

Article

Dynamic Impacts of Economic Growth and Forested Area on Carbon Dioxide Emissions in Malaysia

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Abstract: This study measures the relationship and dynamic impacts of economic growth and forested area on carbon dioxide (CO₂) emissions in Malaysia. Time series data over the period of 1990 to 2016 were used by employing the dynamic ordinary least squared (DOLS) approach. The results of DOLS estimation indicate that the coefficient of economic growth is positive and significant with CO₂ emissions, meaning that RM1 million increase in gross domestic product (GDP) is associated with an increase in CO₂ emissions of 0.931 kilo tons. Instead, the long-run coefficient of forested area found negative and significant, which implies that declining one hectare of forested area (i.e., deforestation) has an impact of three kilo tons of CO₂ emissions rise in Malaysia. Our study findings indicate that economic growth and deforested area have an adverse effect on Malaysia's carbon emissions where GDP growth fosters carbon emissions at a faster rate. Thus, the effective implementation of policy measures and economic instruments including afforestation and reforestation, forest conservation, sustainable forest management, REDD+ (reducing emissions from deforestation and forest degradation plus) mechanism and other emission reduction mechanisms inter alia could be useful for reducing carbon emissions while decreasing deforestation and maintaining the long-term economic growth in Malaysia.

Keywords: forests; deforestation; emissions; economy; DOLS; Malaysia

1. Introduction

Over the 21st century, atmospheric accumulation of greenhouse gases (GHGs) has become a major concern due to climate change. CO₂ is the dominant GHG which is emitted mainly from human induced activities like burning of fossil fuels and deforestation. Since the industrial revolution from the agricultural sector, CO₂ emissions from deforestation and forest degradation have been growing rapidly which is one of the main reasons for the global climatic system changing. Anthropogenic land use change together with deforestation and forest degradation contributes about one-fifth of the global annual CO₂ emissions, which was 0.9 Gt per year [1]. About 10,000 years ago, 45% of the total land surface in the world was covered by the forests, around six billion hectares. However, shrinkage of global forest cover has been continuing from that period and it turned into only about 31% in 2010 [2]. Global forest cover has been changing rapidly over the past few decades where the forest cover in tropical regions has reduced significantly by an annual reduction of 2101 square kilometers per year [3]. Over the last few decades, there has been no significant changes of the net carbon emission annually from deforestation [4]. According to Hansen et al. [3], almost 2.3 million square kilometers of global forest land were lost within 2000 and 2012, while only 0.8 million square kilometers of forest were gained in this time period.

However, forests in tropical regions cover around 7–10% of the total land area in the earth which is also 13% of the total vegetation area around the globe [5,6]. Houghton [4] reported that 1.4 ± 0.5 PG

(petagrams) of carbon are emitted per year over the period of 1990 to 2010 because of deforestation and forest degradation in tropical regions. Due to excessive CO₂ emission from deforestation, massive impacts from climate change have occurred in Malaysia, which is also one of the leading CO₂ emitters among the south-east Asian countries. Malaysia's development and economic growth activities also lead to increasing carbon emissions from land clearing and conversion of the forested land to other economy-based land use activities such as agriculture, settlement, mining, fish farming, etc. [7]. While economic development enhances societal prosperity, it also has an environment cost [8,9]. For instance, forest degradation including non-forestry land uses (i.e., timber harvesting for agricultural land conversion) releases huge carbon into the atmosphere [9,10]. Though the natural resources are limited and exhaustible, still those are used as inputs for production and development processes. Hence, it is difficult to reduce environmental degradation until the functional relationship between natural resources and economic development processes changes [11,12]. These problems are very common, and the risks are higher in the developing countries like Malaysia, where the relations among economic growth, forests and sustainability are critical.

The environmental impact resulting from economic growth is crucial because any economy usually functions for maximising economic growth [13–15]. Nevertheless, a number of research and studies presented empirical evidence which investigated the dynamic relationship between environmental quality and economic growth in different developed and developing countries. During the past two decades, several studies showed the relationships between CO₂ emissions and its determinants such as economic growth and energy consumption [15–25]. However, the Intergovernmental Panel on Climate Change (IPCC) reported that land use, land-use change, and forestry contributed around 17% of the annual global GHG emissions [1]. Instead, the forestry sector also plays a significant role in climate change mitigation and sustainable green economy [26]. Nabuurs et al. [27] estimated that that EU forestry sector currently produces an overall climate mitigation impact that amounts to about 13% of the total EU emissions. Nevertheless, there is a limited study which specifically investigates the dynamic impact between forested area and CO₂ emissions. Though the deforestation rate is higher in developing countries like Malaysia, the specific research on the dynamic impacts of economic growth and forested area on CO₂ emission is lacking. Thus, this article attempts to analyse the dynamic impacts of economic growth and forested area on CO₂ emission in Malaysia by applying these impacts and their relations, employing the dynamic ordinary least squared DOLS approach. The findings of this study would provide better understanding between the interactions of the environment (i.e., carbon emissions, forests and economic growth) towards achieving sustainable development.

2. Forests and Deforestation in Malaysia

Forests play a key role in keeping the balance of the global climatic system by absorbing and storing atmospheric carbon, maintaining hydrological systems, conserving biodiversity and providing habitats for the wildlife. Forests in Malaysia are categorised by three types of forests which are protected forests, permanent reserved forests and state land forests. Figure 1 shows the graphical trend of total forest land in Malaysia. In 1990, total forest land was about 18.8 million hectares, dropping to 17.9 million hectares in 1993 and rising again with 18.47 million hectares in 1997. In 1999, the trend shows downward again, and the total forest land declined to 17.68 million hectares (ha) in 2008. One of the main reasons for this reduction of forest land might be deforestation and forest degradation due to excessive logging and development activities. Between 1990 and 2010, Malaysia lost around 0.86 million ha of forest cover (i.e., 4.23% of its total forest land). The long history of logging activities means there are degraded areas that could be reforested for forest conservation, ecosystem services and carbon sequestration. Since 2009, the total forested areas in Malaysia have been on an upward trend due to some programmes and activities through afforestation, reforestation, forest protection and conservation; thus, the total forest land became 18.4 million ha in 2016. It is remarkable that the area of protected forest land in Malaysia was 1.44 million hectares in 1990 but by the end of 2014, it was 2.76 million hectares, almost doubled in 24 years [28]. Protected forests play a significant role

in ecosystem and biodiversity conservation [29]. This indicates a huge potential of climate change mitigation by increasing forest protection and conservation in Malaysia.

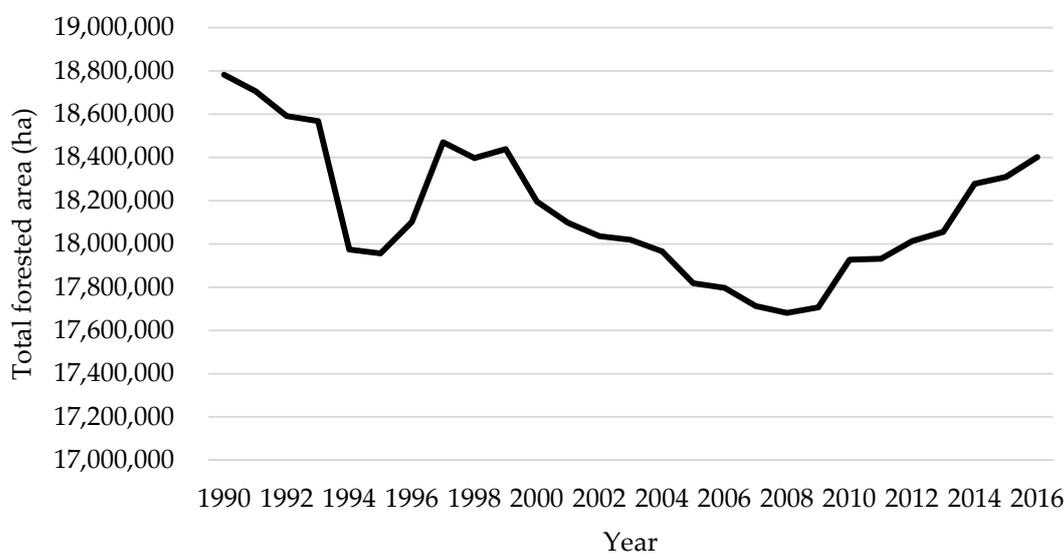


Figure 1. Annual trend of total forest land in Malaysia [data sourced from [28]].

However, Malaysia had a severe rate of deforestation between 1990 and 2010 that is 8.6% of its forest cover, or about 1.92 million ha. This might be due to primarily from industrialisation, urbanisation, settlements, mining, farming, agricultural fires, clearing forest for oil-palm plantations and other forms of agriculture. According to Jomo et al. [30], Sarawak had lost 50% of its forest cover whereas Peninsular Malaysia shrunk to about half of its original forests from 1971 and 1989. Osman et al. [31] reported that more than 1.85 million ha of forests in Sabah were lost (i.e., approximately 50% of Sabah's total forest cover) from 1990 to 2008 due to the expansion of commercial plantations. Table 1 presents the deforestation rate of total and natural forest cover in Malaysia from 1990 to 2010. The loss of forest cover in Malaysia is quite alarming, and it has been reported that the annual deforestation rate of Malaysia increased nearly 86% from 1990 to 2005 [2]. Malaysia lost an annual average of 1.4 million hectares (0.65%) of its forest area from 2001 to 2005, whereas total deforestation declined from 2006 to 2010. Presumably, old-growth natural forests were the main type of forests that were deforested, resulting in greater CO₂ emissions as they hold higher concentrated amount of carbon. According to IPCC [1], deforestation and forest degradation is the second major source of CO₂ emissions. In Malaysia, the land use, land-use change, and forestry (LULUCF) sector also causes CO₂ emissions while contributing a major source of carbon biomass and sequestration. For instance, large tracts of tropical forests have been deforested and converted to agricultural land and settlements due to increasing human population and their anthropogenic activities [7]. Therefore, reducing CO₂ emissions has become a major concern all over the globe to maintain environmental sustainability and to minimise the negative impacts of climate change [32].

Table 1. Deforestation rate in Malaysia * [2].

Years	Total (Net) Forest Cover Change (Per Annum)		Natural Forest Cover Change (Per Annum)	
	1000 ha	Percent	1000 ha	Percent
1990–2000	−79	−0.36	−49	−0.2
2001–2005	−140	−0.66	−49	−0.24
2006–2010	−87	−0.42	−128	−0.64

* Negative signs reflect deforestation.

3. Economic Growth and Carbon Emission in Malaysia

Southeast Asia demonstrates how globalisation plays a role in changing forestry patterns, value-chains and trade, from the 1960s to the present. Since the last two decades, it is apparent that deforestation is linked with globalisation, international business and growing cash crops [33]. Malaysia is one of the world's fastest growing economies since the 1970s [34]. Within a very short time, per capita income has doubled in Malaysia as it is a leading exporter of manufactured goods and primary commodities. Malaysia's forest resource utilisation led to its socio-economic development, resulting in Malaysia becoming the world's leading exporter of tropical timber products, oil palm, rubber, cocoa, pepper, pineapple and tobacco [35–38]. In this regard, Figure 2 shows the forestry sector's contribution to Malaysia's gross domestic product (GDP) in percentage. In 1973, a large percentage of Malaysia's GDP (i.e., about 32%) came from the forestry sector and their activities, whereas in 2017 it declined to only 1.8%. This indicates that the dependency of Malaysia's GDP shifted to industrial and service sectors, and away from the forestry sector. Therefore, sustainable management of forest resources is important to ensure a potential contribution to Malaysia's future economic growth and long-term socio-economic development [39].

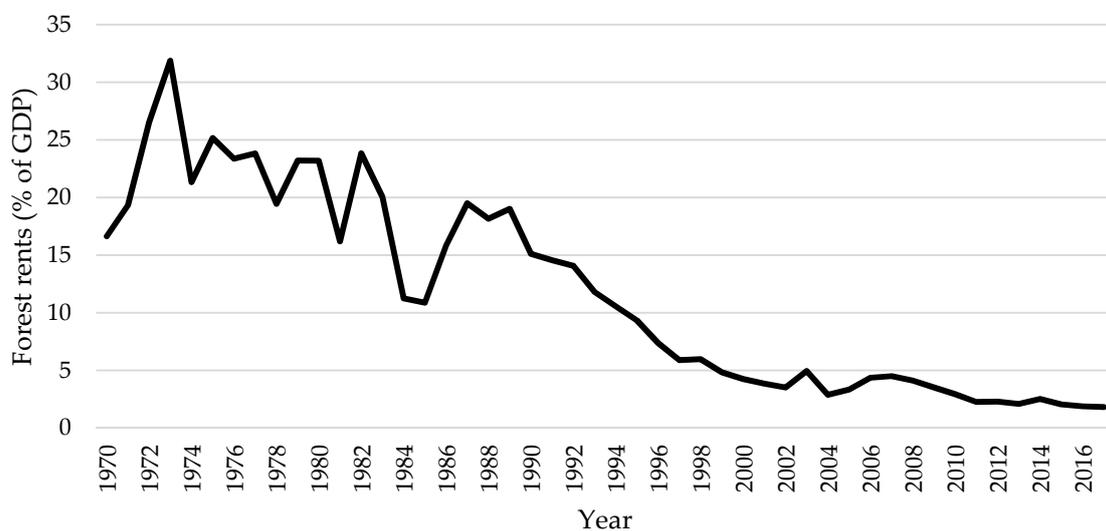


Figure 2. Forestry sector's contribution to gross domestic product (%) in Malaysia [40].

Nevertheless, Malaysia experienced the average economic growth of about 7.7% and 5.8% within the period 1970–1980 and 1980–1990, respectively. The average economic growth within the period 1990 to 2005 was above 6.5%. There are many factors that can contribute to the growth rate of an economy [41]. Since 1990, Malaysia's economic growth decreased only in 1998 due to the Asian financial crisis, and again declined between 2008 and 2009 during the global economic recession. In the meantime, rapid transformation occurred in the agriculture-based economy in Malaysia, which turned into industrialisation. Because of urbanisation, industrialisation and population expansion, CO₂ emissions in Malaysia increased drastically as a consequence of deforestation and forest degradation. The amount of CO₂ emissions in 2007 was about 7.32 tons per capita in Malaysia while the global average CO₂ emissions was only 4.63 tons per capita [40]. Figure 3 presents the per capita GDP (RM 1000) and CO₂ emissions (tons per capita) in Malaysia. In 1960, per capita GDP and CO₂ emissions were RM4824 and 0.44 tons which turned to RM40,063 and 8.09 tons in 2016, respectively. However, per capita GDP and CO₂ emissions rise over the time while GDP growth indicates a steady linear trend.

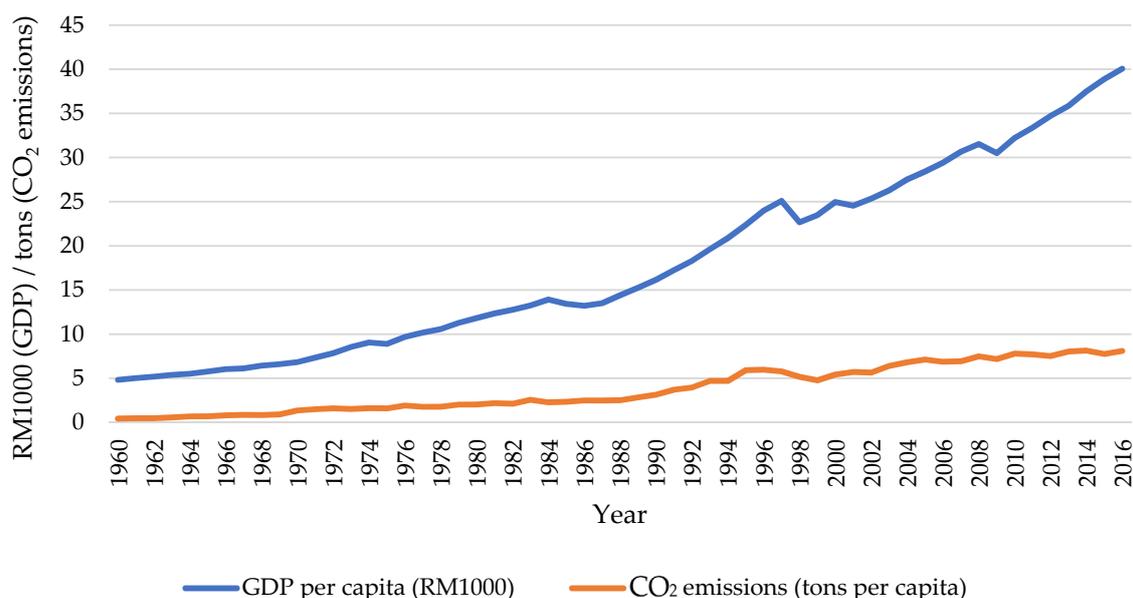


Figure 3. Per capita GDP (RM1000) and CO₂ emissions (tons) in Malaysia [40].

On the other hand, the climate change performance index for Malaysia is quite low, ranked 53rd among the most polluted 61 countries [42]. Furthermore, the average annual growth rate of CO₂ emissions in Malaysia was recorded as 4.6% for the period of 1971 to 2012. It is also apparent from Figure 2 that per capita GDP and CO₂ emissions have augmented significantly over the time. In the last two decades, Malaysia has initiated its national vision policy and economic transformation policy that concentrated on stimulating economic growth and achieving the 2050 vision while implementing intensive economic development with clean environment and sustainability. There exists some constraints and gaps in several GHG emitting economic sectors such as technical and capacity gaps [43]. Hence, Malaysia is one of the few developing countries that recognised the positive contribution of a clean environment on economic development by identifying and implementing various mitigation measures as a part of the framework for development process [44]. However, Malaysia's forestry sector has attracted dual interests to reduce GHG emissions while contributing to the national economy. For instance, tourism activities in Malaysian forests and national parks generate employment and economic activity which ultimately accelerate the national economy [45].

4. Methodology

The facts and figures shown in the previous sections provide a basic understanding of the relationship between forests, economic growth and CO₂ emission in Malaysia. Thus, this study investigated an empirical analysis of the dynamic impacts of economic growth and forested area on CO₂ emissions in Malaysia by using the dynamic ordinary least squared (DOLS) approach of cointegration by Pesaran and Shin [46] and Pesaran et al. [47]. Variables were measured in kilo tons for CO₂ emissions, 1 million Ringgit Malaysia for real GDP and hectares (ha) for forested area. Time series data from 1990 to 2016 for Malaysia was used based on the World Development Indicator (WDI) dataset.

This study considers CO₂ emissions (here after carbon emissions) as dependent variable. Since Grossman and Krueger [12] suggest that economic growth and CO₂ emissions follow a non-monotonic relation, this study considers GDP in the research framework. Forests play a very important dual role for CO₂ emissions. Forests and their tree biomass absorb and store the atmospheric CO₂, which is also called carbon sequestration, while due to deforestation/tree cutting, CO₂ is released into the atmosphere. As deforestation is one of the main causes of CO₂ emissions contributed to by Southeast Asia or Malaysia, this study attempts to show their causal relationship by employing

econometric analysis. Therefore, this study considers annual forested area (FA) as one of the regressors that was collected from the Ministry of Natural Resources and Environment (MNRE), Malaysia. In addition, time series data for economic growth (i.e., GDP in constant local currency unit (million RM, million Ringgit Malaysia)) and CO₂ emissions (kilo tons, kt) were obtained from the WDI dataset. To analyse the time series data, this study applied DOLS, an expanded equation of ordinary least squares estimation. It includes explanatory variables as well as leads and lags of their first difference terms to control endogeneity and to calculate the standard deviations using a covariance matrix of errors which is robust to serial correlation. Inclusion of leads and lags of the difference terms approves that error term is orthogonalised. In addition, the Granger causality Wald tests are used to justify the lagged variables and identify the causality between the variables.

The DOLS estimators have a normal asymptotic distribution and their standard deviations provide a valid test for the statistical significance of the variables [19]. The DOLS approach is efficient in the occurrence of a mix order of integration, enabling integration of the individual variables in the cointegrated outline by estimating the dependent variable (CO₂ emissions in kt) on explanatory variables (annual forested area in hectare and GDP in million RM) in levels, leads and lags. The justification for estimating DOLS model and variables used is described below.

Adopting a standard Cobb-Doglus production function assuming constant rate of returns, the aggregate output function can be shown at time, t as follows:

$$Y_t = F(K_t, AL_t) \quad (1)$$

where Y_t is GDP, K_t is capital and AL_t is effective labour. Presumably, carbon emissions arise due to the production function and economic activities, thus, emission function can be followed as:

$$CO_2(t) = v(F(Y(t))) \quad (2)$$

where v denotes the certain rate of CO₂ emission due to the production function.

Not all forms of capital are responsible for carbon emissions, while energy usage such as oil, coal, gas and electricity primarily cause emissions discharge. Therefore, total capital can be consisted of emitting (K_e) and non-emitting (K_n) capitals as shown below:

$$K = K_e + K_n \quad (3)$$

Thus, carbon emission function might be specified as:

$$CO_2(t) = \phi K_e(Y) \quad (4)$$

As in Equation (1), Y is a function of GDP, so it can be written as follows:

$$\ln CO_2(t) = \beta_0 + \beta_1 CO_{2t} + \beta_2 GDP_t + \varepsilon_t \quad (5)$$

Furthermore, the concentration of carbon emission increases as a consequence of forest cover change, deforestation and forest degradation. Therefore, forested area (FA) can be taken as a proxy of core factors to explain the impacts of carbon emission dynamics. Hence, the model might be specified as:

$$\ln CO_2(t) = \beta_0 + \beta_1 CO_{2t} + \beta_2 GDP_t + \beta_3 FA_t + \varepsilon_t \quad (6)$$

According to Grossman and Krueger [8], the non-linear relationship between GDP and carbon emission which can be considered by the following model:

$$\ln CO_2(t) = \beta_0 + \beta_1 LCO_{2t} + \beta_2 LGDP_t + \beta_3 LFA_t + \varepsilon_t \quad (7)$$

However, the key advantage of the DOLS estimation reflects the existence of mixed order integration of individual variables in the cointegrated outline. For instance, DOLS estimation involved regressing one of I(1) variables compared to other variables, some of which are I(1) with leads (p) and lags (-p) of the first difference whereas others are I(0) variables that include a constant term [48]. Accordingly, this estimation provides the solutions of small sample bias, endogeneity and auto correlation problems due to accumulating the leads and lags among explanatory variable [49]. Finally, this study estimates the following equation:

$$\Delta \ln \text{CO}_2 = \beta_0 + \beta_1 \ln \text{CO}_{2t-1} + \beta_2 \text{LGDP}_{t-1} + \beta_3 \text{LFA}_{t-1} + \sum_{i=1}^p \gamma_i \ln \text{CO}_{2t-i} + \sum_{j=1}^q \delta_j \Delta \text{GDP}_{t-j} + \sum_{k=1}^q \varphi_k \Delta \text{FA}_{t-k} + \varepsilon_t \quad (8)$$

where CO_{2t} is the annual CO_2 emission in kt; FA_t is the annual forested area in hectare; and GDP_t is the annual GDP in million RM. The coefficients (β_1 , β_2 and β_3) denote the long-run elasticities of the explanatory variables such as carbon emissions, GDP and forested area, respectively.

5. Results

Table 2 provides simple descriptive statistics of variables such as mean, standard error, median, standard deviation, minimum and maximum values both in actual and logarithmic form of the variables. Each variable included 27 observations of time series data from 1990 to 2016 for Malaysia. Moreover, skewness and kurtosis values reveal that the variables are normally distributed. These statistics lead us to proceed the unit root test for stationarity of the variables as well as further analysis of the DOLS estimation.

Table 2. Descriptive statistics of variables.

Variables	CO ₂ Emissions (Kilo Yons)		GDP (Million RM)		Forest Area (ha)	
	Actual	Logarithmic (LCO ₂)	Actual	Logarithmic (LGDP)	Actual	Logarithmic (LFA)
Mean	157,853.74	11.8930	699,714.75	13.381	18,145,570.1	16.7138
Standard Error	11,313.046	0.0799	52,409.542	0.0789	60,104.182	0.0033
Median	158,256.71	11.972	648,959.53	13.3831	18,056,000	16.709
Standard Deviation	58,784.31	0.4151	272,327.97	0.4099	312,310.49	0.0172
Kurtosis	-1.1566	-0.4021	-0.8810	-0.83865	-0.7572	-0.7803
Skewness	0.0551	-0.5811	0.3664	-0.253	0.4209	0.394
Minimum	56,592.81	10.9436	291,457.46	12.5826	17,681,000	16.688
Maximum	252,838.58	12.4405	1,229,312	14.022	18,782,000	16.7484

We proceeded to do the unit root test to justify the suitability of employing DOLS estimation instead of cointegration approach by confirming no variable exceeded the order of integration I(1). Thus, we applied the augmented Dickey-Fuller (ADF) and Dickey-Fuller generalised least squares (DF-GLS) approaches based on the trends and constants to detect the autoregressive unit root [50,51]. Table 3 summarises the findings of unit root tests by ADF and DF-GLS. The ADF test result indicates that LCO₂ found stationary at the level and remained stationary after taking first difference while both LGDP and LFA were found non-stationary at the level but become stationary at the first difference. On the other hand, the DF-GLS test illustrated all variables with non-stationary at the level and become stationary after first difference. Hence, the existence of mixed orders integration for variables estimated by the ADF and DF-GLS also validates use of the DOLS analysis.

Table 3. Findings of unit root tests by augmented Dickey-Fuller (ADF) and Dickey-Fuller generalised least squares (DF-GLS).

Logarithmic Form of the Variables	ADF		DF-GLS	
	Level	1st Difference	Level	1st Difference
CO ₂ emissions (LCO ₂)	−2.588 *	−3.062 **	−2.068	−3.181 *
Economic growth (LGDP)	−1.922	−3.699 ***	−1.505	−4.024 ***
Forested area (LFA)	−2.151	−2.752 *	−0.515	−3.300 *

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Moreover, Granger causality tests used to identify the causalities between the variables. Table 4 presents the results from Granger causality Wald tests indicating bidirectional causality existence between CO₂ emission to economic growth, CO₂ emission to forested area and economic growth to forested area. This result also justified for using lagged variables in the DOLS estimation.

Table 4. Results of Granger causality Wald tests.

Equation/Excluded	Chi-Square	Df.	p-Value	
LCO ₂	LGDP	26.129 ***	4	0.000
	LFA	41.907 ***	4	0.000
	All	89.686 ***	8	0.000
LGDP	LCO ₂	12.953 **	4	0.012
	LFA	22.979 ***	4	0.000
	All	33.688 ***	8	0.000
LFA	LCO ₂	21.872 ***	4	0.000
	LGDP	23.347 ***	4	0.000
	All	30.669 ***	8	0.000

*** and ** denote significant level of 1% and 5%, respectively.

Table 5 presents the results of DOLS estimated by Equation (8). The coefficient value of GDP shows a positive relationship with CO₂ emissions that is statistically significant at 1% level. This means that a RM1 million rise in GDP is associated to an increase in CO₂ emissions of 0.931 kt, all other things constant. Instead, the results showed a negative coefficient of forested area on CO₂ emissions with 1% level of significance. This implies that declining one hectare of forested area (i.e., deforestation) has an impact of three kilo tons of CO₂ emissions rise in Malaysia. It is noteworthy that the signs of the estimated coefficients are consistent both from theoretical point of view and practical expectations. In addition, we investigated our estimated model's goodness of fit with some diagnostic tests. First, the value of R² and adjusted R² were 0.9838 and 0.9825, respectively, depicting a very good fitting of the estimated regression model. This clarifies 98% of the variation in change of dependent variable can be explained by the independent variables. Second, the F-test indicated that the estimated DOLS regression is justified by its dependent and independent variable. The p value of F-test was less than 0.0001, meaning that the linear relation of the model was statistically significant. Third, the root mean square error (RMSE) provided an accurate measure of model predictions for various times. The value of RMSE was 0.055 (close to 0) and non-negative, indicating the results of DOLS model was an almost perfect fit to the data.

Our findings prove that economic growth has a significant impact on CO₂ emissions, where GDP growth fosters CO₂ emissions at a faster rate in Malaysia. In line with this, Holtz-Eakin and Selden [52]; and Shafik [53] found a monotonic relationship between CO₂ emissions and income levels. Our findings are also supported by other studies in Malaysia such as Azlina and Mustapha [54], who reported Granger causality relations among economic growth, energy consumption and pollutant emissions. Ang [25] also found a bidirectional relation from economic growth to energy consumption in Malaysia. The present study found strong causality from CO₂ emission to deforestation, from economic growth

to CO₂ emission, and from deforestation to CO₂ emission. Nevertheless, compromising between economic growth and forest conservation is a central issue of sustainability in terms of CO₂ emissions; that is why this article did not consider other factors such as energy consumption, population, poverty and so on. Moreover, our study is distinct from those previous, as it is based on the latest and greater data set of 1990 to 2016. In addition, Bilan et al. [55] found long-run causality from CO₂ emissions to GDP for EU countries whereas Pao et al. [56] found bidirectional long-run Granger causality of CO₂ emissions and economic growth in Brazil, Russia, India, and China (BRIC) countries. Wang et al. [57] reported that in the long run, energy consumption and economic growth have positive impacts for CO₂ emissions in China. According to Tiwari [58], CO₂ emissions Granger-causes GDP while, GDP does not Granger-cause CO₂ emissions in India. Instead, Ozturk and Acaravci [59] found no causal evidence from the per capita real GDP to per capita carbon emissions in Turkey.

Table 5. Results of DOLS; dependent variable, LCO₂.

Variables	Coefficient	Standard Error	t-Statistic	p-Value
GDP (LGDP)	0.9313719 ***	0.0313171	29.74	0.000
Forested area (LFA)	−2.972577 ***	0.7481949	−3.97	0.001
Constant	49.11344 ***	12.73751	3.86	0.001
Number of observations	27			
df (degrees of freedom)	26			
R-squared	0.9838			
Adjusted R-squared	0.9825			
Standard error of the estimate	13.51702			
Mean of dependent variable	11.89308			
F-value	9.3393529			
Prob > F	0.0000			
Root MSE	0.05497			

*** denote significance at the 1% level.

Moreover, some studies revealed the environmental Kuznets curve (EKC) presenting the simple trail of economic growth and environmental pollutions or emissions for various countries including EU [55,60,61], Organisation of Islamic Cooperation (OIC) countries [32], and BRIC [56]; Middle East and North Africa (MENA) [62]; Organisation for Economic Co-operation and Development (OECD) [63]; industrialised [64]; and small-economy countries [65]. Furthermore, some studies are based on single country such as Bangladesh [15]; China [57,66–71]; Turkey [59]; South Korea [72]; India [58]; and the USA [23,73]. It is noteworthy that none of these studies have taken into consideration deforestation as an independent variable. However, our study findings indicate the long run relationship and impacts of the forested/deforested area and economic growth on CO₂ emissions in Malaysia. Our findings are also supported by other studies, although they used different set of variables and methods of analysis. For instance, Mansson et al. [74] combined DOLS with the Ridge regression estimator in order to demonstrate the EKC for a wide variety of different situations in energy economics and environmental studies. Islam et al. [75] reported a negative relationship of forested area with the CO₂ emission along with other socioeconomic variables by using cointegration and vector error-correction modelling techniques. Nepal et al. [76] analysed the relationship between global forested area and economic growth under the EKC framework. Nevertheless, any program and activities that escalate forests would be valuable for controlling and managing Malaysia's rising GHG emissions. The novelty of this study offers new findings with the latest estimation of the dynamic impacts of economic growth and forested area on carbon dioxide emissions by using 27 years of time series data in Malaysia. The findings indicate the importance of Malaysia's green growth and urgent action to combat climate change impacts associated with the forestry sector.

6. Discussion and Implications for Sustainability

Our findings from DOLS regression showed that an increase in GDP and deforestation (declining forested area) leads to an increase in CO₂ emissions in Malaysia. Malaysia is a tropical country with 67.55% of forested area [40] that plays various beneficial roles for environmental protection and sustainability including emission reduction through atmospheric carbon sequestration and reducing climate change [44]. GHG emission through the forestry sector are mainly associated with cutting down the trees. Reduction of GHG emissions from the forestry sector can be possible by reducing timber harvesting as well as minimizing deforestation and forest degradation [46]. Hence, deforestation is a major concern for sustainable management of environment and natural resources because it affects the climatic system so badly. However, the rate of deforestation is still high in Malaysia. Thus, it is a matter of concern that restoring forested area, high economic growth and better environmental quality through emissions reduction are jointly exclusive.

However, the atmospheric accumulation of CO₂ and its possible greenhouse effect on global climatic system has become a major environmental issue [77]. Forests keep a crucial role in regulating climate change by controlling the quantity of atmospheric CO₂. Forests perform as both sources and sinks of GHG, through which they have a vital impact on the global climatic system [78]. For the past few decades, tropical countries have been experiencing rapid land use and forest cover changes due to heavy deforestation [79]. Deforestation in the tropical region is the second major source of GHG emissions, responsible for almost five billion tons CO₂ emissions per year, which is about 17% of the total worldwide emissions of CO₂ to atmosphere, causing global warming and climate change [80]. Clearing forests by cutting down the trees is the most significant cause of deforestation all over the world. For instance, huge tropical forests have been converted to agriculture because of increasing population and their economic opportunities [81]. However, Malaysia is one of the Southeast Asian countries which is rich in biodiversity [82]. Malaysia has experienced biodiversity loss and the destruction of wildlife habitat because of the forest cover changes over the last few decades due to heavy deforestation. Uncontrolled development and land use changes are threatening these forests, causing both deforestation and degradation of the natural forested areas. At the beginning of the 20th century, forests covered almost 90% of the total area of Peninsular Malaysia [30]. In comparison, only 44% of Peninsular Malaysia consisted of forested areas in 2016 [28]. These remaining forests are also frequently fragmented, leading to loss of habitat for many important species.

Furthermore, avoiding deforestation makes great sense from a functional viewpoint. Conserving forests in tropical regions may hold 300–400 tons CO₂ per hectare in forest biomass [83]. However, it is not possible to diminish the global climate change problem without reducing the emissions from deforestation. There are a few countries that have proposed a mechanism to pay developing countries with a higher deforestation rate for conserving their forest areas and reducing deforestation and degradation. The Malaysian government is also implementing different policy instruments; for example, REDD+ (Reducing Emissions from Deforestation and forest Degradation), which includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks [79,84,85]. Thus, CO₂ emissions can be minimised by applying these programs. Appropriate implementation of these forestry instruments can decrease the deforestation rate by managing and controlling the forest logging activities, which ultimately provide support for the worldwide effort to reduce GHG emissions as well as to increase national economic growth. Malaysia has given its attention to the beneficial role played by forestry sector; for example, watershed conservation, soil protection, biodiversity conservation, fulfilling aesthetic and recreational demands from the tourists, climatic system regulation and carbon sinks. These beneficial roles by the forestry sector can take part to reduce climate change vulnerabilities and to mitigate climate change. Therefore, Malaysia planned to maintain a minimum 50% of its total land as forested areas [44]. Malaysia is one of the signatory countries of the Kyoto Protocol and has ratified to reduce GHG emissions [37].

Moreover, Malaysia has undertaken several efforts to address climate change actions including adaptation and mitigation, and continually reevaluates its mitigation potential in various key sectors.

These actions have contributed to achieve Malaysia's conditional voluntary indicator to reduce its GHG emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005, consisting of 35% on an unconditional basis and a further 10% on a condition upon receipt of climate finance, technology transfer and capacity building from developed countries [44]. The Malaysian forestry sector has attracted some interest from the international community to address emissions reduction [43]. Nevertheless, appropriate implementation of emission reduction policies with sufficient investment for emission reduction through the forestry sector could be a possible way for Malaysia to achieve the goals for sustainable environment and long run economic growth [33]. Government initiatives for increasing forest carbon biomass with implementing policies related to carbon trading scheme and carbon emissions tax can be supportive for Malaysia's long-term economic growth. The potential impact of forest carbon sequestration through various forestry related mitigation activities such as afforestation, reforestation, forest conservation, and sustainable forest management, etc., and their cost-effectiveness could play a significant role in environmental sustainability by reducing global GHG emissions with low cost compared to other non-forestry GHG emission reduction technologies. Instead, plantation activities can be carried out in appropriate areas such as vacant land and bare hills to limit and prevent the destruction of existing natural forests. Therefore, CO₂ emission reduction through the forestry sector of Malaysia could reduce the financial barriers to mitigate climate change while accelerating the national economy.

7. Conclusions

The results of DOLS estimation reveal that economic growth and deforested areas have an adverse impact on Malaysia's carbon emissions where GDP growth fosters carbon emissions at a faster rate. The vital advantage of the DOLS approach is that it also reflects the existence of a mix order integration of variables as like co-integrated approach. The estimated DOLS encompasses regressing one of the I(1) variables against other I(1) and I(0) variables [25], hence, the plausible endogenous and small sample bias problems can be solved. Thus, the obtained estimation of our DOLS model are asymptotically efficient. The overall findings imply that forest protection and conservation is crucial to reduce carbon emissions. Thus, the effective implementation of national climate change, green technology and environmental policies together with economic instruments in the forestry sector including REDD+ mechanism, afforestation and reforestation (tree planting programs), forest conservation and sustainable forest management, among others, could be useful for reducing carbon emissions while decreasing deforestation and maintaining long-term economic growth in Malaysia. Nevertheless, the significant contribution of this study is to investigate the inter-temporal links in the forested area/deforestation–environment–economic nexus for Malaysia that could be helpful for policy makers to understand their relationships for design and implementing effective forest management as well as climate change and environmental policies. The facts, trends and empirical evidence of dynamic impacts and relationship of economic growth, forested area and carbon emissions might help to frame issues and challenges of current forest management practices that affect the response to lowering carbon emissions, tackling climate change and improving environmental quality and sustainability in Malaysia. Finally, this article can serve as an entry point for comprehensive researches of climate change mitigation strategies in order to implement effective policy measures for achieving sustainable forest management and a low carbon economy in Malaysia.

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