The Impact of Gross Domestic Product, Trade Openness, Air Transportation, and Total Final Energy on Carbon Dioxide Emission in Malaysia

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Abstract

The current paper provides an empirical analysis of the relationship between carbon dioxide (CO2) emissions and economic factors, namely Gross Domestic Product (GDP), air transportation, energy consumption, and trade openness in Malaysia, based on the annual data from 1990 until 2016. By utilising the cointegration analysis, it is demonstrated that CO2 emissions exhibit a positive and significant long-run relationship with air transportation and energy consumption. Meanwhile, GDP and trade openness are significant in influencing CO2 emissions in the short run. It was also demonstrated that the disturbances fluctuate while entering the long-run relationship in a dampening manner rather than monotonically. It is advised for policymakers to continually consider the movements of these economic determinants due to their significant effect on CO2 emissions in Malaysia in both the short and long run.

Keywords: Carbon Dioxide Emissions, Air Transportation, Energy Consumptions, Gross Domestic Product, Trade Openness.

1. Introduction

Carbon dioxide (CO2) emissions are created through the combustion of solids, liquids, gas fuels, and gas flaring. According to Marais et al. (2008), CO2 has a long-term impact on atmospheric life and outweighs the effects of other greenhouse gases. In addition, the IPCC (2014) stated that CO2 emissions account for 65 percent of the global greenhouse gas emissions by gas, and this excessive energy consumption causes increases in greenhouse gas (GHG) emissions (EPA, 2022). GHG emissions from fossil fuel burning contribute to global warming and climate change (Milner et al., 2012).

In Malaysia, concern over CO2 emissions has increased in relation to the economic progress of the country since its formation in 1963. As an upper middle-income country, Malaysia aspires to expand its economy, and the development activities lead to an increase in energy consumption (Ong et al., 2011; Begum et al., 2017). According to the World Bank Databank, Malaysian CO2 emissions increased tremendously from 3.1 metric tonnes per capita in the 1990s to 7.7 metric tonnes per capita in 2019. As an important backbone of the economy, the transportation system also expanded as the country moved from an economic to a tertiary economy, and in 2018 alone, the transportation sector contributed to 36.4% of the energy demand in Malaysia (Solaymani, 2022). Begum et al. (2017) argue

that the concerns about CO2 emissions are not unfounded since the energy to power industries is heavily reliant on fossil fuels, including oil, coal, and natural gas.
Trade openness also has a substantial impact on CO2 emissions, as reported by the World Trade Organization (2021), and the pollution from international trade flows has the potential to undermine environmental measures (Peters & Hertwich, 2008). Since Malaysia is primarily reliant on exports for its economy, the volume of goods carried in and out of the country and the manufacturing of these products may also contribute to CO2 emissions in Malaysia. This is evident from Peters & Hertwich (2008), who reported that the embodied emissions for Malaysian exports are 59.7% while imports are 39.5%, higher than the average embodied emissions for countries that ratified or acceded to the United Nations Framework Convention on Climate Change.

To understand the issue, several studies have been conducted to analyse the relationship between economic factors and CO2 emissions (Erdogan et al., 2020). Yet, in the case of Malaysia, the influence of air transportation and trade openness was scarcely analysed. In addition to that, previous studies have mainly focused on the long run (Ramli et al., 2018) without assessing its short-run impact. An ambiguous relationship was observed between economic factors, particularly economic growth and CO2, where some findings revealed a negative correlation while others exhibited a contradiction of results, as argued by Begum et al. (2015) and Saboori et al. (2012). This leads to uncertainty about the effectiveness of policies taken to address the issue, as the relationship between the variables may be heterogeneous.

To address the issue, the current paper outlines twofold objectives, namely, to identify the long-run relationship as well as the short-run relationship between CO2 emissions and its economic factors. This research is significant not just due to its possible contribution to the body of knowledge but also to policymaking. By focusing on the impact of economic factors on CO2 emissions in both the short run and long run, it provides a source of reference for policymakers, not just to understand the depth of the impact of economic factors on CO2 emissions but also to construct correct strategies to offset the negative consequences of economic factors on CO2 emissions based on different periods.

The organisation of the paper in the later components is as follows: the literature review provides the theoretical review and empirical findings from past research, while in Methodology, cointegration, and error correction modeling, as well as the diagnostic tests, are discussed. The Results and Discussion starts with the tabulation of results from the cointegration model and error correction modeling. The findings of the long-run and short-run relationships for selected economic variables on carbon emissions are then discussed. Finally, in Conclusion and Recommendation, the paper summarises the main findings as well as outlines the recommendation for future research.

2. Literature Review

2.1 Theoretical Review

According to Callan et al. (2013), when it comes to environmental degradation, the Environmental Kuznets Curve (EKC) represents a hypothesised connection between economic development and pollution levels that are represented as an inverted U shape where pollution levels increase in the early stages of industrialisation and then decrease as industrialisation proceeds. The EKC hypothesis argues that economic expansion causes environmental deterioration for a period of time before becoming a factor in pollution reduction after reaching a particular degree of development.

Ozcan (2013) examines the empirical relationship between carbon emissions, energy consumption, and economic development in the Middle East and North Africa (MENA) nations. It was identified that countries including Egypt, Lebanon, and the United Arab Emirates were demonstrated to follow the inverted U-shaped EKC theory. This is similar to Apergis et al. (2015) for 14 Asian nations and Jebli et al. (2015) in Tunisia. Yet in the case of Malaysia, Saboori et al. (2013) found no evidence of an EKC based on aggregated energy usage, in contrast to Saleem et al. (2018), who supported the presence of an EKC for airways and railway passengers with respect to CO2 emissions.

2.2 Carbon Dioxide Emissions and its Economic Factors

Pao et al. (2011) reveal that CO2 emissions appear to be energy consumption elastic and output inelastic in the long-term equilibrium. The causality results show that there is a bidirectional, strong Granger causality running between output, energy usage, and emissions and that if a shock occurs in the system, each variable adjusts in the short run to restore the long-run equilibrium. Hamit-Haggar (2012) meanwhile, demonstrated that in the long run, energy consumption has a positive and statistically significant impact on greenhouse gas emissions, whereas greenhouse gas emissions and economic growth have a non-linear relationship.

In the case of Malaysia, Sarkar et al. (2019) postulate a positive relationship between CO2 emissions and GDP. This is somewhat contradictory to Begum et al. (2015), who articulated a long-run cointegration between CO2 emissions and GDP growth. Yet, contrary to the generally accepted EKC model, the relationship is described based on a U-shaped curve instead, which Manu et al. (2017) argue happens when CO2 emissions drop as economic growth increases and invalidates the existence of the EKC. This is contradicted by Saboori et al. (2012), where it was revealed that an inverted U-shaped connection existed between CO2 emissions and income in the short and long term.

According to Sgouridis et al. (2011), there is a positive relationship between air transportation and CO2 emissions, and Sausen et al. (2005) estimated that the CO2 percentage contribution to overall GHG impacts is about 53%. Saleem et al. (2018) said that this positive connection between CO2 emissions and air transportation is prevalent in many countries, including South Korea, Indonesia, Iran, Mexico, the Philippines, Turkey, Bangladesh, Egypt, Nigeria, Pakistan, and Vietnam. Apart from air transportation, road transportation is also a leading cause of emissions for over 26 emerging and industrialising countries (Marcotullio et al., 2005).

Numerous studies have also been done using energy consumption with Shahbaz et al. (2014), Farhani et al. (2015), and Agbanike et al. (2019) that showed energy consumption has a net positive relationship with per capita CO2 emissions in the long and short term. Begum et al. (2015) said energy consumption per capita has a significant relationship with CO2 emissions since a considerable element of CO2 emissions in Malaysia came from the electricity, industrial, and transportation sectors.

Additionally, trade openness is one of the key factors in determining economic performance and may lead to CO2 emissions, as argued by Kasman et al. (2015). Yet, according to Ramli et al. (2018), trade openness is not a significant factor in understanding Malaysia's CO2 emissions in the long run. However, the impact of trade openness can still be explored, particularly in the short run, as demonstrated by Farhani et al. (2014) in the case of Tunisia.

Based on the literature, it is shown that the impact of economic growth, air travel, trade openness, and final energy consumption has not been thoroughly studied in the case of Malaysia. Moreover, previous research has mostly ignored the short-term effects in favour of a long-term perspective, and there is an ambiguous relationship between economic factors and CO2 emissions, with some results suggesting a negative correlation and others showing contradictory results.

3. Data and Methodology

The current study collected the carbon dioxide (CO2) emissions, Gross Domestic Product (GDP), trade openness, air transportation, and total final energy consumption from 1990 to 2016 based on the Statistical Economic and Social Research and Training Centre for Islamic Countries (SESRIC) database. All the variables were transformed to the natural logarithm in conducting the test. To test for non-stationary time series data, unit root tests were conducted based on the Augmented Dickey-Fuller test, where a unit root suggests that the time series under examination is non-stationary.

3.1 Cointegration Analysis

The existence of time series variables that are varied in the level of stationarity, either I(0), I(1), or both, warrants the use of the Autoregressive Distributed Lag (ARDL) cointegration model in assessing the long-run relationship between the variables. The ARDL cointegration method is used to determine the long-run connection between series with varying orders of integration (Pesaran et al., 1998; Pesaran et al., 2001; Pinjaman & Kogid, 2018). The ARDL model also addresses the issue of autocorrelated errors that are encountered with the finite distributed lag model (Pesaran, 1997; Pesaran et al., 1998).

The ARDL model used in this analysis is as expressed below:

$$y_t = A_0 + \sum_{i=1}^{p} \theta_i y_{t-i} + \sum_{i=0}^{p} \mathrm{B}_i y_{t-i} + \lambda'_1 y_{t-1} + \lambda'_2 x_{t-1} - \mu_t \quad (1)$$

Where $A_0$is the drift, while θ, B, and λ are the coefficients to be estimated and μ_t is the error correction term. The term refers to CO2 emissions, and λ' is a set of economic factors, namely, GDP, trade openness, air transportation, and total final energy consumption.

To convert into a natural logarithm, the variables were transformed based on Hefeker and Busse (2005):

$$y = ln\,(\sqrt{(x^2 + 1)})$$

The Akaike Info Criterion (AIC) is used to find the optimum number of lags in the ARDL model for this study where a model with a certain number of lags on the right-hand side of the variable that gives the lowest value of AIC is deemed optimal.

To determine whether or not a long-run connection exists, the following hypotheses are tested:

1. H_0: $\lambda_1 = \lambda_2 = 0$, insignificant long-term relationship between variables.
2. H_1: $\lambda_1 \neq \lambda_2 \neq 0$, significant long-term relationship between variables.

Using the estimated F-statistics of bounds test, the hypotheses are evaluated in comparison to two critical bound values for a particular significance level, namely the lower and upper bound critical values.

3.2 Error Correction Model

The short-run relationship is analyzed based on the Error Correction Model (ECM), as described below:

$$\Delta y_t = A_0 + \sum_{i=1}^{p} \theta_i \Delta y_{t-i} + \sum_{i=0}^{p} \mathrm{B}_i \Delta x_{t-i} + \lambda'_1 ECT_{t-1} + \varepsilon_t \quad (2)$$

Where $ECT_{t-1} = \varepsilon_{t-1} = y_{t-i} - A_0 - \mathrm{B}x_{t-1};\ -1 \leq ECT \leq 0.$

The least squares approximation is used to assess the ECM function, with the number of lags in the model selected based on the lowest AIC values and the number of lags in the model chosen based on the lowest AIC values.

3.3 Diagnostic Tests

Several diagnostic tests were conducted, including the Ramsey (1967) specification error test (RESET) to test the model specification error and the CUSUM test to detect the stability of the model.

4. Results

4.1 Unit Root Tests

Based on the results of the Augmented Dickey-Fuller (ADF) unit root tests as shown in Table 1, the level of stationarity is mixed, where the carbon dioxide (CO2) emissions, Gross Domestic Product (GDP), air transportation, and trade openness are stationary at the first difference, or I(I) while total final energy consumptions are stationary at level, or I(0). The mixture of stationarity levels of the variables warrants the use of the ARDL cointegration to analyse the long-run relationship between CO2 emissions and its economic factors, while the error correction model is used for the short-term estimates.

Table 1: Unit Root Test with Trend and Intercept

Augmented Dickey-Fuller (ADF) Test		
Variables	**At level**	**At 1^{st} difference**
Carbon Dioxide	-2.1752	-6.2697***
Gross Domestic Product	-1.3667	-3.9481**
Final Energy Consumption	-4.5845***	-5.2437***
Trade Openness	-2.2278	-4.3253**
Air Transportation	-3.0130	-4.2078**

Notes: 1. Null hypothesis: The model contains a unit root.
2. *,**,***, denotes as 10%, 5% and 1% significance level respectively
3. The number of lags is automatically selected based on the Schwarz information criterion

4.2 ARDL Cointegration Test Results for Long-run Estimates

Based on the construction of the ARDL model, the optimal ARDL lags are (1,3,2,3,3) as the model generated the lowest value of the Akaike Information Criterion (AIC)[1]. Table 2 shows the bound test for cointegration based on the ARDL model, which is used to assess the joint long-run relationship between economic factors in explaining CO2 emissions in Malaysia. The F-statistic of 4.6171 is demonstrated to be higher than the upper critical bound at the 5 percent level and indicates the joint long-run relationship between CO2 emissions and economic factors.

[1] The carbon dioxide emission contains 1 lag while trade openness, gross domestic product, air transportation and total final energy consumption contain 3,2,3,3 lags, respectively.

Table 2: Long-run Joint Relationship Between Economic Factors and Carbon Dioxide Emissions

F-Statistic: 4.6171 **Critical Value**	**Lower Critical Bound**	**Upper Critical Bound**
10% Significance	2.2	3.09
5% Significance	2.56	3.49
2.5% Significance	2.88	3.87
1% Significance	3.29	4.37

Table 3 shows the individual relationship between CO2 emissions and economic factors. It is shown that final energy consumption and air transportation are significant in explaining CO2 emissions, while GDP and trade openness are not. Based on the coefficients, final energy consumption and air transportation are positively related to CO2 emissions, which suggests the contributing effects of the two variables.

Table 3: Long-run Individual Coefficient

Variable	**Coefficient**
Constant	-3.4947
Gross Domestic Product	0.0511
Final Energy Consumption	0.5511***
Trade Openness	-0.0738
Air Transportation	0.5457**

Note: 1. Long-run coefficients of independent variables with public debt are analyzed based on the ARDL (1,3,2,3,3) model.
2. *, **, *** denote as 10%, 5%, 1% significance levels respectively.

4.3 Error Correction Model (ECM) Results for Short-run Estimates

In-text The ECM model developed from the ARDL cointegration model is used to assess the short-run impacts of economic variables on Malaysia's CO2 emissions. Table 4 depicts the short-term individual association between economic variables and CO2 emissions. Based on the Wald test, GDP and trade openness are significant in contributing to CO2 emissions in the short run, while air transportation and total final energy consumption indicate no causal relation to CO2 emissions in the short run[2].

Table 4: Short-run Individual Relationship of Independent Variables Towards Carbon Dioxide Emissions

Independent Variable	**Wald Test F-statistics (P-Value)**
Gross Domestic Product	5.6686 (0.0274)
Total Final Energy Consumption	2.4471 (0.1486)
Trade Openness	4.2557 (0.0617)
Air Transportation	1.3024 (0.3468)

In addition, Table 5 presents the short-run speed of adjustment derived from the ECM model. The error correction term value is -1.3369, with a 1 percent significance level. This suggests that the error correction process varies about the long-run relationship in a dampening way rather than monotonically converging to equilibrium directly. Yet, the convergence to the equilibrium route happens quickly after this phase is completed.

[2] The error correction term is below -1 and indicate that the relationship between the variables are unstable in the short run since

Table 5: Short-run Adjustment

Variable	Coefficient
Error Correction Term (-1)	-1.3369***

Note: 1. ECT(-1) as the lag one of ECT insert as one of the independent variables in the Error Correction Model.
2. *** indicates a 1% significant level.

4.4 Diagnostic Tests

The Breusch-Godfrey Serial Correlation LM and the Breusch-Pagan-Godfrey Heteroskedasticity tests are performed to determine whether or not the ARDL and the ECM models have any issues. By referring to the results, the models are free from serial correlation and heteroskedasticity. Meanwhile, the Ramsey RESET, the CUSUM, and the CUSUM of Square tests indicate that the models are also correctly specified and stable.

5. Conclusion

The purpose of this study is to examine the short-run and long-run relationship between CO2 emissions and economic factors. It is demonstrated that the economic factors, namely GDP, trade openness, air transportation, and total final energy, are jointly significant in explaining the carbon emissions in Malaysia.

Based on the long-run individual relationship, air transportation has a positive and significant relationship with CO2 emissions. This is in line with Hassan and Nosheen (2018), where an increase in air transportation leads to larger CO2 emissions. Similarly, final energy consumption also has a positive and significant relationship with CO2 emissions, and this is aligned with the finding of Farhani et al. (2015). Despite the positive coefficient for the GDP and the negative sign for trade openness, both variables are found to be insignificant in the long run. Nevertheless, the error correction modelling showed that both variables are significantly related to CO2 in the short term, while air transportation and total final energy consumption are not substantial. In the meantime, the error correction term process is demonstrated to fluctuate around the long-run value in a dampening manner.

By referring to the results, it is necessary for policymakers to take into account the movements of these economic factors consistently owing to their considerable influence on CO2 emissions in Malaysia for both the short run and long run. As air transportation and total final energy consumption are important contributors to CO2 emissions, the government needs to create an appropriate policy to guarantee that CO2 emissions are being monitored.

For future research, it is suggested to address the other important economic factors that are not included in this study. Additionally, a study between the economic sectors needs to be conducted to further understand the issue of CO2 emissions in the country.

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