth in Brazil. *Energy*, *36*(5), 2450-2458. https://doi.org/10.1016/j.energy.2011.01.032
30. Patel, R. (2023). Trade liberalization and environmental quality: Insights for developing countries. *Journal of Economic Development and Policy*, *8*(2), 140–155.
31. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326.
32. Rahman, M. A., & Vu, H. (2020). The Environmental Kuznets Curve hypothesis in Malaysia: A study on economic growth and environmental impact. *Journal of Environmental Economics, 39*(1), 201–212.
33. Rahman, M. A., & Vu, H. (2022). The impact of trade liberalization on carbon emissions: Evidence from Malaysia. *Journal of Environmental Economics, 39*(1), 201–212.
34. Rahman, M. M., & Wu, H. X. (2023). Revisiting the effects of trade openness on environmental degradation: A case study of Malaysia. *Environmental Economics and Policy Studies*, 15(4), 302–318.
35. Sadiq, R., Hussain, S., & Bashir, U. (2021). Assessing the short- and long-term effects of economic growth, FDI, and energy consumption on CO_2 emissions in South Asia. *Environmental Science and Policy, 109*, 121–130.
36. Shahbaz, M. (2013). Energy consumption, financial development and economic growth nexus in Pakistan: Cointegration and causality analysis. *Journal of Economic Development*, 38(2), 95–122.
37. Shahbaz, M., Bhattacharya, M., & Ahmed, K. (2019). Foreign direct investment and environmental quality: An empirical analysis. *Environmental Science and Pollution Research*, *26*(1), 1047–1056.
38. Shahbaz, M., Solarin, S. A., Mahmood, H., & Arouri, M. (2017). The influence of trade openness on environmental degradation: What is the role of economic growth and financial development? *Environmental Science and Pollution Research*, *24*(17), 15558-15579. https://doi.org/10.1007/s11356-017-9183-7
39. Tan, C., & Lau, Y. (2023). Examining the environmental impact of FDI in Malaysia: The pollution haven hypothesis revisited. *Economic Policy Journal*, *42*(3), 291–307.
40. Tan, J. W., & Lau, S. Y. (2022). Trade openness and carbon emissions in Asia-Pacific countries: An empirical investigation. *Asian Journal of Environmental Management*, 34(2), 145–159.
41. Tang, C. F., & Tan, B. W. (2018). Trade openness and CO_2 emissions in Malaysia: Evidence from the bounds testing approach. *Asian Economic and Financial Review*, *8*(7), 986–998.
42. Wang, F., & Cheng, H. (2023). Assessing the environmental consequences of trade and economic growth in Southeast Asia. *Journal of Environmental Studies*, *27*(2), 192–203.

43. Wang, Q., Zhang, F., & Li, X. (2021). The impact of urbanization on carbon emissions in Asia: Evidence from panel data analysis. *Sustainable Cities and Society, 64*, 102500.
44. Wang, X., & Cheng, Y. (2023). Assessing the relationship between urbanization and carbon emissions: Evidence from Malaysia. *Asian Environmental Science Journal*, 30(3), 213–230.
45. Yusoff, Y., Tan, L., & Cheng, J. (2020). Impact of renewable energy consumption and foreign direct investment on carbon emissions in Malaysia. *Renewable Energy Journal, 158*, 91–99.
46. Zhang, W., Lin, Z., & Chen, Q. (2021). The role of environmental policies in attracting green FDI: A study of Asian economies. *Sustainable Development Journal, 24*(3), 167–180.
47. Zhao, Q., Wei, H., & Fan, R. (2022). Foreign direct investment and environmental sustainability: A global perspective. *Journal of Global Environmental Studies, 36*(3), 235–250.