Exploring the impact of interest rates on carbon emissions: Malaysia in perspective

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Abstract:

The growing global concern about climate change has spurred scholars and policymakers to investigate the intricate relationship between economic activity and environmental impacts. This study, which uses carbon emission (CO2) to explore the connection between gross domestic product (GDP), export growth (EG), and real interest rates (INT) in Malaysia, is a significant contribution to this field. The study employs Autoregressive Distributed Lag (ARDL) regression to analyze 1988–2018 data. The dataset, meticulously constructed from reliable sources such as the World Bank, Our World in Data, and Department of Statistics Malaysia open-source databases, ensures the robustness of the analysis. The analysis reveals a positive and significant link between gross domestic product (GDP) and CO2 emissions in both the long and short run. In contrast, real interest rates (INT) did not show any significance in the long run but negatively affected CO2 emissions in the short run, while export growth (XG) did not show any significance in the long and short run. These findings enrich the academic understanding of the issue and have significant implications for policy-making, particularly the central bank, in formulating monetary policy and devising comprehensive economic strategies to maintain a robust economy without compromising the environment.

Keywords: *Interest rates, gross domestic product, carbon emission (CO2), Autoregressive Distributed Lag (ARDL), Malaysia*

1. Introduction and Background

The global community has witnessed unprecedented economic growth in recent decades, particularly in emerging markets such as Malaysia. This surge in economic activity has undeniably contributed to advancements in various sectors, improving living standards and fostering technological progress. However, this economic prosperity has come at the cost of a notable increase in carbon dioxide (CO2) emissions, one of the primary contributors to climate change.

According to the Cambridge Dictionary (Cambridge University, 2023), carbon dioxide (CO2) is a non-toxic, odorless gas produced as a byproduct of the combustion of carbon and the respiration of living beings. It is classified as a greenhouse gas because it traps atmospheric heat. The term "emissions" refers to the act of releasing greenhouse gases and their precursors into the atmosphere over a particular geographical region and for a certain amount of time. Carbon dioxide emissions, also known as CO2 emissions, are created as a byproduct of the combustion of fossil fuels and the production of cement. These emissions include the carbon dioxide produced during the consumption of solid, liquid, and gas fuels and the flaring of gas waste.

Global concerns about climate change have intensified recently, prompting researchers and policymakers to investigate the intricate relationship between economic activities and environmental outcomes. The nexus between economic growth and environmental sustainability has become a subject of global significance. Like many other nations, Malaysia grapples with balancing economic expansion with the imperative to curb

environmental degradation.

Emissions of carbon dioxide (CO2) in Malaysia, like emissions in many other nations, have consequences for the environment on both a global and a local scale. These emissions are primarily the consequence of a wide variety of human activities, such as the generation of energy, transportation, numerous industrial operations, and the cutting down of forests (United States Environmental Protection Agency, 2023). Changes in the global climate impact Malaysia, just as they do on the rest of the globe. The increase in CO2 levels contributes to global warming, which causes temperatures to rise and causes changes in weather patterns. This can increase the frequency and severity of extreme weather events, such as storms, floods, and droughts. (United Nations, n.d.)

In addition, carbon dioxide emissions are frequently linked to the production of other types of pollution, such as particulate matter (PM2.5 and PM10) and nitrogen oxides (NOx). These pollutants can lower air quality, resulting in various health consequences for the general population, including respiratory disorders. Also, when temperatures around the world rise, Arctic ice caps and glaciers melt, which makes the water level rise ((Alola et al., 2023).

CO2 emissions cause climate change, which may disturb environments and put species at risk. With its many tropical jungles, Malaysia is home to many rare species that may be in danger because of changes in the climate. Weather changes and how it rains can also affect crop output and food production. Malaysia is a farming country, and problems caused by the weather can make food security less stable. As changing temperature and humidity patterns create more conducive conditions for disease vectors, climate change can contribute to the spreading of disease. (Ma et al., 2022). This can have an effect on public health in Malaysia. In addition, climate change can result in significant economic costs, including infrastructure damage, increased healthcare costs, and decreased agricultural output. These expenses can burden both the government and the private sector.

In the global pursuit of sustainable development and climate mitigation, in a recent address, current Prime Minister Datuk Seri Anwar Ibrahim affirmed Malaysia's determination to play a pivotal role in reducing emissions while embracing the growth of the low-carbon economy. As part of this commitment, Malaysia has revised its Nationally Determined Contribution (NDC), aiming to reduce the intensity of greenhouse gas emissions by 45 percent by 2030 compared to 2005 levels. The integration of these efforts is evident in key policy documents, namely the 12th Malaysia Plan and the National Energy Policy 2022– 2040 (Economic Planning Unit, 2022). The NEP 2040 strategically positions the energy sector as a catalyst for socio-economic development, with a specific six focus on the Low Carbon Nation Aspiration. The government also promotes environmental sustainability by advocating for zero waste and increased recycling efforts. This is being facilitated through initiatives such as the implementation of the Low-carbon Cities Master Plan and the adoption of circular economy principles. Furthermore, a concerted effort is to enhance private sector involvement in achieving the ambitious goal of zero greenhouse gas (GHG) emissions.

In emphasizing the role of natural gas as a clean and crucial component in the energy mix, Malaysia recognizes its importance in transitioning toward a lower carbon economy. Additionally, the government's commitment to the global methane pledge aims to cut emissions by 30 percent by 2030 compared to 2020. (Economic Planning Unit, 2022). The intersection of these national policies and commitments with the economic variables under investigation forms a critical backdrop for understanding the dynamics of CO2 emissions in Malaysia. As the nation positions itself for sustainable development, this study aims to contribute insights that align with Malaysia's evolving energy landscape and global climate responsibilities.

The remaining segment of this study is followed by the literature review, where the framework of discussion will be customized to facilitate an understanding of this study, the methodology, and finally, the conclusion.

2. Literature Review

The findings of earlier studies on the relationship between gross domestic product, real interest rate, and export growth toward carbon dioxide emission will be explored in depth in this chapter to provide better knowledge and understanding of the present state of this research. This study aims to investigate the correlation in terms of causes and effects between independent variables and dependent variables that relate to the research objectives.

2.1 Carbon Dioxide Emissions

Emissions of carbon dioxide, also known as CO2 emissions, are those that are created when fossil fuels are burned, as well as when cement is manufactured. These emissions mainly include the carbon dioxide produced when using solid, liquid, and petrol fuels and the carbon dioxide formed when petrol is flared. However, it could be aroused from other causes, such as the increase in GDP, changes in interest rates, and expansion in export growth. Furthermore, another empirical research indicates that unemployment and population have an impact on CO2 (Karim et al., 2023).

Despite being cognizant of the issue, people's environmental engagement could be much higher in the early stages of economic development. Although there is widespread awareness of climate change, only 1% of the population has heard of it, according to a previous study; of those who are aware, 29% have "just a little," 10% have "a fair amount," and 56% have "a lot." (Whitmarsh, Seyfang & O'Neill, 2011). Regarding media assertions concerning climate change, most respondents are skeptical and believe they require additional data before forming a definitive opinion (Whitmarsh et al., 2010).

This is extremely concerning due to the potential environmental repercussions that may result. The investigation pertains to carbon emissions, specifically carbon dioxide (CO2), which stands as a prominent greenhouse gas accountable for heat retention within the Earth's atmosphere, thereby precipitating climate change and global warming. The current level of greenhouse gas (GHG) concentrations disrupts the thermal equilibrium of the planet, whereas emissions of this magnitude would result in an approximate two °C increase in 13 temperatures. For example, considering the cumulative anthropogenic emissions of one trillion tonnes of carbon (3.67 trillion tonnes of CO2), of which approximately half has been released since the inception of industrialization, the most probable peak warming caused by carbon dioxide is two °C above pre-industrial levels. This estimation is accompanied by a 5–95% confidence interval of 1.3–3.9 °C. (Allen et al., 2009).

2.2 Exports Growth

The number of studies examining the impact of exports on global CO2 emissions is relatively abundant. The literature includes mixed findings on the relationship between export growth and CO2 emissions. Ahmad & Wyckoff (2003) found a significant aspect of carbon emissions, revealing that certain OECD countries attribute over 50% of their domestic emissions to foreign trade. On a broader scale, their findings indicate that trade-related carbon emissions account for an average of approximately 14% of total emissions across all countries. In the study conducted by Majekodunmi et al. (2023). The findings suggest that an increase in exports will have detrimental effects on Malaysia's environment. The study indicates that heightened export activities contribute to higher production levels and increased energy consumption. On the contrary, Muhammad et al. (2020) indicated that exports decreased carbon emissions in low and high-income countries but increased them in lower-middle-income countries.

An additional study elucidates that China's CO2 emissions could impede economic progress; ultimately, the burden of CO2 emissions should fall on the export sector, given that the transition to export-oriented manufacturing has contributed to a portion of the pollution surge in China (Yunfeng & Laike, 2010). China contributed two-thirds of the worldwide 3.1% increase in CO2 emissions in 2007 through an 8% increase in national emissions. China now ranks first among nations in terms of CO2 emissions. Soybean oil, the primary agricultural export crop in Brazil and the most traded commodity globally, is notorious for its severe environmental impacts. An estimated 223.46 metric tons of total greenhouse gas emissions resulted from Brazilian soy exports between 2010 and 2015; more than half of these emissions were imported by China, whereas the European Union imported more emissions from deforestation (Escobar et al., 2020).

Pakistan ranks within the top ten most susceptible nations concerning the impacts of climate change. Natural disasters, water scarcity, and flooding are thus unmistakable outcomes resulting from climate change. Khan et al. (2020) the relationship between Pakistan's agricultural export trade, carbon emissions, energy consumption, GDP, and urbanization was examined from 1975 to 2017. From 1990 to 2018, the impact of international trade is examined by analyzing exports and imports separately. All variables, including gross domestic product (GDP), imports, and exports, have a more significant long-term effect than their short-term coefficients indicate. The long-term and short-term empirical evidence supports the notion that exports adversely impact carbon emissions from consumption (Z. A. Khan et al., 2021).

2.3 Gross Domestic Product

Onofrei et al. (2022)) study investigates the dynamic interplay between economic growth and CO2 emissions in the 27 European Union (EU) member states from 2000 to 2017. Their findings suggest a long-run cointegrating relationship between economic growth and CO2 emissions in EU countries. Utilizing the Dynamic Ordinary Least Squares (DOLS) method, the study reveals a statistically significant effect of economic growth on CO2 emissions. Specifically, a 1% change in GDP is associated with an average of 0.072 change in CO2 emissions.

In addition, Caporale et al. (2021) focus on the relationship between the logarithms of CO2 emissions and China's real Gross Domestic Product (GDP). Applying fractional integration and cointegration methods, the study suggests the existence of a long-run equilibrium relationship between the two variables in first differences, indicating a linkage in their growth rates over the long term.

In a separate investigation, Akalpler & Hove (2019) explores the effects of energy consumption, CO2 emissions, real GDP per capita, exports, and imports on economic growth in India. The empirical results reveal both short-term and longer-term equilibrium relationships among the variables. Notably, past values, energy consumption, CO2 emissions, imports, and growth in exports and carbon emissions exhibit varying impacts on real Gross Domestic Product per capita in the Indian economy.

2.4 Real Interest Rate

The impact of real interest rates on CO2 emissions remains an underexplored area in the literature specific to Malaysia. Financial policy has been the subject of extensive scholarly analysis in the field of environmental economics as it is a critical instrument in the pursuit of sustainable economic development. According to the findings of a prior investigation in South Korea, financial mechanisms, such as green loans, when designed with supportive interest rates, can be effective tools in achieving more substantial and accelerated reductions in GHG emissions. Particularly, it was found that the implementation of a maximum supporting interest rate of 4.45% has the potential to enhance the greenhouse gas (GHG) emission reduction effect by approximately three to five times compared to the present level (Kim et al., 2022).

An additional study assesses the environmental ramifications of negative interest rate policy, furnishing monetary authorities with valuable policy insights that can be utilized to devise efficacious measures that foster synchronized environmental and economic progress. Ni & Ruan (2023) study adopts a robust approach, utilizing panel data encompassing 45 countries over the period from 2007 to 2019. Employing a multi-period difference-in-differences (DID) method, the research delves into the intricate mechanisms and transmission pathways associated with the implementation of a negative interest rate policy on carbon dioxide emissions. Notably, the study's findings demonstrate a significant reduction in CO2 emissions attributable to adopting a negative interest rate policy. This suggests a potential avenue for policy interventions to leverage monetary instruments in achieving environmental sustainability goals by curbing carbon emissions.

3.0 Methodology

3.1 Model Specification

According to Pesaran et al., (2001), autoregressive distributed lag (ARDL) bound testing provides long-term linkages and dynamic interaction among a variety of interests. The advantages of bound testing are attractive since it enables the use of different integrated levels, such as level I(0) or I(1). It is also consistent with the empirical findings obtained from a small sample. ARDL utilizes a simplified model structure consisting of a single equation, which facilitates its implementation and interpretation. Additionally, it enables the inclusion of varied lag lengths from various variables as they are incorporated into the model.

Therefore, to analyze the influence of XG, INT, and GDP on CO2 emissions in Malaysia, we will use the following model:

$$CO2 = f(GDP, INT, XG) \quad (1)$$

Where CO2 represents CO2 emissions, GDP represents the gross domestic product, INT refers to the real interest rate, and XG is the export of goods and services. Regarding empirical and theoretical literature, GDP is hypothesized as positively significant to CO2, INT is estimated as negatively related to CO2 once they reach high, and XG boosts CO2 due to the country's development. Estimation of Equation (1) yields only long-run estimates.

Therefore, this study additionally utilizes an error-correction model in an effort to examine the immediate impact. Pesaran et al. (2001) provide an econometric method that allows for the simultaneous estimation of both the long-run and short-run impacts in a single phase.

$$lnCO_{2t} = \beta_0 + \beta_1 lnXG_t + \beta_2 lnINT_t + \beta_3 lnGDP_t + \varepsilon_t \quad (2)$$

All study variables are logged (ln). In Eq. (2), β_1, β_2, and β_3 represent the long-term elasticity coefficient of CO2 emissions from the gross domestic product (GDP), real interest rate (INT), export of goods and services (XG), and error term (ε_t).

3.2 *ARDL bound testing method*

The autoregressive distributed lag (ARDL) bound approach is advantageous since it allows for the investigation of equations when the variables are stationary at a level I(0) and also in the first difference I(1) (Pesaran et al., 2001). Establishing the cointegration between the variables is a prerequisite for using the ARDL model. Afterwards, the ARDL bound test is used to examine whether there is cointegration among the variables in both short-term and long-term relationships.

The unrestricted or unconstrained error correction models for CO2 emissions, XG, INT, and GDP based on the ARDL model are as follows:

$$\Delta \ln CO2_t = \beta_0 + \sum_{i=1}^{k} \beta_1 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta lnINT_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta lnXG_{t-i} + \varepsilon_t \quad (3)$$

Where Δ is the first difference operator, β_0 represents the constant term, and ε_t denotes the residual term. The short-run relationship coefficient is denoted by β_1, β_2, and β_3, while the long-run relationship coefficient is denoted by γ_1, γ_2, and γ_3, respectively.

Ordinary least squares (OLS) are applied to estimate Equations (3) to determine whether the series are cointegrated. The subsequent procedure involves employing the F-test to assess whether the lagged levels of the variables are equal to zero. The null and alternative hypotheses for cointegration in Equations (3) can be stated as follows:

H_0: $\gamma_1 = \gamma_2 = \gamma_3 = 0$
H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 = 0$

The null hypothesis of cointegration is rejected, indicating that the series are cointegrated over a long period of time. The subsequent phase involves evaluating the error correction model (ECM), which is expressed as follows:

$$\Delta lnCO2_t = \beta_0 + \sum_{i=1}^{k} \beta_1 \Delta lnCO2_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta lnINT_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta lnXG_{t-i} + \gamma ECM_{t-1} + \varepsilon_t \quad (4)$$

Although the ARDL cointegration technique does not necessitate pre-testing for unit roots, the study nonetheless conducts unit root tests to prevent the occurrence of an integrated stochastic trend of I(2) in the series (Debele, 2019; Manzoor et al., 2021). The study employs Augmented Dickey-Fuller (ADF) and Philip Perron (PP) for this unit root testing (Table 1).

3.3 Data

This study covers the time series data of 30 years from 1988 to 2018, sourced from the World Bank, Our World in Data, and the Department of Statistics Malaysia. This study uses CO2 per capita emissions as the dependent variable measured by metric tons per capita. The explanatory series consists of GDP in thousands, INT in percentage, and XG, which refers to the annual growth percentage.

4.0 Results and Discussion

This study used an ARDL estimator to investigate the influence of real interest rates on CO2 emissions in Malaysia. It is necessary to examine whether the series is stationary at level I(0) or exhibits first-order differencing I(1) to establish its nature. The augmented Dickey-Fuller (ADF) and Phillips–Perron (PP) tests are used to determine stationarity. Both the null hypothesis in the ADF and PP stationary tests suggest that the series does not exhibit stationarity.

Table 1

Stationary Tests

	ADF		PP	
	Level	**1 Diff.**	**Level**	**1 Diff.**
LCO2				
Intercept and Trend	-2.6071	-6.5026***	-2.6890	-6.5026***
LGDP				
Intercept and Trend	-2.0166	-4.6534***	-2.1630	-4.6191***
LINT				
Intercept and Trend	-6.4356***	-9.1304***	-6.3771***	-17.9130***
LXG				
Intercept and Trend	-5.6235***	-6.5819***	-5.6555***	-28.9139***

Note: *, **, *** imply 10%, 5%, 1% level of significance

The results for each series are shown in Table 1 by using 'with intercept and trend'. Accordingly, the null of having a unit root is rejected for both CO2 and GDP based on the ADF and PP tests in the first-order

integrated, I(1). However, INT and XG rejected the null hypothesis in level I(0) for both the ADF, and PP test with intercept and trend.

4.1. Bounds cointegration test

Table 2 displays the outcomes of the boundaries cointegration test. The calculated F-statistic of 10.4140 is more than the critical value for all significance levels, given a finite sample size of 30. Thus, the hypothesis that there is no cointegration is rejected. Therefore, the set of variables exhibits a stable long-term cointegration.

Table 2

The ARDL Cointegration Bound Test

Test Statistic	Value	Sig.	I(0)	I(1)
F-statistic	10.4140			
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Note: Critical values are in Narayan (2005)

4.2. Log-linear long run coefficient

This study has conducted a log-linear long-run estimation for Malaysia, assuming that the model of the study focuses on CO2 emissions as the anticipated variable. The log-linear long-run coefficient is determined by analyzing the ARDL estimations provided in Table 3. Table 3 indicates that the coefficient for the GDP variable is positively and significantly correlated at a 5% level of significance. The GDP coefficient indicates that for every 1% rise in GDP, there is a corresponding 0.5% increase in CO2 emissions. Put simply, the country's ecology is contaminated by 0.5% as a result of the linear economic expansion. This empirical research verifies that there is a positive correlation between Malaysia's GDP and its environmental conditions. The results align with the previous research conducted by Halkos & Tzeremes (2011) and Yan et al. (2022), which demonstrates that GDP has a positive correlation with carbon emissions.

Meanwhile, the INT and XG are inelastic, negative, and statistically insignificant at the 5% significance level. In particular, a 1% increase in INT leads to a 0.1% and 0.008 % decrease in CO2 respectively. This shows that a decrease in INT and XG has a negative effect on environmental degradation. However, it is identified as insignificant.

Table 3

Long Run and Bounds Estimates using the ARDL approach

Dependent Variable: LCO2			
Variables	**Coefficient**	**Std. Error**	**t- (p-value)**
LGDP	0.5172	0.0870	5.9451 (0.0000)
LIINT	-0.1153	0.0853	-1.3520 (0.1885)
LXG	-0.0075	0.0773	-0.0973 (0.9233)
C	5.9546	2.4254	2.4551 (0.0214)

Note: The maximum lag length is ARDL (1,0,0,0) based on the SC

4.3. Log-linear error correction model (ECM)

Table 4 presents the results of the estimated ECM, and these findings indicate that the coefficient of the CO2 model is positive and statistically significant at a 5% significance level. The short-run CO2 states that a total of 0.27% of CO2 is increased with each 1% rise in GDP. The short-run INT is also significant and posits a negative and significant influence on CO2 at about 0.04% for every 1% increase in INT. The short-run XG suggests that a 1% change in XG can result in a fall of CO2 of 0.02%. However, it is not significant at a 5%

level of significance. Meanwhile, the approximate coefficient of the (ECT) error correction term is negative and statistically significant at 1%. The outcome implies that the short-run deviation adjustment procedure is very high. The ECT coefficient -0.216 defines a rapid adjustment rate at any short-run deviation will take about four years and a half. It gives a meaning that within 4 years, if the GDP and INT are left ignored, thus, the CO2 will take effect.

Table 4

Log-linear short-run estimates and ECM

Variable	DLGDP	DLINT	DLXG	ECT(-1)
Coefficient	0.2730***(0.0185)	-0.0402***(0.0341)	-0.0223(0.2256)	-0.2160***(0.0032)
R-squared	0.5103			
Adjusted R-squared	0.4319			
F-statistic	6.5137			
Prob (F-statistic)	0.0009			
DW stat	2.5457			

Note: *, **, *** imply 10%, 5%, 1% level of significance

4.4. Diagnostic test

The results of diagnostic assessments are summarized in Table 5 and Figure 1 below. The evaluated ARDL model is tested on serial correlation problems (as the sample is small, thus, this study uses two different lags, 2 and 4, to show the good fit of the sample) and the stability of the parameters. Table 5 proves that the assessed ARDL model passed all the serial correlation tests, which means the model is free of serial correlation that could spoil the result once it appears. The Cumulative Sum (CUSUM) parameter stability test plot in Figure 1 also proves that the estimated parameters are within the upper and lower bounds. This is evidence that the model is stable.

Table 5

Diagnostic test for ECM-based ARDL model

Test Statistic	Obs*R-squared	Prob. Values
Serial correlation (lag 2)	1.4962	0.4733
Serial correlation (lag 4)	1.8973	0.7546
CUSUM	Stable	
CUSUM of Squares	Stable	

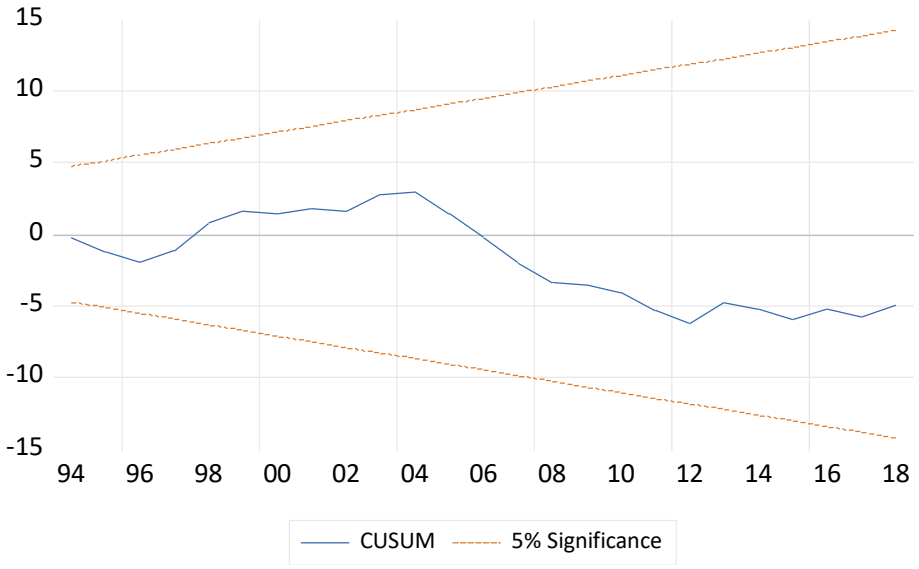

Figure 1. A plot of the cumulative sum of recursive residuals

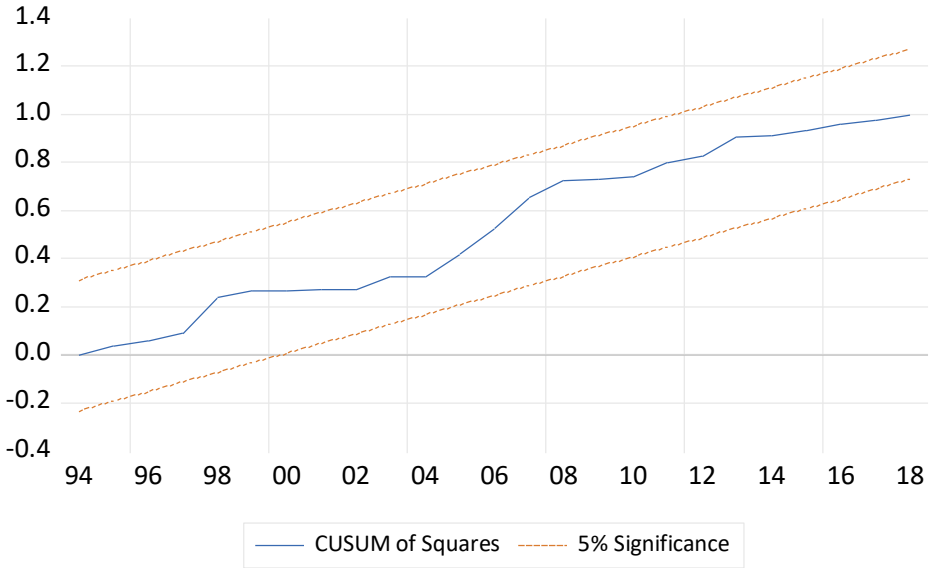

Figure 1. A plot of the cumulative sum of recursive squares residuals

5. Conclusion

In conclusion, it is presumed that the relationship between gross domestic product (GDP) and real interest rate (INT) significantly impacted CO2. The research acknowledges several limitations that may impact the interpretation of findings, particularly unexpected insignificance correlations related to export growth (XG) on CO2 emissions. The negative relationship contradicts common findings in previous studies, raising concerns about potential anomalies or inaccuracies within the model. The study recommends further scrutiny and sensitivity analyses in future research that should explore additional variables to enhance the analysis's comprehensiveness. The unexpected negative relationship between XG and CO2 emissions prompts further investigation into underlying factors for future research. In the review of current policies, the study recommends diversifying the energy mix, reducing reliance on fossil fuels, investing in renewable sources for long-term sustainability, and suggesting that policymakers (the central bank) should promote the stability of the real interest rates channel to reduce CO2 emissions and encourage renewable energy investment. Additionally, the formulation of comprehensive green policies is advised to encourage sustainable practices and the integration of environmental considerations into business operations. Aligning monetary policies with environmental objectives is proposed, suggesting the development of financial instruments that incentivize environmentally responsible practices. In summary, the research provides recommendations for policymakers, stakeholders, and researchers in Malaysia to address the complex relationship between economic variables and CO2 emissions, fostering sustainability and environmental responsibility.

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