Jurnal Ekonomi Malaysia
http://dx.doi.org/10.17576/JEM-2023-5701-12

How Does Carbon Emission Affect the Economy?
(*Bagaimana Pelepasan Karbon Memberi Kesan kepada Ekonomi*)

Andrew Kam Jia Yi
Universiti Kebangsaan Malaysia

Evelyn S. Devadason
Universiti Malaya

ABSTRACT

The objective of the study is to determine the effect of carbon (CO2) emissions, energy consumption and the usage of renewable energy on the Gross Domestic Product. Using Malaysian data from 1990 to 2020, this study employs multivariate VAR estimation, namely the impulse response function and the Toda-Yamamoto Granger causality method to identify the relationships between the variables. The findings show a significant and reciprocal relationship between GDP and energy use. However, the consumption of renewable energy has little impact on the GDP due to the country's low levels of renewable energy consumption in comparison to its usage of fossil fuels. Since renewable energy plays a critical part in lowering carbon emissions, its usage needs to be intensified to fully have an impact on the economy. Hence, policies to reduce carbon emissions, such as incentives for adopting green technology and production standards, should be emphasized.

Keywords: Economic development; environment and growth; environment and development; sustainability; empirical studies of economic growth; time series model

ABSTRAK

Objektif kajian ini ialah untuk menentukan kesan pengeluaran karbon (CO2), penggunaan tenaga dan penggunaan tenaga boleh perbaharui dalam keluaran dalam negara kasar. Dengan menggunakan data Malaysia, dari 1990 hingga 2020, kajian ini menggunakan anggaran VAR multivariat, khususnya fungsi tindak balas impuls dan kaedah kausaliti Toda-Yamamoto Granger untuk mengenalpasti perhubungan antara variabal. Kajian mengenalpasti perhubungan resiprokal yang signifikan antara GDP dan penggunaan tenaga. Sebaliknya, penggunaan tenaga boleh perbaharui kurang mengesani GDP disebabkan kurang penggunaan berbanding tenaga fosil. Memandangkan tenaga boleh perbaharui berperanan kritikal untuk mengurangkan pengeluaran karbon, kegunaannya perlu dipertingkatkan lagi untuk memberi kesan sepenuhnya terhadap ekonomi. Sayugianya, polisi pengurangan pengeluaran karbon, seperti insentif penggunaan teknologi hijau dan penggunaan piawaian pengeluaran perlu diutamakan.

Kata kunci: Pembangunan ekonomi; pertubuhan alam sekitar; pembangunan dan alam sekitar; kelestarian; kajian empirik pertumbuhan ekonomi, model siri masa.

JEL: O1, O44, Q56, O47, C22

Received 10 September 2022; Revised 19 March 2023; Accepted 5 May 2023; Available online 19 May 2023

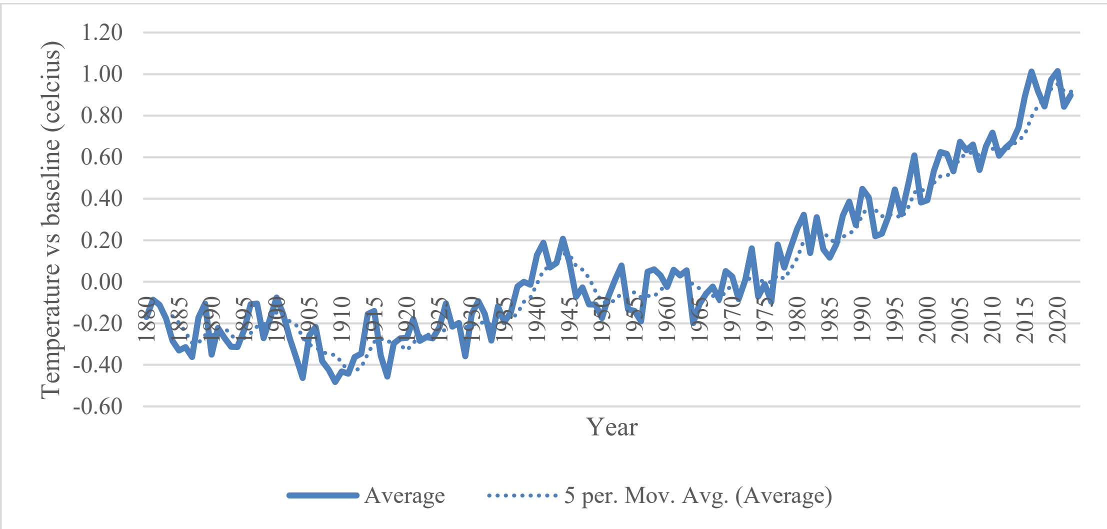
INTRODUCTION

Global warming has a severe impact on the environment and economic growth. According to past studies, climate change is linked to an increase in natural disasters, a rise in diseases, a decline in labour productivity, and a loss in economic gains as a result of the societal cost of rising carbon emissions. (Wu et al. 2020; Wasti et al. 2020; Chavaillaz et al. 2019; Rasiah et al. 2017). Climate change due to carbon emissions, therefore, impedes the sustainability[1] of economic development. Three key strategies are needed to accomplish sustainable development; namely *economic*, *environmental*, and *social development* (Pierantoni 2004; Ghosh 2008; Ciegis et al. 2009). The economic strategy, which involves allocating energy resources to maintain environmental sustainability and promote social development, is the study's main area of interest. The use of energy resources to carry out this strategy, however, leads to an increase in carbon emissions, which in turn pollute the air, damage the ecosystem, and speed up global warming.

Figure 1 illustrates how swiftly global warming has advanced by highlighting a significant increase in the average global temperature over the previous 50 years. Emissions of greenhouse gases (GHGs) are the significant reason for the temperature rise. Malaysia has committed to reducing its GHG emissions intensity by 45% of its GDP by 2030, compared to the emissions intensity of its GDP in 2005, as part of the Paris Agreement, which was signed during the 2015 UN Climate Change Conference (COP21) in Paris. This pledge consists of 35% that is unconditional and another 10% that is contingent on receiving climate financing, technological transfer, and capacity building from industrialized nations. With this commitment in mind, the Eleventh Malaysian Plan (2016 – 2020) or RMK-11 further dedicated a chapter titled 'Pursuing Green Growth for Sustainability and Resilience in Malaysia's main economic development policy document. Three strategies were outlined in strengthening governance to drive transformation, enhancing awareness to create shared responsibility, and establishing sustainable financing mechanisms.

Although Malaysia voluntarily agreed in 2009 to reduce greenhouse gas (GHG) emissions from 1990 levels by 40% by 2020, the country's national energy consumption level had increased by 240% from 1990 to 2018[2] despite the pledged commitments. Malaysian Energy Statistics Handbook in 2020 also showed that final energy consumption in Peninsular Malaysia increased from 35,593 (ktoe) to 47,446 (ktoe) from 2010-2018, an increase of more than 30%. The primary production of natural gas, crude oil, coal and coke increased from 46,186 ktoe to 101,921 ktoe, a significant increase of 121%. Despite the sluggish rate of reduction, some industries like palm oil continued to be committed to cutting GHG emissions by 45% by 2030[3]. Petroliam Nasional Bhd (Petronas), the nation's oil company, has similarly committed to achieving net-zero GHG emissions by 2050.

The growing number of promises to reduce GHG emissions further demonstrated that Malaysian industry understands the significance of environmental sustainability. Alongside this, the country's use of renewable energy increased from 2% in 2008 to 10%, with a 20% target in 2050[4]. The Sustainable Energy Development Authority (SEDA) of Malaysia recently awarded the LSS4 (large-scale solar program), which suggests renewable energy is anticipated to contribute up to 3% of the electricity generation capacity in the peninsula, Sabah, and Labuan. The development in Malaysia suggests that the country intends to arrive at net-zero carbon emissions soon, which supports the idea that it is better to conduct early measures to prevent extremely high corrective expenditures.



Source: National Aeronautics and Space Administration (NASA), https://data.giss.nasa.gov/gistemp/

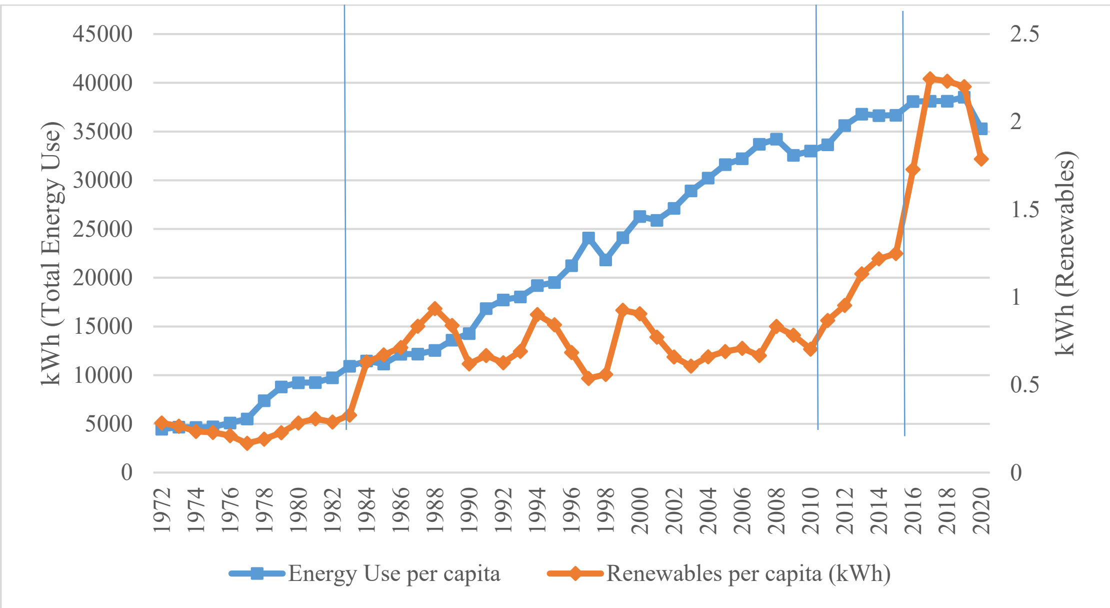
FIGURE 1. Earth's surface temperature on average

One channel where climate change impacts the economy is through firms. The growing understanding of the harm caused by carbon emissions has encouraged businesses to become more "carbon-sensitive". Firms are increasingly aligned to the environment, social and corporate governance (ESG) approach where profit maximization is tied to social and environmental goals. Businesses diversify their operations into environmentally friendly industries including urban financial goods and services, green buildings, climate-smart agriculture, and renewable energy. The assistance of the government and the contributions of these businesses are essential in the nation's shift to a low-carbon economy. Renewable energy is the key to lowering carbon emissions.

The benefits of renewable energy for the environment and the economy have prompted enormous efforts, even though the bulk of Asian countries have not yet fully adopted it. To encourage the adoption of renewable energy technology, Malaysia established the National Green Technology Policy in 2009. The Feed-in Tariff (FiT) program was created and put into effect by the Renewable Energy Act of 2011 as a follow-up to encourage the production of electricity from renewable resources. To increase the use of renewable energy in Malaysia and ensure that the Renewable Energy Act targets and the Eleventh Malaysia Plan are realized, further measures were taken to support Greentech Malaysia in promoting the Low Carbon Cities Framework (LCCF) (Malaysian Edge

Organization, 2019). Efforts to increase the contribution of renewable energy in electricity generation will be enhanced through the Twelfth Malaysian Plan. Various initiatives were adopted such as i) increasing the share of various renewable energy sources, ii) utilising new and old technologies, such as solar thermal, fuel cells, and co-generation, iii) creating a number of clusters of bioenergy to serve as key collection centres, iv) encouraging the creation of floating solar projects and waste-to-energy production, and v) increasing rooftop solarphotovoltaic installation using current financing methods

While renewable energy usage has grown, the country is still lagging behind the nation's increasing rate of carbon emissions. The impetus for change in Malaysia’s policy direction is partly due to the rising concerns about energy use per capita over the years. There were concerns on whether the country’s economic performance is over-reliant on unsustainable energy sources. Figure 2 shows that renewable energy sources are only made up of a small fraction of total energy use per capita in Malaysia. However, albeit contributing to a small amount, it seems that policy intervention may have played a role in the spikes shown in 1983, 2010, and 2015. The first spike may be due to an outcome of the Four-Fuel Diversification Policy (1981), the second may be due to National Green Technology Policy (NGTP) in 2009, and finally, the third spike may be attributed to the Paris Accord whereby the government puts forth its commitments under the RMK-11.



Note: Renewables are the sum of energy from hydropower, wind, solar, geothermal, wave and tidal, and bioenergy. Traditional biofuels are not included.
Source: Our World in Data, https://ourworldindata.org/grapher/per-capita-enewables? tab= chart&region= Asia&country=~MYS

FIGURE 2. Energy Use- and Renewables per capita in Malaysia (kWh), 1972 – 2020.

The figures merely provide anecdotal (visual) evidence of the relationships between economic growth, carbon emissions, and renewable energy. The question as to whether causality exists between these three elements are yet to be discussed. An empirical investigation is therefore conducted in the next section to elucidate the relationships. The fundamental subject of this article is whether or not Malaysia's economic growth was influenced by these emissions. Since the 1980s, there has been a rapid rise in CO2 emissions, which has been linked to increased reliance on energy sources including oil, coal, and gas. Further worries are generated by predictions that CO2 emissions will continue to rise in the future despite international attempts to reduce them. The rise of CO2 emissions, which also contributes to global temperatures, may also impede the Malaysian economic growth by 20% in 2050 (Murugiah 2021). This is attributed to the reduction in economic output and factors that affect CO2 emissions. Therefore, the objective of the study is to elucidate whether variables that affect CO2 emissions, such as energy consumption and the usage of renewable energy, exert an impact on a country's capacity for economic growth.

The literature review and study hypothesis are presented in Section 2. A summary of Malaysia's energy usage is given in Section 3. The approach and model linking CO2 emissions, energy use, renewable energy, and economic growth are covered in Section 4. The empirical results are presented in Section 5, and the conclusion and policy recommendations are presented in Section 6.

LITERATURE REVIEW

The literature on economic growth and environment is immense. Within the context of environmental economics, Jansson et. al. (1994) argued that economic activities will be at risk if the resource base degrades. This was in tandem with Goldin and Winters (1995) theory that environmental protection and economic growth are parallel in terms of importance. Both theories hinge on concerns that economic growth is not sustainable as it consumes most of environmental resources that supports the production of goods and services. The Environmental Kuznet Hypothesis /Curve (EKC) popularized by the World Bank (1992) and Grossman and Krueger (1995), further invoked the notion that environmental degradation and GDP per capita are related. Pollution emissions and other environmental effects rise during the early stages of economic expansion, but above a certain GDP per capita threshold (which varies with different indicators), the trend changes, leading to environmental improvement at high income levels. However, when contemporary studies decomposes this relationship, many contestations on it emerged. The ambiguous relationship is due to the diverse structural characteristics of the countries studied, their growth stage, the econometric techniques employed, and the time frame examined. While many econometric methods were used, the most widespread one is the granger causality method owing to its ability to identify the causal direction(s) of the variables.

This section discusses the empirical literature on the relationships. It first explains the working definitions used in the study followed by the mechanism of CO2 emissions in affecting GDP and the hypothesis. *The release of carbon into the atmosphere* is defined to as CO2 emission. According to earlier research (Lüthi et al. 2008; Lindsey 2009; Collins & Knutti 2013; Dunn et al. 2020), CO2 emissions are the main contributor to climate change. The burning of fossil fuels produces CO2 emissions as a result of energy consumption for industrial development. The level of national development also has an impact on the results of numerous studies on the relationship between energy use and CO2 emissions.

In Malaysia, several studies have explored the relationship between economic growth, energy consumption, and CO2 emissions. However, the ambiguity in the results, or the mixed findings, created knowledge gaps that motivate further studies. For example, the study by Narayan & Smyth (2015) examined the long- and short-term links between economic development, energy use, and CO2 emissions in Malaysia from 1971 to 2012 using the autoregressive distributed lag (ARDL) model. They discovered a one-way causal relationship. On the other hand, Shahbaz et al. (2017) study utilized the bounds testing approach to investigate the relationship between economic growth, energy consumption, and CO2 emissions in Malaysia from 1971 to 2014. They however, found a bidirectional causality between energy consumption and economic growth, while the relationship between CO2 emissions and economic growth was unidirectional. The mixed results therefore, warrant further examination. A caveat is that such mixed findings is not unique to Malaysia.

According to the study by Al-Mulali et al. (2012), energy use and CO2 emissions are positively connected in the majority of African countries. This finding is consistent with Wu et al. (2020), who made a similar argument that increased energy use significantly increases carbon emissions. This suggests low correlation between energy use and CO2 emissions in low-income countries. According to Liu et al. (2020), cutting energy use lowers carbon emissions, but cutting carbon emissions also requires an alternative energy source, one of which is renewable energy. Renewable energy can help developing economies reduce their carbon emissions, according to Zaman et al. (2021) as per the case of China. Renewable resources which include solar energy, wind, hydrogen, and geothermal energy provide a cleaner alternative energy source than burning fossil fuels. Many studies have established connections between economic growth, renewable energy, and CO2 emissions[5].

Past studies have suggested that more energy will be consumed, in the less developed regions where there are fewer rules and poor energy regulations. Additionally, they discovered that carbon emissions in the transportation sector were reduced when energy was used more effectively, thus, indicating a positive spillover effect with greater energy efficiency. This led to the conclusion that there is a negative link between renewable energy and carbon emissions. On this cognizance this study posits the following hypotheses:

H_{1a} Carbon emissions are positively correlated with overall energy use.
H_{1b} Consuming renewable energy has a negative relationship with carbon emissions.

Empirical research has shown a correlation between economic growth and CO2 emissions, but the exact nature of this relationship is still unknown. Understanding this link between economics and carbon emissions will therefore enable policymakers to balance environmental protection and economic developmental goals. Salahuddin et al. (2016) used panel data analysis to examine the links between economic growth and CO2 emissions in OECD nations and concluded that these associations depend on the country's level of development and the nature of its economic activity. This is consistent with the findings in different studies. The first causal assumption is that increased economic development reduces CO2 emissions (Tamazian et al. 2009; Jalil & Feridun 2011), meaning that growth in the economy has a negative impact on CO2 emissions. However, a reverse relationship is also possible in which economic growth significantly increases CO2 emissions (Zhang 2011). Some studies also state that CO_2 emissions follow an inverted-U relationship as earlier mentioned in relation to the Environmental Kuznets Curve (EKC). This pattern is also consistent with research done in Turkey where the level of CO_2 emissions initially rises with increasing wealth before starting to fall (Ozturk & Acaravci 2013) thus suggesting a non-linear correlation between economic growth and carbon emissions. Some studies went further to show the absence of connection between the two factors (Ehigiamusoe et al. 2020). Therefore, to determine the relationship between economic development and carbon emissions for Malaysia, we evaluate the causality between economic growth and emissions in this study as posited in the following hypothesis:

H_2 Economic growth has positive relations with the amount of carbon emissions.

The final relationship examined in this paper is between energy consumption and economic growth. While growth is necessary, evidence however suggests that environmental degradation is a result of the rapid rise in energy consumption (Asif et al. 2015). According to conventional wisdom, rising CO_2 emissions is a major factor in rising energy consumption (Wasti & Zaidi 2020). CO_2 emissions, however, can be controlled. As mentioned earlier, an increase in the use of renewable energy will contribute to a reduction in CO_2 emissions over long and short periods in China. Non-renewable energy such as fuels and gas is declining in its usage in wake of increasing sustainability concerns and a "green" movement toward more environmental-friendly options. This again implies that that the relationship is also not linear. It can be a two-way relationship as suggested by Salahuddin and Gow (2019) who discovered a bidirectional impact between economic growth and energy usage in Qatar.

The green movement has caused a steady change in industrial production methods worldwide, moving away from fossil fuel energy toward clean, affordable, and renewable energy sources (Wang et al. 2020). A U-shaped pattern identified in policy studies suggest that the economy will benefit in the long run even though energy conservation regulations and decreased fossil fuel usage will slow down economic growth in the short term (Liu et al. 2020; Le & Van 2020). In short, there will be economic consequences during the transitional period of renewable energy consumption, but the increase in yield from the transition will only manifest in the long run.

We, therefore, propose the following hypotheses to explore the connections between energy usage and economic development:

H_3 The relationship between total energy consumption and economic development is positive.

METHODS

The secondary time-series data were sourced from the World Bank database (refer Appendix 1 for full data description). Data of key variables[6] were extracted from the year 1990 to 2020. Diagnostic tests were conducted using correlation, and unit root tests. Initial correlation analysis revealed the relationships between the variables. The Toda-Yamamoto estimation approach was used to test the causality relationship between these variables (Furuoka 2015). To ensure data stationarity, the unit root test was conducted before the estimation. Finally, the impulse response function, which introduced a brief input signal or series of shocks called an impulse, subsequently provided an analysis of the dynamics in its output. The impulse response showed how the chosen dynamic system reacts to changes in the environment (Lin et al. 2020; Sulaiman & Abdul-Rahim 2017).

The data were transformed into natural logs to ensure the coefficients were interpreted as elasticities. The transformation also ensured the data followed a normal/near-normal distribution. In addition, the log transformation dampened skewness. The base model specification postulates that CO_2 emissions are impacted by the three key variables GDP, energy- and renewable-energy consumption:

$$CE_t = f(RC_t, EC_t, GDP_t) \quad (1)$$

Where CE is a proxy for CO_2 emissions (metric tons per capita), "renewable energy consumption (% of total final energy consumption)" is represented by RC. EC is "energy use (kg of oil equivalent per capita)", and finally, economic development and growth are proxies for "real gross domestic product per capita (constant 2010 US$)". Full data description is in Appendix 1. To examine the stationarity of the variables initial diagnostic tests were conducted. The standard "augmented Dickey-Fuller (ADF)" test, "the Phillips-Perron (PP)" test, and "the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS)" test were applied (Dickey & Fuller 1979; Phillips 1988; Kwiatkowski et al. 1992).

The co-integration (long-run relationship) between variables was later tested using the limits/bounds test, with ΔCE serving as the dependent variable for the base specification.

$$\Delta CE_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\Delta CE_{t-i} + \sum_{i=1}^{p} \beta_{2i}\Delta RC_{t-i} + \sum_{i=1}^{p} \beta_{3i}\Delta EC_{t-i} + \sum_{i=1}^{p} \beta_{4i}\Delta GDP_{t-i} + \varphi_1 CE_{t-1} + \varphi_2 RC_{t-1} + \varphi_3 EC_{t-1} + \varphi_4 GDP_{t-1} + \varepsilon_{1t} \quad (2)$$

Where p is the number of lag orders, β_0, β_1, β_2, β_3, β_4 and φ_1, φ_2, φ_3, φ_4 respectively are the slope coefficient for the lagged difference and lagged levels. ε_t is the error term. The null hypothesis for the co-integration test is expressed as:

$$H0{:}\ \varphi_1 = \varphi_2 = \varphi_3 + \varphi_4 = 0 \quad (3)$$

To examine the causal relationship between the variables, the study used the "Toda-Yamamoto causality" approach. This method alters the *base* specification, which allows for the examination of the relationships between the variables (Toda & Yamamoto 1995). Upon examining the unit root test, various integration orders were discovered. This justifies the use of "Toda-Yamamoto causality analysis" to mitigate the limitations of the Granger causality test (where there is a need for all variables to have the same co-integration order). Finally, a vector autoregression (VAR) model based on the Toda-Yamamoto approach was analyzed along the impulse response function (IRF). The VAR model is as follows:

$$\mathrm{CE}_t = \beta_{10} + \sum_{i=1}^{k+d} \beta_{11i} CE_{t-i} + \sum_{i=1}^{k+d} \beta_{12i} RC_{t-i} + \sum_{i=1}^{k+d} \beta_{13i} EC_{t-i} + \sum_{i=1}^{k+d} \beta_{14i} GDP_{t-i} + \varepsilon_{1t} \quad (4a)$$

$$\mathrm{RC}_t = \beta_{20} + \sum_{i=1}^{k+d} \beta_{21i} CE_{t-i} + \sum_{i=1}^{k+d} \beta_{22i} RC_{t-i} + \sum_{i=1}^{k+d} \beta_{23i} EC_{t-i} + \sum_{i=1}^{k+d} \beta_{24i} GDP_{t-i} + \varepsilon_{1t} \quad (4b)$$

$$\mathrm{EC}_t = \beta_{30} + \sum_{i=1}^{k+d} \beta_{31i} CE_{t-i} + \sum_{i=1}^{k+d} \beta_{32i} RC_{t-i} + \sum_{i=1}^{k+d} \beta_{33i} EC_{t-i} + \sum_{i=1}^{k+d} \beta_{34i} GDP_{t-i} + \varepsilon_{1t} \quad (4c)$$

$$\mathrm{GDP}_t = \beta_{40} + \sum_{i=1}^{k+d} \beta_{41i} CE_{t-i} + \sum_{i=1}^{k+d} \beta_{42i} RC_{t-i} + \sum_{i=1}^{k+d} \beta_{43i} EC_{t-i} + \sum_{i=1}^{k+d} \beta_{44i} GDP_{t-i} + \varepsilon_{1t} \quad (4d)$$

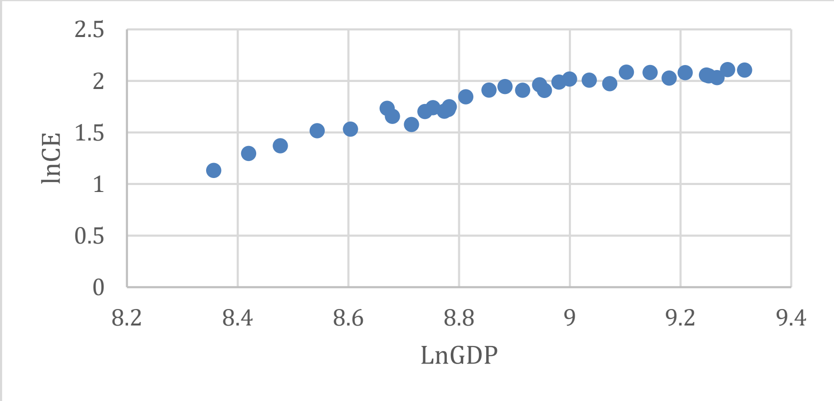
Where d is the additional lag order, which is the highest order of integration, and k is the ideal lag order. In this test, the Akaike info criterion (AIC) was used to calculate the lag length while the ADF test was used to identify the maximum order of integration.

RESULTS

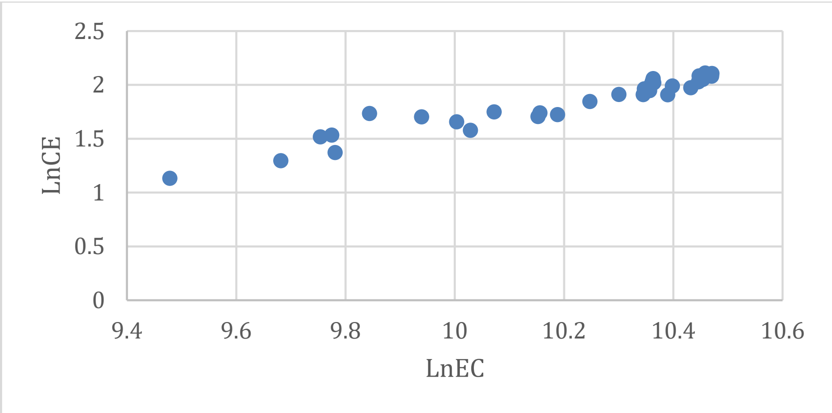
CORRELATION ANALYSIS

The correlation analysis (Figure 5) examines the earlier patterns revealed in Figures 2, 3, and 4. Results in Figure 5(a) show that from 1990 to 2021, energy consumption and GDP in Malaysia was rising in tandem. This was expected as it was accordingly confirmed in Figure 3. Energy consumption also moved in the same pattern as carbon emissions (Figure 5(b)) which is consistent with reports in past literature and considering that Malaysia was well into its industrialized phase during the 1990s. The rise in energy consumption is also commensurate with the rise in CO2 emissions in an industrialized country. However, when examining the correlations between renewable energy and CO2 emissions, Figure 5(c) suggests there is a negative correlation. The presence of renewable energy coincides with incidences of lesser CO2 emissions. This implies that it provides an alternative to fossil fuels, hence influencing the intensity of CO2 emissions. The findings thus support our hypothesis that energy consumption is positively correlated with GDP growth and increase in carbon emissions.

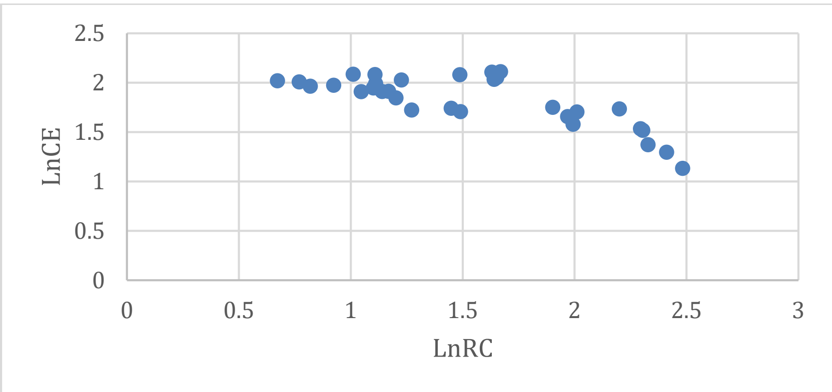
(a)



(b)



(c)



Source: Calculated by the Authors using World Development Indicators (WDI), 1990 - 2020

FIGURE 5. Correlations between variables

TABLE 1. Unit root analysis

			CE	RC	EC	GDP
ADF	Level	C	-3.055***	-1.804	-2.556**	-1.669
		C&T	-2.585	-0.683	-0.575	-3.183
	1st difference	C	-3.452***	-2.813**	-4.776***	-3.951***
		C&T	-3.973**	-3.480**	-7.040***	-4.127***
PP	Level	C	-3.900	-1.838	-4.660***	-2.045
		C&T	-3.826	-1.855	-4.001***	-1.983
	1st difference	C	-5.962***	-4.019**	-5.443***	-5.076***
		C&T	-5.982***	-3.972**	-13.4323***	-5.083***

Notes: C = Constant, C&T = Constant and Trend. The asterisks show significance: *** at the 1% level. ** at the 5% level. * at the 10% level.

Three tests were run to evaluate stationarity. The CE was integrated with order zero (I(0)) when using the Augmented Dickey-Fuller (ADF) test. However, the orders of RC, EC, and GDP were all integrated in the first order (I(1)). Similar results were obtained via the Philips-Perron (PP) test, which revealed that GDP, CE, and RC are also I(1) while EC is I(0). Last but not least, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test demonstrates that CE and GDP were both I(0), while EC and RC were integrated at I(1). The outcomes of the unit root tests show that integration orders vary across the four variables. As a result, the standard Granger causality test could not be used in this study; instead, the Toda-Yamamoto causality approach was employed.
5.2 Results: Causality analysis.

TABLE 2. Toda-Yamamoto estimation

Dependent Variable	CE	EC	RC	GDP
Carbon Emissions (CE)		8.54*	2.59**	10.45**
Energy Consumption (EC)	1.63**		1.45**	7.02*
Renewable Energy Consumption (RC)	2.57	4.07**		28.9**
Gross Domestic Product (GDP)	10.3**	14.7**	23.7**	

Notes: Chi^2 Values (**) and (*) respectively show significance at the 1% and 5% levels.
Lags in the Granger test are determined by the *Varsoc* post-estimation test using STATA.

The Toda-Yamamoto estimation shows the bi-directionality, or dual causality, of most of the variables above. At the current juncture, the findings show that Malaysia's economic growth creates high energy usage, increase in carbon emissions and also usage of renewable energy. In return, the energy consumption and emission also increased the economic activity of the country. The relationship between GDP and EC is as expected since Malaysia's economic development (GDP) is driven mainly by energy consumption. Conversely, the economic activities in the country also create the need to consume more energy, hence forming a cyclical pattern between economic development and energy consumption. The finding confirms the third hypothesis and is consistent with those of past studies. This circular pattern may not be sustainable for the environment as it continues to produce and increase carbon emissions. In consequence, this finding is consistent with that of prior research and supports Hypothesis 1a, according to which energy use increases carbon emissions. In return, the increase in energy consumption and attendant carbon emission, also fueled the economic growth of the country as shown by the dual causality relationship between GDP and CE. In addition, the results further confirmed that the energy consumed during Malaysia's development phase also increased carbon emissions. The finding verifies Hypothesis 2 and is consistent with those of past research.

However, the results also implies that a mitigation of carbon emissions as renewable energy has an impact on carbon emissions. The statistics when paired with Figure 5c results suggest that an increase in renewable energy may cause the decline in carbon emissions, hence verifying Hypothesis 1B. This result needs to be interpreted with caution for only a small fraction of renewable energy is used in the country (see Figure 4) since traditional fossil fuels have not yet been completely replaced in the country. Renewable energy should not however be interpreted as having insignificant importance, rather this should be seen as an opportunity for the country to promote and intensify its use for environmental and sustainability purposes. It should not also be construed as a policy failure since efforts to address the 2015 Paris Accord are only at their early stages. More time is needed to analyze its impact on the country's economic growth and carbon emissions.

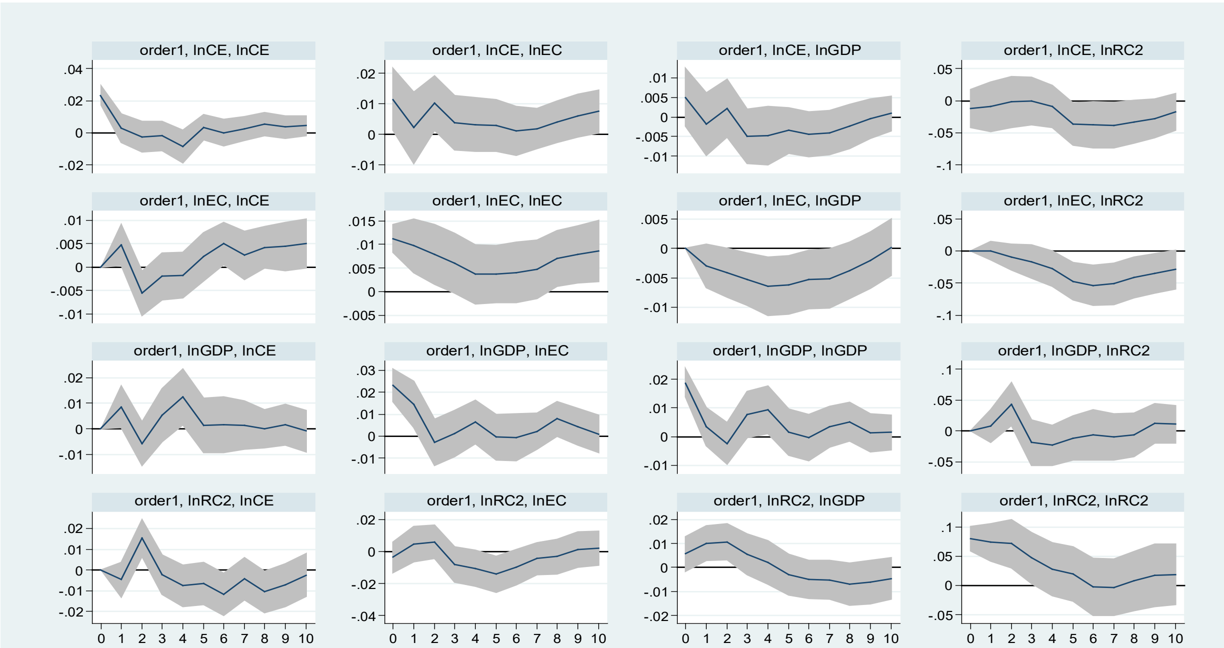
ANALYSIS OF THE IMPULSE RESPONSE FUNCTIONS

The IRF, which shows the effect of all the variables, further evaluates the model's sensitivity. A two-period lag is utilized to estimate the VAR. Using its residual, an LM serial correlation diagnostic test was conducted. The outcome revealed no problems with serial correlation. The errors and the VAR system were verified to be normally distributed following a multivariate normality test (the Jarque-Bera).

Figure 6 displays the findings of the IRF analysis. Every impulse response function was near the 95% confidence limit. Table 3 further synthesizes the causality and IRF results. Even though CE and EC have a two-way relationship, a one standard deviation (SD) shock in CE has different impact on EC in comparison to its inverse relationship. While carbon emissions may have a moderating impact on energy consumption, a shock in energy consumption has an increasing impact on carbon emissions. This indicates that understanding energy consumption pattern is important to address long term carbon emission issues. In the early 1990s, a variety of legislative initiatives aimed at finding alternatives to fossil fuels may have contributed to the variations that temporarily lowered carbon emissions. On the impact of renewable energy (RE) and carbon emission (CE), a one SD shock to RC will also have a negative impact on CE in the short and long run. The IRF and Toda-Yamamoto estimation result suggests a cyclical impact that is below zero, implying renewable energy has a one way and inverse relationship with carbon emissions.

The impact of RC on EC is a two-way relationship but is less pronounced compared to EC on RC since the latter is not consumed at a larger scale that may affect overall EC. On the other hand, the need for RE is prevalent when EC increases due to environmental and sustainability awareness of the public. This is also supported by the relationship between RC and GDP whereby the IRF shows that a one SD shock in RC increases GDP at the early period before decaying to zero. This implies that RC affects GDP but will not be sustainable if usage or consumption is low. The subdued impact of renewable energy consumption suggests that there is a need for policy intervention to boost its usage and favourable impact to the economy.

Finally, the response of GDP to one SD shock in EC shows that the impact of GDP declined and became negative from periods 2 to 4. The impact became positive after period 3 and move with minor fluctuations marginally above zero. This also suggests that GDP and energy use have a strong connection. This conclusion supports the findings of Salahuddin & Gow (2019), Wasti & Zaidi (2020), and Asif et al. (2015) that energy consumption has a beneficial impact on economic growth. GDP growth exerts an increasing impact on renewable energy should more resources be allocated to promote its usage based on the IRF.



Note: 95% Confidence interval (shaded), and orthoganalized IRF (lines within shaded area)

FIGURE 6. Impulse response function (IRF)

TABLE 3. Summary and synthesis of results.

One SD shock of:	Causality	Impulse response pattern	Discussion
Carbon Emissions (CE) to			
• EC	Two-way	Decreases EC in the first period but increases in the second before decreasing again from period 2 to 7. It has a short increase from 8th onwards.	Carbon emissions affect energy consumption in a fluctuating manner.
• RC	One-way	Low fluctuations around zero throughout. Mainly below zero.	Increase usage of RC shows lesser usage (or negative response) on carbon emissions.
• GDP	Two-way	Generally decreasing and hoovers around zero since the 3rd period but with an increasing response.	Increase in carbon emissions affect GDP negatively at initial stage but slowly contributing to GDP throughout the years.
Energy Consumption (EC) to			
• CE	Two-way	The pattern is increasing. Increases carbon emissions from 2nd period onwards.	This is a much clearer pattern compared to the inverse relationship. The more energy being consumed, the more carbon is being emitted.
• RC	Two-way	U-shaped pattern, meaning shock in energy consumption will initially reduce renewable energy consumption, but later increases after the inflection point in the 6th period.	Initially, energy consumed in the country are mostly stemmed from fuels. However, the impact on renewable energy is only prevalent in later period as the country continues to place importance in managing energy consumption.
• GDP	Two-way	U-shaped pattern below zero, implying negative impact on GDP at initial stage but increases in later stage.	There may be negative externalities with energy being consumed increasingly at the early stages.

Renewable Energy Consumption (RC) to			
● CE	No causality	A short spike in early period but generally hovers around zero when the lag effect kicks in.	Although it is a two-way relationship, the impact of RC on EC is less pronounced compared to EC on RC. This is because RC is not being consumed in a larger scale that may affect overall EC. On the other hand, the need for RE prevalent when EC increases due to environmental and sustainability awareness.
● EC	Two-way	Energy consumption hovers around zero with no distinctive patterns.	
● GDP	Two-way	Increases GDP in early period before decaying to zero.	RC affects GDP but will not be sustainable if usage if consumption is low.
Gross Domestic Product (GDP) to			
● CE	Two-way	Increases until the fourth period before decaying to zero	GDP growth contributes to the fluctuations in carbon emissions.
● EC	Two-way	Declines initially but hovers positively above zero after second period.	GDP growth contributes to additional energy consumption
● RC	Two-way	Hovers around zero from 3rd period but in an increasing pattern	GDP growth contributes may have an increasing impact on renewable energy should more resources are being allocated to promote its usage.

Source: Summarized by Author

CONCLUSION

According to this empirical analysis, rising GDP and energy use are positively correlated with CO2 emissions. These findings were anticipated because rising economic growth also means rising fuel consumption and, consequently, rising CO2 emissions. The study's findings support the existence of a significant, bidirectional relationship between GDP and energy use. Additionally, there is a correlation between energy use and CO2 emissions. Renewable energy contributes to the reduction in CO2 emissions.

Due to Malaysia's low level of renewable energy consumption, in comparison to its usage of fossil fuels, its consumption has little impact on Malaysia's economic development. By providing alternatives to traditional energy sources like fossil fuels, one may assume that renewable energy, as its name suggests, can play a critical role in lowering CO2 emissions in the developing economy. However, the low percentage of renewable energy use (less than 10% of all energy)[7] needs to be intensified to fully register an impact on economic development. This may imply that Malaysia has not arrived at the inflection point as suggested by the Environmental Kuznets Curve (EKC). Environmental deterioration and economic growth still move in tandem on the positive slope of the EKC. However, should the EKC holds, one would anticipate that Malaysia will reach a turning point where there will be environmental improvement as the economy grows. Efforts can be seen at the current juncture since Malaysia is committed to using 25% more renewable energy as part of its overall energy consumption in the green agenda. Future policies should therefore focus on the use of renewable energy for it to exert a greater impact on economic growth in the future, as indicated in foreign studies.

Mitigating carbon emissions is important because of various long-term implications that transcend economic and production activities. The COVID-19 pandemic highlighted the importance of food security and its value chains. Climate change, which is partly caused by carbon emissions has created various impediments in the agriculture sector. With uncontrolled CO2 emissions or the equivalent, the long-term implications to the economic well-being of the country go beyond the confine of GDP measurement alone. As a result, the Malaysian government ought to promote the adoption of green technologies. Small-scale actions, such as putting solar panels on homes or businesses should encourage the usage of renewable energy. A gradual switch to using electric public transportation is also a way to reduce the use of fossil fuels. Incentives for adopting green technology and production standards should also be emphasized. Industries with high consumption of fossil fuels, i.e iron and steel, construction, and utilities should be regulated to control their carbon emissions.

While some of the regulations are already in place, their monitoring and policy support in terms of incentives to upgrade or procure capital investments in green technology should also be in place. The findings also suggest that at the current usage of renewable energy, particularly its use rate, Malaysia has to increase its efforts to meet the targets of the 2015 Paris Agreement. Meeting the target is just a subset of the country’s longer-term policy objective on achieving its Sustainable Development Goals (SDG), namely Goal 13 on climate change. As shown in the study, renewable energy has yet to create an impact on the country, hence greater efforts should be placed on Target 13.2: *Integrating climate change measures into policy and planning*. One key area that is missing is the policy and strategy on Reducing Emissions from Deforestation and Forest Degradation (REDD++). Policies that integrate national economic growth with climate change have yet to be implemented.

There are some limitations to the study which basically discussed the energy-growth relationship mostly on the macro level. Micro aspects, i.e channels that facilitate the transitions into renewable energy such as green financing (or voluntary carbon market (VCM) to help finance forest conservation), green technology and the role of digitalization has yet to be explored. Such micro aspects need to be the focal points for further research.

NOTES

[1] The long-term continuity in economic development while preserving sufficient resources for future generations.

[2] Total greenhouse gas emissions (kt of CO2 equivalent), World Development Indicators (multiple years).

[3] Palm Oil Trade Fair and Seminar in January 2021

[4] https://cleanenergynews.ihsmarkit.com/research-analysis/malaysia-to-rely-on-annual-tenders-to-achieve-7-gw-renewable-t.html (accessed 7 September 2022)

[5] The *Gross Domestic Product* (GDP) is used in this study to measure economic growth.

[6] Energy- and renewable consumption, carbon emissions, and economic growth.

[7] Comparing this to other ASEAN nations is a big contrast. Laos uses 60%, Myanmar uses 60%, Cambodia uses 64%, Indonesia uses 36%, Vietnam uses 34%, and the Philippines uses 27%, according to 2014 data.

REFERENCES

Al-Mulali, U., Sab, C.N.B.C. & Fereidouni, H.G. 2012. Exploring the bi-directional long-run relationship between urbanization, energy consumption, and carbon dioxide emission. *Energy* 46(1): 156–167.

Asif, M., Sharma, R.B. & Adow, A.H.E. 2015. An empirical investigation of the relationship between economic growth, urbanization, energy consumption, and CO2 emission in GCC countries: A panel data analysis. *Asian Social Science* 11(21): 270–284.

Chavaillaz, Y., Roy, P., Partanen, A.-I., Da Silva, L., Bresson, É., Mengis, N., Chaumont, D. & Matthews, H.D. 2019. Exposure to excessive heat and impacts on labour productivity linked to cumulative CO2 emissions. *Scientific Reports* 9(1): 1–11

Ciegis, R., Ramanauskiene, J. & Martinkus, B. 2009. The concept of sustainable development and its use for sustainability scenarios. *Engineering Economics* 62(2).

Collins, M. & Knutti, R. 2013. J. Arblaster, J., Dufresne, J.L., Fichefet, T., Friedlingstein, P., Gao, X., Gutowski, W.J, Johns, T., Krinner, G., Shongwe, M., Tebaldi, C., Weaver, A.J, & Wehner, M. *Long-Term Climate Change: Projections, Commitments and Irreversibility, in: Climate Change* 1029–1136.

Dickey, D.A. & Fuller, W.A. 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association* 74(366a): 427–431.

Dunn, R.J.H., Stanitski, D.M., Gobron, N., Willett, K.M., Ades, M., Adler, R., Allan, R., Allan, R.P., Anderson, J. & Argüez, A. 2020. Global climate. *Bulletin of the American Meteorological Society* 101(8): 9–127.

Ehigiamusoe, K.U., Lean, H.H. & Smyth, R. 2020. The moderating role of energy consumption in the carbon emissions-income nexus in middle-income countries. *Applied Energy* 261(December 2019).

Furuoka, F. 2015. The CO2 emissions-development nexus revisited. *Renewable and Sustainable Energy Reviews* 51: 1256–1275.

Ghosh, N. 2008. The Road from Economic Growth to Sustainable Development: How was it Traversed? *Available at SSRN 1082686*.

Goldin, I. & Winters, A. 1995. *The Economics of Sustainable Development*. Cambridge: Cambridge University Press.

Grossman, G. & Krueger, A. 1995. Economic growth and the environment. *Quarterly Journal of Economics* 110: 353–77.

IHS Markit database, multiple years (https://www.spglobal.com/en/)

Jalil, A. & Feridun, M. 2011. The impact of growth, energy and financial development on the environment in China: A cointegration analysis. *Energy Economics* 33(2): 284–291.

Jansson, A.-M., Hammer, M., Johansson, O., Folke, C. & Costanza, R. 1994. *Investing in Natural Capital: The Ecological Economics Approach to Sustainability (International Society for Ecological Economics*). Island Press; 1998th edition (May 1, 1994) Washington, D.C.

Khan, H., Khan, I. & Binh, T.T. 2020. The heterogeneity of renewable energy consumption, carbon emission and financial development in the globe: A panel quantile regression approach. *Energy Reports* 6: 859–867.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. & Shin, Y. 1992. Testing the null hypothesis of stationarity against the alternative of a unit root. How sure are we that economic time series have a unit root? *Journal of Econometrics* 54(1–3): 159–178.

Le, H. P. & Van, D.T.B. 2020. The energy consumption structure and African EMDEs' sustainable development. *Heliyon* 6(4).

Lin, S., Xiao, J. & Ye, H. 2020. Disguised carry trade and the transmission of global liquidity shocks: Evidence from China’s goods trade data. *Journal of International Money and Finance* 104.

Lindsey, R. 2009. Climate and earth’s energy budget. *NASA Earth Observatory* 680.

Liu, H., Wang, C. & Wen, F. 2020. Asymmetric transfer effects among real output, energy consumption, and carbon emissions in China. *Energy* 208.

Lüthi, D., Le Floch, M., Bereiter, B., Blunier, T., Barnola, J.-M., Siegenthaler, U., Raynaud, D., Jouzel, J., Fischer, H. & Kawamura, K. 2008. High-resolution carbon dioxide concentration record 650,000–800,000 years before present. *Nature* 453(7193): 379–382.

Narayan, P.K. & Smyth, R. 2015. Energy consumption, CO2 emissions, and economic growth in Asian economies. *Energy Policy* 76: 123-131.

National Aeronautics and Space Administration (NASA). https://data.giss.nasa.gov/gistemp/ and https://earthobservatory.nasa.gov/world-of-change/global-temperatures (accessed, 30 August 2022)

Our World in Data (multiple years). https://ourworldindata.org/co2-emissions#global-co2-emissions-from-fossil-fuels-global-co2-emissions-from-fossil-fuels.

Ozturk, I. & Acaravci, A. 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics* 36: 262–267.

Panayotou, T. 1993. *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*. International Labour Organization.

Phillips, P. and P.P. 1988. *Testing* for a unit root in time series regression. Peter C.B. Phillips and Pierre Perron Published by: Oxford University Press on behalf of Biometrika Trust Stable URL: https://www.jstor.org/stable/2336182 references Lin. *Biometrika* 75(2): 335–346.

Pierantoni, I. 2004. A few remarks on methodological aspects related to sustainable development. *Fpf TyrÁR FtyfgwpÁ 7p Pw Xpy*, 63.

Rasiah, R., Ahmed, A., Al-Amin, A.Q. & Chenayah, S. 2017. Climate change mitigation: comparative assessment of Malaysian and ASEAN scenarios. *Environmental Science and Pollution Research International* 24(3): 2632–2642.

Salahuddin, M., Alam, K. & Ozturk, I. 2016. The effects of Internet usage and economic growth on CO2 emissions in OECD countries: A panel investigation. *Renewable and Sustainable Energy Reviews* 62: 1226–1235.

Salahuddin, M. & Gow, J. 2019. Effects of energy consumption and economic growth on environmental quality: Evidence from Qatar. *Environmental Science and Pollution Research* 26(18): 18124–18142.

Sulaiman, C. & Abdul-Rahim, A.S. 2017. The relationship between CO2 emission, energy consumption and economic growth in Malaysia: A three-way linkage approach. *Environmental Science and Pollution Research International* 24(32): 25204–25220.

Shahbaz, M., Solarin, S.A., Hammoudeh, S. & Shahzad, S.J.H. 2017. Bounds testing approach to analyze the environment Kuznets curve hypothesis with structural beaks: The role of biomass energy consumption in Malaysia. *Energy Economics* 68: 548-562

Tamazian, A., Chousa, J.P. & Vadlamannati, K.C. 2009. Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy* 37(1): 246–253.

Murugiah, S. 2021. Climate change could cut Malaysian economic growth 20% below expectations by 205”, *theedgemarkets.com.*https://www.theedgemarkets.com/article/climate-change-could-cut-malaysian-economic-growth-20-below-expectations-2050-%E2%80%94-report

Toda, H.Y. & Yamamoto, T. 1995. Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics* 66(1–2): 225–250.

Van Aalst, M.K. 2006. The impacts of climate change on the risk of natural disasters. *Disasters* 30(1): 5–18.

Wang, Z., Flores, I., Donahue, E.K., Lundquist, A.J., Guo, Y., Petzinger, G.M., Jakowec, M.W. & Holschneider, D.P. 2020. Cognitive flexibility deficits in rats with dorsomedial striatal 6-hydroxydopamine lesions tested using a three-choice serial reaction time task with reversal learning. *NeuroReport* 31(15): 1055–1064.

Wasti, S.K.A. & Zaidi, S.W. 2020. An empirical investigation between CO2 emission, energy consumption, trade liberalization and economic growth: A case of Kuwait. *Journal of Building Engineering* 28.

World Bank. 1992. *World Development Report 1992*. New York: Oxford University Press.

Wu, H., Xu, L., Ren, S., Hao, Y. & Yan, G. 2020. How do energy consumption and environmental regulation affect carbon emissions in China? New evidence from a dynamic threshold panel model. *Resources Policy*, *67*.

Zaman, Q. uz, Wang, Z., Zaman, S. & Rasool, S.F. 2021. Investigating the nexus between education expenditure, female employers, renewable energy consumption and CO2 emission: Evidence from China. *Journal of Cleaner Production* 312.

Zhang, Y.-J. 2011. The impact of financial development on carbon emissions: An empirical analysis in China. *Energy Policy* 39(4): 2197–2203.

Andrew Kam Jia Yi*
Institute of Malaysian and International Studies (IKMAS)
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor, MALAYSIA.
E-mail: Andrew@ukm.edu.my

Evelyn S. Devadason
Department of Economics
Faculty of Business and Economics
Universiti Malaya
50603 Kuala Lumpur, MALAYSIA.
E-mail: evelyns@um.edu.my

*Corresponding Author

APPENDIX 1. Data Description

	Variable Name	Proxy	Description	Source
1.	CE	CO2 emissions (metric tons per capita)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute. Available at: https://www.climatewatchdata.org/ghg-emissions. See SP.POP.TOTL for the denominator's source.
2.	RC	Renewable energy consumption (% of total final energy consumption)	Renewable energy consumption is the share of renewable energy in total final energy consumption.	World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.
3.	EC	Primary Energy Consumption Per Capita (KWh/Person)	Primary energy consumption per capita, measured in kilowatt-hours per person per year.	1. BP Statistical Review of World Energy. 2. International energy data from the U.S. Energy Information Administration (EIA). BP Statistical Review of World Energy; U.S. Energy Information Administration (EIA); Bolt, Jutta and Jan Luiten van Zanden (2020), “Maddison style estimates of the evolution of the world economy. A new 2020 update“.
4.	GDP	Real gross domestic product per capita (constant 2010 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data are in constant 2015 U.S. dollars.	World Bank national accounts data, and OECD National Accounts data files.