The Green Enigma: How Taxes, Technology and Growth Outline Carbon Emissions in Malaysia

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ABSTRACT: This study examines the repercussion of environmental taxes, technological innovation, and economic augmentation on carbon emanation in Malaysia during 1990–2021. The study applied a deductive research approach and used annual time-series data attained from secondary sources. Econometric analyses were carried out using EViews. To check the homogeneity of variables, the unit root test is employed, and to determine long-run relationship of variables, Johansen cointegration test is executed, after obtaining the relationship Vector Error Correction Model (VECM) to examine the long-run causality and short-run dynamic linkage. Empirical results prove that environment taxes play significantly and positively on carbon emission and it can significantly reduce carbon emissions. However economic growth and technological advancement had no significant and positively related on carbon emissions. Long-run relationship also proved by VECM test and the speed of convergence to long-run equilibrium was determined.

KEYWORDS: Environmental Taxes, Technological Innovation, VECM Economic Growth, Carbon Emissions, Malaysia, Johansen Cointegration

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Introduction

In current times, one of the most thought-provoking problems is climate change particularly originating from carbon emissions. Due to growing energy consumption enhanced because of the speedy growth of the economy in many countries carbon emissions have been increasing hurriedly over the years globally (Erdogan & Solarin, 2026; Zhang et al., 2022). These alarming situations are leading to further substantial changes such as changes in temperature and changes in precipitation patterns. Increases in floods, storms, droughts, and global temperatures have also been occurring for the reason of excessive carbon emanation (Wu et al., 2024; 2026).

There has been a lot of discussion that how important it is for developing countries to grow their economies in such a way that it protects the environment as well as produces low-carbon emissions. This can be done by using less energy and finding ways to avoid pollution. The transformed concept of sustainability now includes three interrelated components: the environment, economy, and societal impartiality. Therefore, stakeholders need to modify their techniques of doing things and how they improve sales and use of technological innovations (Loganathan et al., 2020; Zhao et al., 2022). However, some contradictory theories are making it difficult to settle on plans and guidelines (Chai et al., 2026). By supporting national mitigation initiatives and intergovernmental mechanisms—most notably the (UNFCCC), a non-binding pact aiming at decreasing CO2 emissions—many nations, including Malaysia, have actively contributed to reducing these emissions. At the 15th Conference of Parties (COP15) in Copenhagen in 2009, Malaysia established a goal to cut its carbon emission concentration by 40% by 2020 (based on 2005 levels). Since they support the creation of new goods and processes that aid in energy conservation, waste and pollution reduction, and improved environmental management, green technology innovation and environmental taxes can be considered the primary factors in resolving the shocking environmental issues (Chen et al., 2020). Countries are working to prevent environmental deterioration and reach the goal of net-zero carbon dioxide exhalation resulted from the global suffering caused by climate change (Ruslan & Mokhtar, 2026). Malaysia is facing sharp environmental deterioration including deforestation, air pollution, and ecological imbalance. Malaysia stands at a crucial stage where the connections amid environmental taxes, technological innovations, economic growth, and carbon emissions permit inclusive examination. The sector that contributes significantly to Malaysia's carbon emissions is coal-fired electricity power plants which are accountable for 43.4% of the overall emissions. As per World Economics over the past decade, Malaysia's GDP grew by an average of 5.4% yearly. The study attempts to fill the void between theories and what happens in Malaysia by considering various mentioned variables.

Literature Review

The literature review will incorporate the definitions of each variable and linkages of dependent and independent variables. 200 papers had been gathered through the process of Harzing and Prisma. Through Harzing papers from 1994-2025 were collected which after sorting and exploring out remained 32 articles. In recent years, it has been essential to address various climate challenges. This theoretical framework will reflect the interconnections between environmental taxes, technological innovations, economic growth, and carbon emissions (Loganathan et al., 2020).

Environmental Kuznets Curve (EKC) Theory

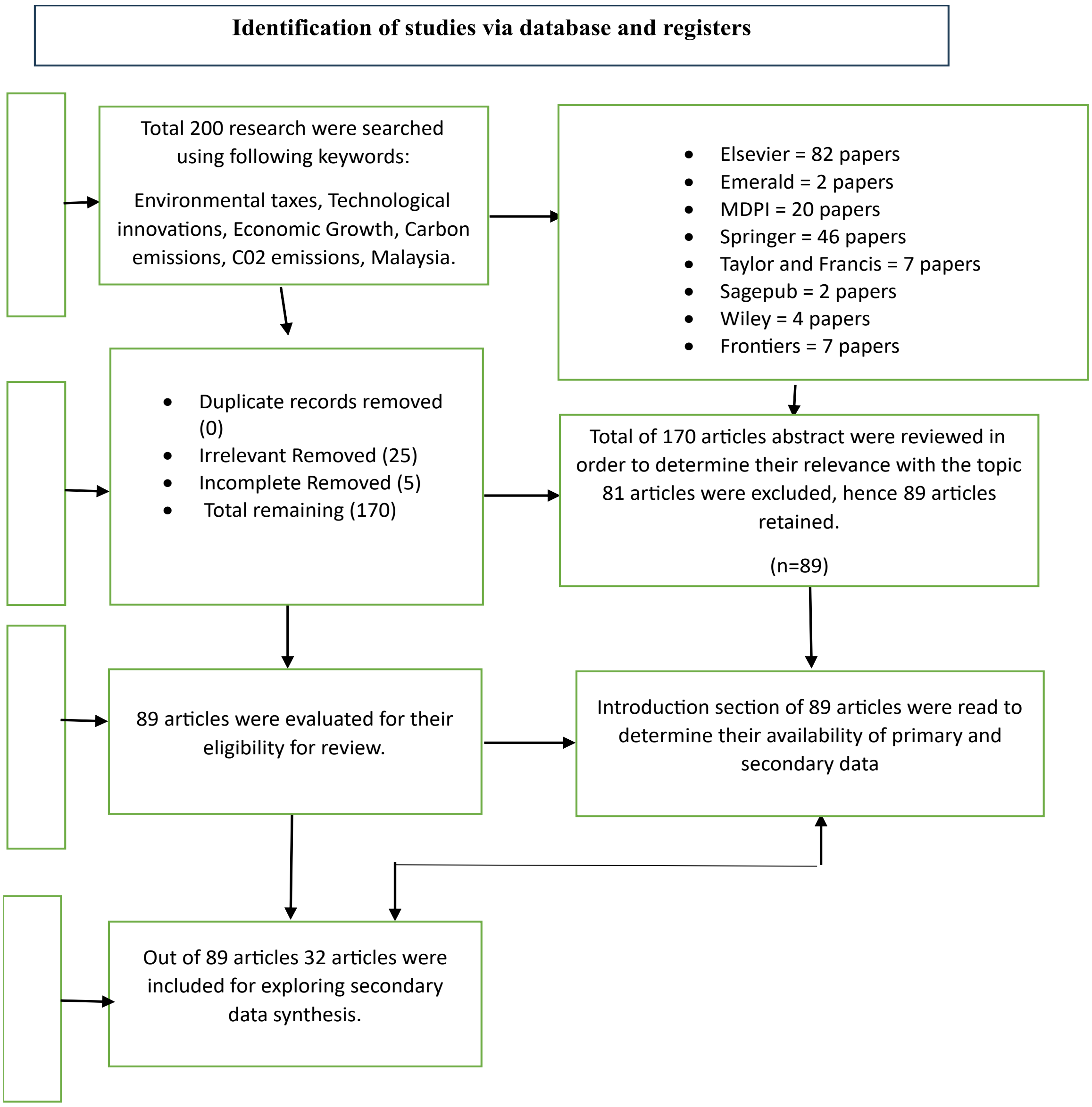
The first theory which supports these variables is the Environmental Kuznets Curve (EKC) theory. This theory was proposed by Simon Kuznets (Kuznets, 1955).This theory speculates the connection between economic growth and the environment (pollution), it states that when economic development accelerates environmental quality degrades. This happens when to boost their economies rapidly they may ignore or overlook environmental regulations. However, as countries become wealthier and economies become mature, they start to prioritize and look over environmental concerns. They even tend to invest more in cleaner technologies. Environmental taxes can sort this issue it can push companies to reduce pollution by making it less profitable to pollute heavily. Because of the concept of EKC theory, many researchers and scholars from the early 1990s believe that economic growth should be prioritized so that all environment-related issues can be excluded. According to the article (Kaika & Zervas, 2013), According to this theory in the initial stages, the excess yield of carbon emissions harms the environment as economic growth but later it starts safeguarding the environment by investing in green projects and by prioritizing eco-friendly policies. In conclusion, it means that today's efforts can lead toa green future (Hao et al., 2021).

Porter Hypothesis

Another supporting theory is the Porter Hypothesis, which was proposed by an economist (Porter & Linde, 1995). This supports the connection between environmental regulations and economic benefits. According to this theory, environmental taxes can lead to a diminution in carbon emanation, technological innovations determined by strict regulations can introduce more carbon-efficient processes and products, and economic growth powered by these innovations can craft resources for more environmental investments (Porter, 1996). According to Porter's hypothesis, strict and firm environmental principles can advantage businesses by enabling them to be more efficient and innovative.

Figure 1

Prisma Protocol



Environmental Taxes and Carbon Emissions

A carbon tax is like putting a price on carbon emissions and it can detract people to yield a lot of pollution. These studies are the evidence that environmental taxes in coordination with technological innovations are effective in carbon emission reduction (Wu et al., 2026; Chen et al., 2023; Ocansey & Haywood-Dadzie, 2025). The use of limited resources could be lowered by increasing environmental taxes. Data from the carbon pricing dashboard claims that the impact of environmental taxes varies, which means that the rise in environmental taxes at first encourages firms to invest more in greener technologies but if it tends to increase much higher it may hurt the economy (Yunzhao, 2022). To plan and promote Green technological innovations and to reduce carbon emissions imposition of environmental tax is essential and most important (Chai et al, 2026). Sharif et al. (2020) signifies that both the environment and the economy are facilitated due to environmental taxes. Environmental taxes refer to a form of pricing structure that targets to enhance the environment while encouraging economic development (Khan et al., 2021).

H1: Environmental taxes have a significant impact on Carbon Emissions.

Technological Innovations and Carbon Emissions

Wang & Zhu (2020) investigated that not every innovation is equal for reduction in carbon emission but different types of energy innovations impact differently on technological innovations while eliminating carbon emissions. Anwar et al. (2021) identified that G-7 countries are the most advanced in the context of having great technologies but even with enough technological innovations and advancement they are still unable to maintain and protect their environmental conditions. These nations should refrain from too much on fossil fuel supplies; they should opt use of renewable energy. To invest more in greener means these nations should upgrade themselves for R&D to simplify and assist technological innovations. Discussing ASEAN countries (Salman et al., 2019) claimed that carbon emissions can be controlled by technological innovation if they tend to enhance energy efficiency. Based on the empirical results of Wenlong et al. (2023) the findings expose that Carbon emissions decrease by 0.24 units in the long term and 0.04 units in the short term due to the one-unit rise in technological innovation. This concludes that technological innovations have a constructive and significant effect on environmental quality in Asian countries. Therefore, technological innovations may result in reduction of carbon exhalation and by encouraging technological innovations these countries can adopt greener economies by replacing harmful resources with ecological ones (Muqattash et al., 2026).

H2: Technological Innovations have a significant impact on Carbon Emissions.

Economic Growth and Carbon Emissions

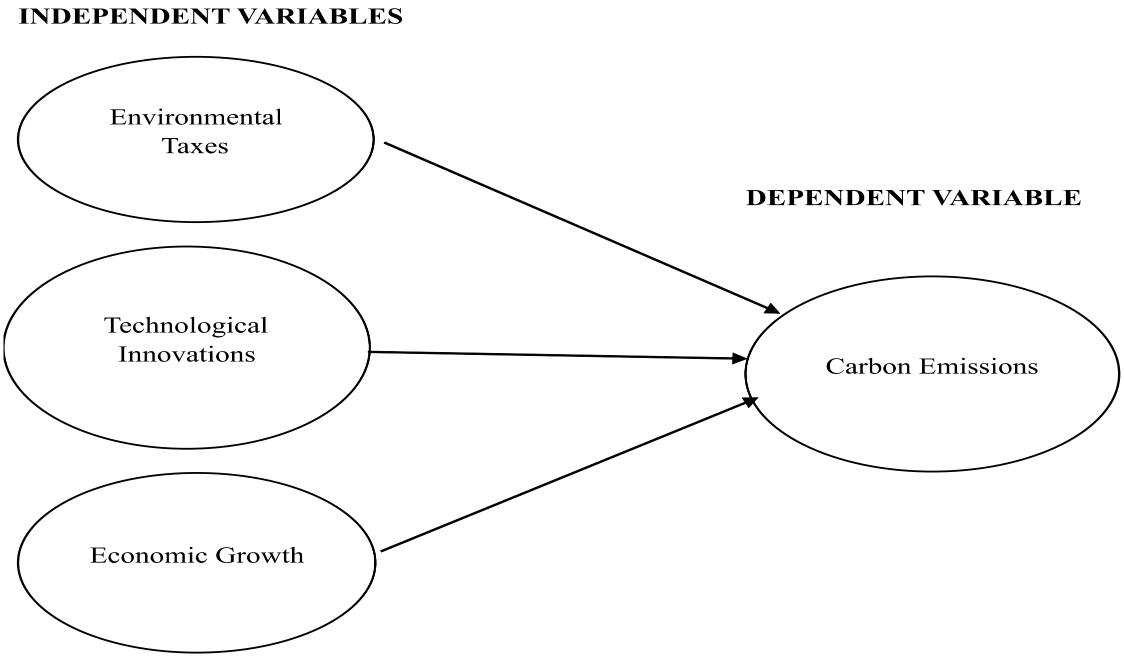
With the rise in the economy carbon emissions slowly but surely rise till economic growth touches a particular stage, from which carbon emissions start to reduce as the economy remains advanced and established (Wang et al., 2018). This pattern is verified by recent empirical assessments showing that sustained structural transitions eventually allow emerging economies to decouple growth from emissions (Nguyen et al., 2026). Saboori et al. (2012) discussed how economic growth and carbon emissions are interlinked in Malaysia. They moved towards industrial development from an agrarian economy; they also faced a rise in population and carbon emissions. Back in 2007, per-person carbon emissions in Malaysia were more than the world average. Recent regional assessments continue to monitor this path, showing that Malaysia's rapid urban and economic expansion maintains per-capita emission pressures unless countered by strict climate governance (Jama et al., 2026). According to the findings of Saidi and Hammami (2015), it has been highlighted that there is a negative influence between economic growth and carbon emissions, indicating that when carbon emissions per capita rise the GDP of the country falls. The study suggests that countries should invest in energy projects to achieve GDP growth (Wang et al., 2018). Balsalobre-Lorente et al. (2018) identified that there is a positive correlation between economic growth and carbon emissions and a negative correlation between consumption of renewable electricity and carbon emissions (Freire-González et al., 2024). This trade-off remains highly visible in newer data models where fossil-fuel consumption directly expands carbon output, while renewable investments consistently mitigate environmental degradation (Li et al., 2026). Sharif et al. (2023) highlighted the fact that to achieve green innovations and less carbon emissions it is important to certify a firm and stable economy. Hence, sustainable development should be a top priority to manage stable economic augmentation and carbon emanation (Freire-González et al., 2024; Wang et al., 2018).

H3: Economic Growth has a significant impact on Carbon Emissions.

Theoretical Framework

Figure 2

Framework



Data Sources and Research Methodology

Sources of Data

This study fundamentally investigates the connections and associations between environmental taxes, technological innovations, economic growth, and carbon emissions in Malaysia from 1990 to 2021. The comprehensive overview of the model's variable accompanied by a detailed description and suggested measurement methodologies have been discussed in Table 1. Environmental taxes are measured in Environmental Taxes (% of GDP), which refers to the total amount of environmentally related tax collected by the Malaysian government articulated as a percentage of GDP. For technological innovation, research and development expenditure (% of GDP) has been used as a proxy, which refers to the expenditure and investment in R&D operations by all the economic sectors. Economic growth has been measured through Malaysia's annual GDP. Carbon emissions have been quantified and measured by CO_2 emissions (metric tons per capita), which refers to the total amount of CO_2 yielded by an average person living in a specific region. By dividing the country's total CO_2 emissions by its total population, it can be calculated. All of the details and information about TI, EG, and CE have been compiled from the World Bank Indicators, and facts and figures about ET have been aggregated through the International Monetary Fund from 1990 to 2021.

Variables Definition

Environmental Taxes: One strategy for gaining power is environmental taxes. These taxes aim to nudge businesses, industries, and individuals towards lowering their carbon footprint (Waweru et al., 2008).

Technological Innovations: Technological innovation is referred to as an essential way to yield less carbon and to establish an economy that depends less on fossil fuels. In short, energy technological innovations refer to create flexible means to utilize energy efficiently. It also means to develop advanced ideas in science and technology (Sagar, 2004),

Economic Growth: Economic growth includes all the economic activities which need particular attention, these activities have major contributions towards GDP (Gross Domestic Product). Such activities include activities related to agriculture and industry (Lewis, 2013).

Carbon Emissions: Carbon emissions are produced via consuming fossil energy massively and this amount of carbon emissions has been rising every year. Due to these emissions, there are numerous chances of worldwide climate-related disasters and because of carbon emissions greenhouse gases are also increasing (Liu et al., 2023; Liu, 2025).

Measurement of Variable Table

Table 1

Measurement of Variable Table

Variables	Proxies	Sources
Environmental Taxes	Environmental Taxes (% of GDP)	IMF
Technological Innovation	R&D expenditures (% of GDP)	WDI
Economic Growth	GDP growth (annual %)	WDI
Carbon Emissions	CO2 emissions (metric tons per capita)	WDI

Methodology

The study used data on an annual basis for Malaysia from 1990 to 2021. The analysis procedure was performed using EViews software. First, a descriptive analysis was done to examine the study variables' mean, median, maximum, minimum, standard deviation, skewness, kurtosis, Jarque–Bera test, and probability. Second, there was a need to check for the multi-collinearity problem, hence, the study used Variance Inflation Factor (VIF). Third, the study used Ordinary Least Square (OLS) regression to estimate the long-run relationship between the independent variables and the dependent variable. The OLS regression results revealed coefficients, t-test results, p-value, F-statistic, R-square, adjusted R-square, and several other statistics. Fourth, the study used Johansen Cointegration Test to determine the long-run relationship between the independent variables and the dependent variables, examining trace statistics, and the maximum eigenvalue to reveal cointegrating relationships. Additionally, interpreting trace statistics revealed the number of cointegrating variables. The normalized cointegrating coefficients reveal the long-run relationship, and the adjustment coefficients reveal the speed of adjustment of the variables in the long run. Lastly, the study used a Vector Error Correction Model to examine the short-run dynamics of the study variables and estimate speed of adjustment of the variables towards long-run equilibrium. The results of the VECM indicated the ECT term which revealed how fast the variables adjusted to achieve long-run stability.

Equation 1

Johansen cointegration model

$$\Delta CO2t = \theta + \sum_{i=1}^{p} \theta 1i \Delta ETt - 1 + \sum_{i=1}^{p} \theta 2i \Delta TIt - 1 + \sum_{i=1}^{p} \theta 3i \Delta EGt - 1 + \mu t$$

Equation 2 depicts the short-run links between the dependent variable which is carbon emissions and the independent variables which are Environmental taxes, technological innovations, and economic growth. Past changes among the variables have been notified through summation (**∑**) terms. ECM error correction mechanism certifies that over time variables adjust back. The residual (**υt**) term refers to unaddressed deviations and fluctuations in carbon emissions.

Equation 2

VECM

$$\Delta CO2t = \alpha 0 + \sum \delta 1 \Delta ETt - 1 + \sum \varphi 2 \Delta TIt - 1 + \sum \omega 3 \Delta EGt - 1 + \delta ECMt + \upsilon t.$$

Results and Discussions

Descriptive Tests

Table 2 represents the key findings from the descriptive tests. The mean values of Environmental Taxes, Technological innovations, Economic Growth, and Carbon Emissions are 0.004342, 0.005329, 0.046866, and 6.407490 respectively. The mean values indicate the central tendency of data over a specified period of timeframe. The mean value of Environmental Taxes is quite low, reflecting that only a nominal amount of Malaysia's Economic potential is committed to these taxes. The low mean value of Technological Innovation shows that technological innovation is not a key priority in Malaysia's Economy. The mean value of Economic Growth is moderate signifying the gradual improvement of the economy. The mean value of Carbon Emissions represents the intense number of emissions.

The median is a statistic that highlights the central point of an organized dataset. It is an essential measure that assists in understanding the typical values. The median values of Environmental Taxes, Technological innovations, Economic Growth, and Carbon Emissions are 0.004400, 0.005344, 0.054322, and 6.737747 respectively. Median values of Environmental Taxes and Technological Innovations are relatively low. The median value of Economic Growth reflects that the economy is growing at a persistent speed. The median value of Carbon Emissions is moderate but relatively high for a developing country.

Maximum values demonstrate the highest magnitudes touched by each variable. The maximum values of Environmental Taxes, Technological innovations, Economic Growth, and Carbon Emissions are 0.007800, 0.014152, 0.100027, and 7.719436 respectively. These levels indicate minimal allocation of environmental and R&D outlay, accelerated GDP growth, and maximum Carbon output depicting the highest environmental impact.

The minimum values display the most declined value of each variable over a specified period of timeframe. The minimum values of Environmental Taxes, Technological innovations, Economic Growth, and Carbon Emissions are 0.002000, 0.000000, -0.073594, and 4.286164 respectively. The minimum value of technological Innovations indicates low or no investment in the development of technology. The standard deviation measures the dispersion of data points for each variable. The standard deviation values for Environmental Taxes, Technological Innovations, Economic Growth, and Carbon Emissions are 0.001947, 0.005059, 0.040336, and 1.033336, respectively. The standard deviation of environmental taxes indicates minimal variability as a percentage of GDP, with values closely aligned to the mean. The standard deviation of technological Innovation is stable with little deviations. The standard deviation of economic growth shows higher fluctuations, suggesting that the economy has witnessed both consequences speedy growth and downturn. In this context, the threshold of standard deviation below 1% is considered low, from 1% to 3% as moderate, and 4% and above is considered high. The high standard deviation of Carbon Emissions indicates abundant fluctuations probably due to increasing industrialization and altering economic operations.

Skewness is the statistical measure that calculates the asymmetry of the distribution of data over a specific period. The data is said to be symmetric when the skewness is close to zero. Skewness between –o.5 to 1 or 0.5 to 1 is mildly skewed. Positive skewness indicates a longer tail on the right side whereas negative skewness represents a longer tail on the left side. Skewness above -1 or 1 is said to be highly skewed. The skewness values of Environmental Taxes, Technological innovations, Economic Growth, and Carbon Emissions are 0.149513, 0.221526, -1.666495, and -0.532945 respectively. The values of Environmental Taxes and Technological Innovations are slightly positively skewed and are almost symmetrical. Economic Growth is negatively skewed indicating a long tail on the left side probably due to a limited growth period. Carbon Emission is mildly negatively skewed, indicating a minimal left-side tail.

The Kurtosis values of Environmental Taxes, Technological innovations, Economic Growth, and Carbon Emissions are 1.390092, 1.521487, 5.557745, and 1.958113 respectively. Values of Environmental taxes, technological innovations, and Carbon emissions are less than 3 representing platykurtic distribution. Economic Growth has sharper peaks as its Kurtosis is greater than 3 indicating leptokurtic distribution.

Jarque-Bera test defines whether the dataset's distribution deviated from a normal distribution. It provides a particular measure by combining values of skewness and kurtosis. The values of Jarque-Bera of Environmental Taxes, Technological innovations, Economic Growth, and Carbon Emissions are 2.904656, 2.580818, 19.12179, and 2.406787 respectively. Values of Environmental taxes, Technological Innovations, and Carbon Emissions are low, reflecting no substantial variance from a normal distribution.

Table 2

Descriptive Statistics

Statistic	Environmental Taxes	Technological Innovations	Economic Growth	CO_2 Emissions
Mean	0.004342	0.005329	0.046866	6.407490
Median	0.004400	0.005344	0.054322	6.737747
Maximum	0.007800	0.014152	0.100027	7.719436
Minimum	0.002000	0.000000	-0.073594	4.286164
Standard Deviation	0.001947	0.005059	0.040336	1.033336
Skewness	0.149513	0.221526	-1.666495	-0.532945
Kurtosis	1.390092	1.521487	5.557745	1.958113
Jarque–Bera	2.904656	2.580818	19.121790	2.406787
Probability	0.234025	0.275158	0.000070	0.300174

Note. N = sample period observations. Probability values correspond to the Jarque–Bera test for normality.

Table 2b

Variance Inflation Factors

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
Constant	0.394598	15.19324	—
Economic Growth	17.88206	2.589422	1.077136
Environmental Taxes	8929.656	7.736594	1.253664
Technological Innovation	1346.621	2.748389	1.275837

Note. All centered VIF values are below the threshold of 10, indicating that multicollinearity is not a concern among the independent variables.

Ordinary Least Square (OLS)

Table 3 depicts the results of Ordinary Least Square (OLS). F-statistics aims to assess the collective significance of the regression model, whether the overall independent variables have a significant relationship with the dependent variables or not. The value of the F-statistic is 5.843889 and the Prob(F-statistic) is 0.004290. Since the prob(F-statistic) is less than 0.05, it indicates that all the independent variables i.e. Environmental taxes, Technological innovations, and economic growth have a significant relationship with Carbon emissions, and at least one of the IV has an impact on Carbon Emissions.

R-squared and adjusted r-squared targets to calculate the goodness of fit of the regression model. The R-squared value is 0.443484 which represents about 44.34% of the deviation in the Carbon emissions i.e. the dependent variable is described by the independent variables. The value of adjusted R-squared is 0.367596. This proposes that the mode is a moderate fit and has limited explanatory strength.

Economic growth has a p-value of 0.5119 since it is greater than 0.05, the null hypothesis fails to be accepted which indicates that it is statistically insignificant. Due to the negative value of -2.819383, the coefficient represents the negative relationship between Economic growth and Carbon Emissions.

The environmental tax has a p-value of 0.0213, there is a significant relationship between Environmental taxes and carbon emissions as the null hypothesis is rejected. The negative coefficient value which is -234.2453 denotes the negative relationship between Environmental taxes and Carbon emissions. With the increase in environmental taxes, carbon emissions will decrease.

Technological innovation has a p-value of 0.0743 and a coefficient value of 68.76870 which represents that there is a positive insignificant relationship between Technological innovations and Carbon Emissions. With 1 unit increase in Technological innovations, carbon emissions are expected to increase by 68.77 units.

Table 3

Ordinary Least Squares Regression Results

Variable	Coefficient	Std. Error	t-Statistic	p
Economic Growth	-2.819383	4.228718	-0.666723	.5119
Environmental Taxes	-234.245300	94.496860	-2.478868	.0213*
Technological Innovation	68.768700	36.696340	1.873993	.0743
Constant	7.190304	0.628170	11.446420	.0000*

Note. Dependent variable: CO_2 emissions. R^2 = .443484, adjusted R^2 = .367596, F = 5.843889, p = .004290. *p < .05.

Johansen's Cointegration

The values of Table 4, Table 5, Table 6, Table 7, 8 till 11 serve as the results of Johansen's cointegration test and associate findings. Identifying the long-term cointegration between the variables is the core objective of these tests. Eigenvalue aims to demonstrate the robustness of cointegrating relationships. Higher eigenvalues indicate a stronger relationship. Trace statistics assess the number of cointegration relationships in long-term relationships. Maximum eigenvalue focuses on the largest eigenvalue and is much like trace statistic; used to test the number of cointegration relationships.

Table 4 illustrates the unrestricted cointegration rank test (Trace), determines the cointegration equations, and tests the long-term relationship among variables. Based on the results of Table 2 it signifies that there is at least one cointegrating relationship, as the trace statistic is greater than the critical value and the p-value is less than 0.05.

Table 4

Unit Root Test Results

Variable	Level t-Statistic	First Difference t-Statistic	p	Order of Integration
Economic Growth	-2.294	-5.962***	.0001	I(1)
Environmental Taxes	-1.853	-6.241***	.0000	I(1)
Technological Innovation	-2.451	-5.487***	.0002	I(1)
CO_2 Emissions	-3.016	-6.753***	.0000	I(1)

Note. ***p < .01. All series are stationary at first difference and integrated of order one.

Table 5

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	p
None*	0.690719	52.13626	47.85613	.0188
At most 1	0.470848	23.97217	29.79707	.2016
At most 2	0.180448	8.696668	15.49471	.3942
At most 3*	0.150718	3.920742	3.841466	.0477

Note. Trace test indicates one cointegrating equation at the .05 level. *Denotes rejection of the hypothesis at the .05 level.

Table 6

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	p
None*	0.690719	28.16408	27.58434	.0421
At most 1	0.470848	15.27551	21.13162	.2701
At most 2	0.180448	4.775926	14.26460	.7698
At most 3*	0.150718	3.920742	3.841466	.0477

Note. Max-eigenvalue test indicates one cointegrating equation at the .05 level. *Denotes rejection of the hypothesis at the .05 level.

Table 7

Unrestricted Cointegrating Coefficients

Equation	Economic Growth	Environmental Taxes	Technological Innovation	CO_2 Emissions
1	45.10121	406.6569	-4.227409	0.461040
2	-6.845754	538.2346	488.6478	-0.255841
3	-13.46898	459.5980	-129.9857	1.698780
4	-11.31996	511.4374	-22.55407	-0.037289

Note. Coefficients are normalized such that b'*S11*b = I.

Table 8

Unrestricted Adjustment Coefficients (Alpha)

Variable	Equation 1	Equation 2	Equation 3	Equation 4
D(Economic Growth)	-0.037804	-0.000402	-0.005501	0.003356
D(Environmental Taxes)	0.000113	-0.000361	-0.000172	-0.000336
D(Technological Innovation)	-0.000580	-0.002062	0.001295	-0.0000902
D(CO_2 Emissions)	-0.055062	-0.076482	-0.083188	0.064261

Table 9a

Normalized Cointegrating and Adjustment Coefficients: One Cointegrating Equation

Normalized Cointegrating Coefficients (Standard Errors in Parentheses)

Economic Growth	Environmental Taxes	Technological Innovation	CO_2 Emissions
1.000000	9.016541	-0.093732	0.010222
	(3.36312)	(1.76669)	(0.00622)

Table 9b

Adjustment Coefficients (Standard Errors in Parentheses)

Variable	Coefficient
D(Economic Growth)	-1.704996 (0.31583)
D(Environmental Taxes)	0.005098 (0.01162)
D(Technological Innovation)	-0.026173 (0.04575)
D(CO_2 Emissions)	-2.483365 (2.99789)

Note. Log-likelihood = 279.3114.

Table 10a

Normalized Cointegrating and Adjustment Coefficients: Two Cointegrating Equations

Normalized cointegrating coefficients (standard errors in parentheses)

Economic Growth	Environmental Taxes	Technological Innovation	CO_2 Emissions
1.000000	0.000000	-7.427770 (2.27142)	0.013016 (0.00766)
0.000000	1.000000	0.813398 (0.19421)	-0.000310 (0.00066)

Table 10b

Adjustment Coefficients (Standard Errors in Parentheses)

Variable	Equation 1	Equation 2
D(Economic Growth)	-1.702244 (0.31942)	-15.58958 (4.72351)
D(Environmental Taxes)	0.007571 (0.01110)	-0.148485 (0.16410)
D(Technological Innovation)	-0.012056 (0.04062)	-1.345880 (0.60066)
D(CO_2 Emissions)	-1.959785 (2.91859)	-63.55684 (43.1595)

Note. Log-likelihood = 286.9491.

Table 11a

Normalized Cointegrating and Adjustment Coefficients: Three Cointegrating Equations

Normalized Cointegrating Coefficients (Standard Errors in Parentheses)

Economic Growth	Environmental Taxes	Technological Innovation	CO_2 Emissions
1.000000	0.000000	0.000000	-0.011788 (0.00757)
0.000000	1.000000	0.000000	0.002406 (0.00076)
0.000000	0.000000	1.000000	-0.003339 (0.00102)

Table 11b

Adjustment Coefficients (Standard Errors in Parentheses)

Variable	Equation 1	Equation 2	Equation 3
D(Economic Growth)	-1.628152 (0.32729)	-18.11779 (5.61675)	0.678383 (3.47943)
D(Environmental Taxes)	0.009886 (0.01141)	-0.227495 (0.19579)	-0.154665 (0.12129)
D(Technological Innovation)	-0.029493 (0.03979)	-0.750902 (0.68281)	-1.173459 (0.42298)
D(CO_2 Emissions)	-0.839332 (2.89671)	-101.7898 (49.7113)	-26.32697 (30.7949)

Note. Log-likelihood = 289.3371.

Vector Error Correction Estimates

Table 12 depicts the results of VECM model. Vector Error Correction Estimates deal with the instant factors influencing CO2 emissions. The variables Environmental taxes and technological innovations demonstrate a statistically significant and positive short-run relationship with carbon emissions based on the positive coefficient, t-statistics, and standard error. Whereas Economic growth indicates a statistically insignificant and negative relationship as per the negative coefficient and t-statistic and positive standard error, suggesting a boost in economic growth there will be a decline in carbon emissions. Long-lasting and the strong connection between the variables are shown by the Error Correction Terms (ECT). It explains that the system adjusts in the short-run to return to equilibrium if it fluctuates away from its long-run balances. The availability of noteworthy ECT ensures the dynamics of the correlations and highlights the importance of both short-term and long-term equilibrium.

Table 12a

Vector Error Correction Model Estimates

Panel A: Cointegrating Equation (CointEq1)

Variable	Coefficient
CO2_EMISSIONS(−1)	1.000000
ENVIRONMENTAL_TAXES(−1)	655.7039 (40.8373) [16.0565]
TIN(−1)	160.4877 (22.6835) [7.07507]
ECONOMIC_GROWTH(−1)	−40.72610 (2.72017) [−14.9719]
Constant	−8.182120

Note. Standard errors in parentheses; t-statistics in brackets.

Table 12b

Panel B: Error Correction Estimates

Variable	D(CO2 Emissions)	D(Environmental Taxes)	D(TIN)	D(Economic Growth)
CointEq1	0.018605 (0.14189) [0.13112]	−0.000408 (0.00041) [−1.00078]	0.000217 (0.00205) [0.10576]	0.062365 (0.00936) [6.66076]
D(CO2_EMISSIONS(−1))	−0.306818 (0.30839) [−0.99490]	−0.002984 (0.00089) [−3.37016]	0.006818 (0.00445) [1.53119]	−0.015354 (0.02035) [−0.75448]
D(CO2_EMISSIONS(−2))	−0.142592 (0.35823) [−0.39805]	−0.001335 (0.00103) [−1.29769]	0.009347 (0.00517) [1.80697]	0.008668 (0.02364) [0.36669]
D(ENVIRONMENTAL_TAXES(−1))	−34.39909 (105.056) [−0.32743]	0.010873 (0.30165) [0.03605]	0.234667 (1.51696) [0.15470]	−38.59373 (6.93252) [−5.56705]
D(ENVIRONMENTAL_TAXES(−2))	−70.73523 (107.614) [−0.65731]	0.183810 (0.30900) [0.59486]	−0.408208 (1.55389) [−0.26270]	−53.69339 (7.10128) [−7.56108]

D(TIN(−1))	−26.71478 (26.8821) [−0.99378]	−0.101077 (0.07719) [−1.30949]	−0.868155 (0.38816) [−2.23657]	−8.445541 (1.77391) [−4.76097]
D(TIN(−2))	−16.02500 (21.2697) [−0.75342]	−0.145599 (0.06107) [−2.38402]	0.058364 (0.30712) [0.19004]	−3.598853 (1.40356) [−2.56409]
D(ECONOMIC_GROWTH(-1))	0.205511 (3.67489) [0.05592]	−0.003698 (0.01055) [−0.35050]	0.005161 (0.05306) [0.09727]	0.776644 (0.24250) [3.20265]
D(ECONOMIC_GROWTH(-2))	−0.505858 (1.99261) [−0.25387]	0.002717 (0.00572) [0.47496]	−0.017989 (0.02877) [−0.62521]	0.082497 (0.13149) [0.62740]
Constant	0.169059 (0.09466) [1.78604]	0.000571 (0.00027) [2.10131]	−0.001789 (0.00137) [−1.30864]	0.002225 (0.00625) [0.35623]

Note. Standard errors in parentheses; t-statistics in brackets. D() denotes the first-differenced series; numbers in parentheses next to variable names indicate lag length.

Discussion

The findings confirm that there are limited policies related to the imposition of environmental taxes and green technology, while the high yield of carbon emissions requires strict policy regulation by policymakers, particularly the government. The study represents how pivotal environmental taxes and technological innovations are in diminishing carbon yields and fostering the environment and economic growth. To comprehend the sustainable future in Malaysia reinforcement and integration of green technology and green taxes are obligatory both in the short run and long run (Lau et al., 2022).

H1: Environmental taxes have a significant impact on Carbon Emissions.

The results indicate that environmental taxes are inversely proportional to carbon emissions. With the increase in environmental taxes, carbon emissions will decrease. It can be proved to be an advantageous measure to combat excessive carbon yields. The empirical results by Wolde-Rufael and Mulat-Weldemeskel (2021), Doğan et al. (2022) and Rakpho et al. (2023) prove the study that environmental taxes are essential, critical, and practical tools to control and diminish the increasing emissions, these studies also support the detail that higher and tight environmental stringent policies will lead to lower carbon emissions.

H2: Technological Innovations have a significant impact on Carbon Emissions.

According to OLS results, the hypothesis will fail to be rejected as the p-value is greater than 0.05 which validates that there is an insignificant relationship between technological innovations and carbon emissions. According to the studies by Ali et al., 2016 and Junsheng et al. (2024), technological advancement did not have a major effect on carbon emissions in reducing carbon emissions. This could be because Malaysia still relies heavily on carbon-intensive technologies, without replacing former systems with updated and advanced ones. The study concluded that rather than dealing with the environmental concerns it might be prioritizing only the economic growth. The conclusion drawn by Amri et al (2019) proves that as compared to high-income countries, in low and middle-income countries technological innovation has an insignificant relationship with carbon emissions. Quite similar results have been explored by Lahouel et al (2021) in high-income countries industries have been shifted towards e-paper, e-commerce, and teleconference which is substantial in reducing carbon yields.

H3: Economic Growth has a significant impact on Carbon Emissions.

Based on the results the p-value of economic growth is greater than 0.05 indicating an insignificant impact on carbon emissions. The null hypothesis fails to be rejected proving the insignificant relationship. The study by Amri et al. (2019) supports the literature that Economic growth is the main cause of Carbon Emissions and has an insignificant relationship with each other. When the economy boosts industrial investment increases which leads towards excessive carbon emissions. Some studies by Osiobe (2020) indicate that the traditional structure of economic growth leads toward extensive emissions while shifting toward green growth and a service-oriented economy can reduce emission activities. The study by Daly et al. (2024) supports the literature that chronically there is no determination between CO2 emissions and Economic growth in the short run but the impact is possible in the long run causing unidirectional significance. Particularly while considering trade openness and energy consumption, the relationship between economic growth and carbon emissions is not always significant proven by the EKC hypothesis as well (Karedla et al., 2021).

Conclusion

Malaysia is yielding an enormous quantity of carbon, which is causing harm to the environment and leading to environmental pollution. Relying heavily on such energy requirements the massive amount of greenhouse gases has been contributing to environmental pollution.The finding of the study concluded that carbon emission has a long-term association with economic growth and a short-term link with environmental taxes.

Findings suggest environmental taxes as one of the strong tools to combat carbon emissions as they share a negative significant relationship with carbon emissions. Environmental taxes encourage industries and consumers to embrace more sustainable practices and focus on cleaner production methods. According to the study 1% rise in environmental taxes as a % of GDP results in a probable reduction of 0.15 metric tons of carbon emission per capita. Approx. 0.78% of GDP has been incorporated by environmental taxes in Malaysia. This refers to the prospective to claim greater benefits to achieve environmental sustainability through auxiliary leveraging (Bashir et al., 2020).

Contrariwise, technological innovations, and economic growth have inconclusive impact on carbon emanation. The current R&D expenditure of Malaysia is 0.65% of the GDP, which is considerably lower than the innovation leaders including Japan and Korea who assign almost over 3% of GDP to research and development expenditure (Ali et al., 2021). Due to this minimal investment in advancement seize the potential of technological advancement in reducing carbon emissions. Extensive reliance on energy-consuming industries has resulted an upsurge in carbon emissions by shifting towards renewable and cleaner energy can boost economic growth by prioritizing environmental sustainability as well. Malaysia emitted 8.1 metric tons of carbon per capita in 2022, which is higher than the nearby territorial areas such as Thailand which emitted 4.5 metric tons, and the Philippines which emitted 1.3 metric tons(Wang et al., 2022). The study focuses on several determinants which can make Malaysia a low-carbon economy.

Policy Implications

The conclusions from this study may practically benefit the government which should consider imposing and raising environmentally related taxes to sustain a cleaner future in Malaysia. For the theoretical implications this study challenges the fact that economic growth solely cannot lead to environmental up-gradation, other factors like policy frameworks and industrial patterns should be incorporated. The managerial implication of the study focuses on that corporations in Malaysia should be environmentally friendly. For strategic implications, the study's findings suggested that Malaysia should make diversification in their economy.

Limitations & Future Directions

Despite the selected facets, other factors can also be included which might assist in recognizing the impact on carbon emissions. The study only focuses on Malaysia. The nature of data is a time series dealing with limited years of data. Future studies should include other geographical regions to enrich the generalization of the findings. Only limited factors have been discussed in the study; other studies could incorporate other influential variables including various other variables such as economic indicators, public awareness, international agreements, and the role of renewable energy adoption for mitigating emissions, to deliver a more inclusive consideration. The study incorporates data from limited years and limited proxies' future studies can move towards data from further years and proxies. Upcoming studies can also choose another model of data analysis. Future studies can investigate comparative studies between two countries.

Recommendations

According to the outcomes of the study, a few recommendations can be suggested to combat the challenges related to carbon exhalation in Malaysia. Firstly, decision makers must prioritize on implying and raising environmental taxes to invest in cleaner production. Secondly, there should be an aim to invest more in technological advancement. Thirdly, the economy and industries should be shifted towards cleaner means of energy. Finally, it is crucial to evaluate the environment-related strategies.

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