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ROLE OF HUMAN CAPITAL, INCOME INEQUALITY AND RENEWABLE ENERGY CONSUMPTION ON CO$_2$ MITIGATION IN MALAYSIA

Rafia Afroz [1*], Riasat Amin Imon [2], Md Muhibbullah[3], Shahana Afroz[4]

[1] Department of Economics, International Islamic University Malaysia
Email: rafia@iium.edu.my
[2] Department of Economics, International Islamic University Malaysia
Email: riasat@iium.edu.my
[3] Department of Economics, International Islamic University Malaysia
Email: md.muhibbullah@live.iium.edu.my
[4] Department of Economics, International Islamic University Malaysia
Email: shimafroz@gmail.com
[*] Corresponding Author

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Abstract:

The present research endeavours to investigate the interconnection among human capital, income inequality, renewable energy consumption, economic growth, and pollution. The ultimate objective is to identify effective policy approaches by uncovering empirical findings. This study employs the innovative approach of dynamic ordinary least square (DOLS) to examine data spanning from 1980 to 2018. In order to evaluate the accuracy of the DOLS estimation, we utilise the fully modified ordinary least square (FMOLS) and canonical correlation regression (CCR) techniques. In order to comprehensively investigate the association between the chosen variables, a paired Granger causality analysis was employed. Findings of this study show that using renewable energy enhances Malaysia's environmental quality, while economic growth, income inequality, and human capital all cause environmental deterioration. Therefore, it is possible that Malaysia could achieve its goal of reducing CO$_2$ emissions and meeting its obligations under the Paris Agreement if it were to successfully adopt policy initiatives to develop human capital, increase the use of renewable energy sources, achieve a low-carbon economy, and reduce the income disparity. The research presents several new findings. The authors show that economic growth is one of the drivers of renewable energy use because it provides inputs for the development of renewable energy technology and infrastructure. But if there is pollution as a result of rapid economic growth, it will also negatively impact worker productivity. As a result, the poor get poorer, and the income inequality gap widens. This will obstruct both economic advancement and government efforts to promote the creation of renewable energy sources.

Keywords:

Human Capital, Income Inequality, Renewable Energy, Economic Growth, CO_2 Emission, Dynamic Ordinary Least Squares

Introduction

The Sustainable Development Goals (SDGs) comprise a quintet of pressing concerns that necessitate the attention and action of the international community by 2030. These goals encompass the domains of individuals, the environment, economic well-being, social harmony, and collaborative efforts. In 2015, the United Nations established the SDGs. The principal impediments to sustainable development on a global scale include income inequality, unemployment, environmental degradation, armed conflict, humanitarian aid, fostering inclusive and peaceful communities, bolstering governmental institutions, and promoting the rule of law. Income inequality and pollution are two pressing political and economic issues that require immediate attention. These topics have been extensively studied in academic research, as evidenced by the work of Uzar and Eyuboglu (2019). It is possible to distinguish the effects of income inequality on pollution levels based on consumption habits and the differences in income between income groups (Yang et al., 2022). The presence of income inequality poses a hindrance to economic development and further amplifies social unrest, ultimately resulting in armed conflict (Law et al., 2020). Empirical studies (Uzar & Eyuboglu, 2019) have demonstrated that income inequality is primarily caused by an uneven allocation of resources among various social groups. Individuals with high levels of wealth are susceptible to causing detrimental effects to the natural environment. According to Das and Basu (2022), individuals who are economically disadvantaged are more vulnerable to the negative effects of pollution, leading to a range of health and societal concerns. The contemporary era of globalisation poses a formidable challenge to the attainment of the Sustainable Development Goals (SDGs) and the conservation of the environment at a global level, owing to the presence of various factors, including income inequality and other related variables. According to recent studies conducted by Zafar et al. (2019) and Ahmed et al. (2022), the allocation of resources towards human capital has been linked to enhancements in energy and safety systems, heightened adherence to environmental regulations, decreased levels of inequality and crime. Human capital is a subject of particular interest to scholars due to its potential to enhance a nation's capacity to create environmentally sustainable and energy-efficient technologies for application in the manufacturing, residential, and transportation domains (Bano et al., 2018). The relationship between human capital and CO2 emissions remains inadequately comprehended.

The utilisation of non-renewable energy sources such as coal, gas, and oil is a common practise in Malaysia, resulting in elevated levels of CO2 emissions and accelerated climate change. According to projections put forth by Basri et al. (2015), it is anticipated that the amount of CO2 emissions generated by power generation will have risen from 298,339 kt in 1999 to 800,519 kt by the year 2020. The interrelationship between Malaysia's economic growth and enhanced environmental sustainability is a critical consideration, as posited by Raihan and Tuspekova (2022). According to the theory of the Environmental Kuznets Curve (EKC), a contrary outcome is anticipated for various developing nations, such as Malaysia. The challenge of allocating budgetary resources towards research, education, and development is compounded by the expanding income disparity. Affluent communities engender ecological harm and squander resources in their pursuit of fulfilling their own needs, thereby exacerbating socioeconomic inequality.

According to Hallegatte et al. (2016), the degradation of the environment has a disproportionate impact on individuals who are economically disadvantaged. Grossman and Krueger (1995) suggest that individuals residing in developing countries may be inclined to increase their resource consumption in order to fulfil their necessities and strive for financial advancement. As a result, it is likely to result in a range of negative environmental impacts. According to the study conducted by Ibrahim (2001), the urban regions of Malaysia serve as the primary location for the nation's economic endeavours. Consequently, a deficit in housing has arisen, leading to the proliferation of slums and squatter settlements. Inadequate management of domestic waste and other fundamental amenities are two instances. Despite the fact that the Malaysian government's prudent policies and strategic initiatives have significantly mitigated the problem of insufficient domestic waste management. Squatter communities and low-income urban apartments are disproportionately impacted by environmental concerns related to solid waste disposal systems. Murad and Mustapha (2010) have suggested that the relevant authorities should establish fundamental policies and procedures to effectively address the environmental challenges at hand. In addition, it is noteworthy that the contribution of education to the gross domestic product of the nation has increased from 4.7 percent in 2017 to 4.5 percent in the current year of 2021. This prompts an inquiry into the potential influence on the declining state of Malaysia's environment. The escalation of carbon dioxide (CO_2) levels in Malaysia can be attributed to the surge in energy consumption, primarily fueled by non-renewable sources, as reported by Afroz and Muhibbullah (2022). According to Mehraaein et al. (2021), the escalation in energy consumption in Malaysia can be ascribed to the growth of its urban and industrial domains. Malaysia's governmental authorities have implemented a series of initiatives aimed at promoting the adoption of sustainable energy sources. The extent to which renewable energy has affected Malaysia's CO_2 emissions remains a subject that has not been thoroughly investigated. According to Shukla et al. (2017), the expansion of renewable energy sources has a beneficial impact on the ecological state of Asian nations. The existing body of literature on Malaysian perspectives pertaining to economic development, income inequality, human capital, and the adoption of renewable energy sources for the purpose of mitigating CO_2 emissions is limited. This study employs the Dynamic Ordinary Least Squares (DOLS) method to investigate the correlation between Malaysia's CO_2 emissions, economic growth, income inequality, human capital, and utilization of renewable energy. The subsequent segments of the investigation are organized in the following manner: The section titled "Literature Review" presents a comprehensive empirical analysis. The section titled "Data sources and methodology" provides an account of the data and methodology employed in the study. The section titled "Results and Discussion" presents the empirical findings and their corresponding discussion. This is then followed by the "Concluding Remarks and Policy Recommendation" section, which presents the conclusion and recommended policies.

Literature Review

The hypothesis known as the EKC has been utilized to examine the correlation between economic growth and environmental degradation. According to the EKC hypothesis, there exists a positive relationship between economic growth and environmental degradation during a certain period, but once the economy attains a certain level of development, it becomes a contributing factor in mitigating environmental problems (Stern et al., 1996). The study conducted by Begum et al. (2015) reveals that there exists a positive correlation between per capita energy consumption, per capita GDP, and per capita carbon emissions in Malaysia over the period of 1980-2009. Thus, it can be concluded that the EKC hypothesis does not hold true in Malaysia within the timeframe of the study. The study conducted by Mui-Yin et al. (2018) indicates that the primary factor responsible for the emission of CO2 in Malaysia is economic growth, which is consistent with the EKC hypothesis. The EKC hypothesis has been validated by several scholars including Usman and Jahanger (2021), Dogan and Inglesi-Lotz (2020), Balsalobre-Lorente et al. (2021), Yang et al. (2021) and Genç et al. (2022). Nonetheless, several studies, including those conducted by Pata and Caglar (2021), Solarin and Lean (2016), Al-Mulali et al. (2016); and Koc and Bulus (2020), have been unable to confirm the validity of the EKC hypothesis. The correlation between income inequality and CO_2 emissions in developed nations has been a significant topic of interest among scholars and researchers. Research of this nature is typically carried out at either a domestic or international level. An investigation was conducted by Sohag et al. (2019) to examine the correlation between the consumption of CO_2 and income inequality. The research employed Environmental Engel curves to analyse the United States' environmental impact between the years 1996 and 2009. The research indicates that an increase in income equity is likely to result in a rise in the demand for collective carbon emissions, as inferred from the analysis of carbon fluctuations over time and the equitable distribution of CO_2 radiation among households. The study conducted by Baloch et al. (2018) investigated the effects of economic growth and income inequality on carbon dioxide emissions within the context of Pakistan. This study considers various sources of CO_2 emissions, including the utilisation of solid and liquid fuels, electricity generation, gaseous fuel consumption, and heat production. The study suggests that there exists a correlation between the rise in income inequality and the escalation of CO_2 emissions, both in the short and long run. Based on the ARDL time series data analysis, it can be concluded that the EKC theory was not in existence between the years 1966 to 2011. Ridzuan et al. (2017) discovered a negative correlation, both in the short and long term, between Malaysia's carbon dioxide emissions and the Gini coefficient.

According to Mahmood et al. (2019), the enhancement of human capital, particularly through higher education, can facilitate the adoption of environmentally friendly manufacturing practises, leading to a reduction in pollution. According to Yao et al. (2021), human capital serves as a crucial driver of technological innovation and knowledge accumulation, thereby facilitating energy efficiency and promoting green production. The study by Bano et al. (2018) employed the Error Correction Model (ECM) and the Autoregressive Distributed Lag (ARDL) model to conduct an empirical analysis on the correlation between human capital and CO_2 emissions in Pakistan, at a macro level. Based on empirical evidence, it can be inferred that the impact of human capital on CO_2 emissions is relatively minor in the short term. Rather, it facilitates the ultimate objective of reducing carbon emissions. According to Khan et al. (2021), there exists a non-linear correlation between human capital and reduced carbon dioxide emissions. The insufficiency of human capital undermines endeavours aimed at mitigating greenhouse gas emissions.

Renewable energy sources hold the potential to enhance the affordability of electricity in the forthcoming times. Consequently, the motivation to develop sustainable energy alternatives would be diminished. The utilization of renewable energy sources is frequently associated with a reduction in carbon dioxide emissions. In addition, the ecological ramifications of renewable energy sources are minimal as they produce minimal or no byproducts, such as carbon dioxide and other harmful substances. According to Rehman et al. (2022), the implementation of this solution has the potential to mitigate the effects of global warming and ensure energy security. Furthermore, the utilization of sustainable energy sources enhances the accessibility of dependable electricity and diminishes the dependence on imported non-renewable fuels (Abbasi et al., 2022). Consequently, a number of countries have initiated a transition from non-renewable energy sources to more sustainable alternatives (Afroz & Muhibbullah, 2022). In contrast, Malaysia possesses a plethora of sustainable energy resources such as municipal waste, rice husks, landfill gas, oil palm tree biomass, mill byproducts, hydropower, solar thermal power, and solar photovoltaics, as reported by Sulaiman et al. (2013). According to Abbasi et al. (2022), there is a statistically significant immediate impact of renewable energy on CO_2 emissions. The study found that there was a statistically significant positive impact on both short- and long-term CO2 emissions due to the depletion rate of non-renewable energy and GDP. Previous studies were limited by their failure to incorporate essential factors such as income inequality and human capital into their analytical frameworks. The present study endeavours to employ DOLS technique to ascertain the validity of the EKC hypothesis in Malaysia. Additionally, the study seeks to investigate the impact of income inequality and human capital on CO_2 emissions in Malaysia during the period spanning from 1980 to 2019, considering both short-term and long-term effects. The present research has significantly augmented the body of literature. The present study diverges from prior research by examining the extent to which renewable energy contributes to the mitigation of CO_2 emissions. Subsequently, a battery of unit root and cointegration tests are conducted to verify the precision of the results. The outcomes of the research will furnish Malaysian policymakers with comprehensive and pragmatic insights to facilitate the formulation of efficacious measures to counteract climate change, promote a low-emission economy, stimulate the adoption of sustainable energy, fund technological progress, and curtail greenhouse gas emissions.

Methodology

Design of the Study

Data

This study utilised time series data spanning from 1980 to 2019 for the country of Malaysia. The regression model employs CO_2 emissions as the response variable, while income inequality and human capital are utilised as the predictor variables. The control variables encompass GDP per capita, and the proportion of energy derived from renewable sources. The GDP per capita metric is commonly employed as a proxy for measuring economic growth. The compilation of data on carbon dioxide emissions and gross domestic product per capita is facilitated through utilisation of the World Bank database. The Penn World Table 10.0 (PWT 10.0) database is a reliable source of information on human capital and can be conveniently accessed through the website www.ggdc.net/pwt. The World Wealth and Income Database (WWID) is utilised to gather data pertaining to the highest decile of income earners, with the aim of computing measures of income inequality. In the assessment of income disparity among distinct societal factions, the upper decile is frequently employed as a proxy for individuals whose earnings are equivalent to or surpass the 10th percentile. According to Wu and Xie (2020), the significance of this index increases as the concentration of wealth becomes more limited. The final forms of renewable energy include tidal, solar, wind, biomass, hydroelectric, and geothermal power. The 2017 edition of the BP World Energy Statistical Review incorporates data pertaining to the utilisation of renewable energy. Table 1 displays the variables, their respective logarithms, units of measurement, and sources of data.

Theoretical underpinning

The long-term associations between CO2 emissions and economic growth, income inequality, human capital, and the use of renewable energy in Malaysia are evaluated using the approach introduced by Heerink et al., 2001 and Bano et al.,2018. The equation is expressed in linear logarithm form:

$$LnCO_2 = \beta_0 + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 INEQ + \beta_4 HC + \beta_4 RE + \mu_i \qquad (1)$$

here CO_2 is carbon dioxide emissions, GDP is gross domestic product, GDP^2 is square GDP, $INEQ$ shows income inequality, HC represents human capital and RE represents renewable energy use in Malaysia. In order to examine the effects of GDP, human capital, income inequality, and renewable energy use on CO2 emissions in Malaysia, this study employed econometric methodologies, which are shown in Figure 6.

DOLS Cointegration Test

$$\Delta LnCO_2 = \beta_0 + \beta_1 LnCO_{2_{t-1}} + \beta_2 LnGDP_{t-1} + \beta_3 LnINEQ_{t-1} + \beta_4 LnHC_{t-1} + \beta_5 LnRE_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LnCO_{2_{t-1}} + \sum_{i=1}^{q} \gamma_2 \Delta LnGDP_{t-1} + \sum_{i=1}^{q} \gamma_3 \Delta LnINEQ_{t-1} + \sum_{i=1}^{q} \gamma_4 \Delta LnHC_{t-1} + \int_{i=1}^{q} \gamma_5 \Delta LnRE_{t-1} + \varepsilon_t \qquad (2)$$

The Robustness of DOLS Estimation

To verify the robustness of the DOLS approach, we estimated the fully modified OLS (FMOLS) and Canonical Cointegrating Regression (CCR) estimates. Phillips and Hansen, 1990 proposed the FMOLS method to estimate an ideal cointegrating estimation. Because the variables are cointegrated, endogeneity and serial correlation are potential outcomes. The FMOLS method can get around these problems by changing the least squares. The FMOLS method also employs traditional OLS methods to estimate non-stationary I(1) data. The CCR technique, however, was put forth by Charnes et al., 1989, and it calls for data conversion to preserve the error term's zero frequency decoupling from the regressors. As a result, the FMOLS approach provides asymptotic efficient estimators as well as asymptotic chi-square tests without annoyance parameters. Examining the effects of serial correlation can aid in the asymptotic consistency of FMOLS and CCR techniques. As a result, Equation (2) uses the FMOLS and CCR estimators to calculate long-term elasticity.

Pairwise Granger Causality Test

This study utilized Granger causality test introduced by Granger, 1969 to examine the causality among the variables. This study utilized this method because it has the capacity to examine a large number of lags with higher-order lags reduction. If the time series of Y variable can predict the future time series of variable X, then Y is said to be the granger causes X. These two-time series variables X_t and Y_t can have time length T where $t = 1,2,3, \ldots \ldots T$. A bivariate autoregressive model can be applied to

$$X_t = \int_{l=1}^{p} b_{11,1} X_{t-l} + b_{12,1} Y_{t-l}) + \varepsilon_t \qquad (3)$$

$$Y_t = \int_{l=1}^{p} b_{21,1} X_{t-l} + b_{22,1} Y_{t-l}) + \epsilon_t \qquad (4)$$

Where p is the model order and $b_{ij,1}(i,j = 1.2)$ are the coefficients of the model and ε_t and ϵ_t are the residuals of the models.

Results

Descriptive Statistics

The descriptive statistics for each variable are shown in Table 2. To determine whether the variables are normally distributed, the results of the skewness, probability, kurtosis, and Jarque-Bera (J-B) tests are also displayed in this Table. All values' skewness values are relatively close to zero. The outcome shows that all the variables are distributed normally. Additionally, all the variable's Kurtosis values are greater than 3, indicating that the series has a platykurtic distribution. They consequently do not have as many extremely high or low values. The J-B test result also demonstrates the normal distribution of all variables. However, descriptive statistics are useful because they are used to examine the stationarity of variables for DOLS estimates.

Correlation Analysis

The relationship between two variables is revealed, and their relationship is verified through correlation analysis. In addition, it determines how one variable will change in response to adjustments made to another variable. The results of the correlation analysis for the variables picked for the study are shown in Table 3. The outcomes show a relationship between each variable. A strong and positive correlation exists between the variables CO_2 emissions ($LnCO_2$), economic growth (LnGDP), human capital (LnHC), and renewable energy (LnRE), meaning that as one variable's value rises, the other variable's value also tends to rise, and vice versa. The value of the other variable tends to decrease as income inequality increases and vice versa, as shown by LnINEQ, which has a negative relationship with $LnCO_2$, LnGDP, LnRE, and LnHC.

Results of The Unit Root Test

The Augmented Dickey-Fuller, Philips-Perron, and tests are three of the most useful ones used in this study to check the order of integration and ensure that no series is I (2). Table 4 lists the outcomes of each test for all test series. According to the findings, all series, with the exception of LnHC, are stationary at the first difference. Therefore, the order of integration for LnHC will be zero, denoted as I (0), and it will be one for all other series, denoted as I. (1). Since there are no variables with orders higher than 2, the DOLS can be used for these series.

Estimated Results of DOLS Regression

The estimated outcomes of the DOLS regression are shown in Table 5. The results in Table 5 are supported by the calculated long-term coefficient of LnGDP, which is positive and statistically significant at the 1% level of significance. This implies that the initial rise in CO_2 emissions and the expansion of the GDP are related. The non-linear relationship between economic growth and CO_2 emissions is shown by the GDP^2 quadratic form coefficient. At the 1% level of statistical significance, it is both negative and significant. According to the relationship, rising per capita income should initially result in higher CO_2 emissions. However, as economic expansion quickens, CO_2 emissions begin to decline after a certain point. In other words, there is a negative relationship between economic growth and environmental quality. It should be noted, though, that this occurs more quickly in lower socioeconomic groups, where pollution rises by 3.21 percent for each percentage point of GDP growth. Malaysia's rising CO_2 emissions are primarily due to the country's increasing energy consumption (Khoo, 2021). Due to the country's heavy reliance on non-renewable energy sources, emissions have increased (Abdul Latif et al., 2021). Malaysian Energy Commission, 2017 reports that, 82.9% of the country's energy came from non-renewable sources, making it one of the main contributors to greenhouse gas emissions. Khan et al.,2020 argues that the positive correlation between economic growth and CO_2 emissions is largely attributable to the failure of developing countries to account for the potential environmental costs of rapid economic growth at the outset of their development.

Additionally, industrialization quickens in the early stages of development when most emerging nations lack strict environmental laws to regulate emissions (Hundie, 2021). The scale effect, which describes the positive proportionate relationship between economic activity and economic growth, may also be to blame for the positive correlation between economic growth and energy consumption. Extreme energy use and poor environmental quality would result from this (Dogan and Inglesi-Lotz, 2020; Lorente and Alvarez-Herranz, 2016). Khan et al. (2020) contend that rapid economic growth in developing nations stimulates the economy and raises energy consumption. The use of non-renewable energy in particular has increased, which is bad for the environment and has increased energy use. To improve environmental quality, renewable energy sources must displace non-renewable sources in emerging economies (Khan et al., 2020; Dogan and Ozturk, 2017). The study's findings also support the EKC theory, according to which emissions will begin to decline with a 1% increase in GDP per capita once an economy reaches a certain stage of development. High levels of economic growth place an emphasis on sanitation and hygiene in all industries, including business, and the government develops more effective environmental laws (Dasgupta et al., 2002). The inverted U-shaped relationship suggests that Malaysians are somewhat in favor of the EKC theory. Numerous other studies support the findings. For examples, see Saboori et al. (2012), Mugableh (2013), Begum et al. (2015). The results also show a positive and significant long-run income inequality coefficient. This indicates that for 1% increase in income inequality, emissions increase by 0.32%. There have been numerous studies with similar findings (for example, Golley and Meng, 2012; Baek and Gweisah, 2013). According to Granser (2021), there is a gap between the expansion of environmental principles and initiatives to prevent environmental harm. In other words, those who earn more money may use more energy to enhance their quality of life, which would be detrimental to the environment. The high consumption of environmentally unfriendly goods and services is another factor contributing to the positive relationship between economic inequality and CO_2 emissions. Income inequality increases the consumption of products and services that are environmentally risky (Schor, 2005). This is so because higher-income households typically consume more products that contribute to pollution. Similar to how income inequality grows, so does the number of hours work. Longer workdays require more energy use, and more energy use increases CO_2 emissions (Bowles and Park, 2005; Knight et al., 2013; Fitzgerald et al., 2015). The Gini coefficient rate in Malaysia was over 46% in 1989 and peaked at around 51% in 1994, according to World Bank data. The nation has seen an increase in economic inequality since 1999, when it almost reached 44 percent. After 1999, the rate started to fluctuate once more, reaching a peak of over 49% in 2007. It decreased even more in 2018 and reached a record-low 42 percent. The results of this study back up by "power-weighted decision rule" which was introduced by Boyce, 1994. This rule suggests that the wealth gap may have contributed to the power imbalance and increased pollution that resulted from it. The study's empirical findings also lend support to the marginal propensity to emit (MPE) theory, and it can be argued that rising income inequality breeds individualism and consumerism, both of which pose serious and significant challenges to the creation of a desirable environment. Due to growing income disparities, those who are less fortunate abuse and exploit natural resources in order to survive. As a result, it's possible that the growing wealth gap is a problem with environmental quality as well as economics and society. The empirical findings of this research are consistent with those of Bae, 2018 for the G20 economies, Baloch et al., 2018 for Pakistan, Baloch et al. 2020 for 46 Sub-Saharan African countries, Knight et al. (2017), Masud et al. (2018), and Knight et al. (2017), for five ASEAN economies, and Liu et al. (2019), for the Chinese economy. The results are not supported by numerous studies conducted in a variety of fields. These results diverge from those of Padhan et al. (2019) and Hailemariam et al. (2019), who examined the effect of income inequality on CO_2 emissions in Next-Eleven countries and Organization for Economic Cooperation and Development (OECD) nations, respectively. The differences in the results can be attributed to a variety of elements, such as the model used for the analysis or the methodology used to measure income inequality. The political and economic environment of a nation may also affect the results (Yang et al., 2021). Hailemariam et al. (2019) contend that the income contribution variable of the top 10% is a superior alternative to the Gini coefficient for measuring income inequality. As a result, choosing different actions could lead to different results. Curiously, however, Malaysian CO_2 emissions increase by 2.85% for every 1% increase in human capital. This finding seems to be supported by Danish et al. (2019) who argued that education does not, over time, lead to a decline in environmental quality. It's likely that the populace hasn't received an education beyond the secondary level that would have equipped them to deal with environmental issues. A positive coefficient for the education variable was also found, which is consistent with earlier findings by Hill and Magnani (2002). The claim made was that as educational standards rise in low-income countries, the underprivileged have easier access to technological advancements that harm the environment. So, as education levels rise, pollution also does. This might also suggest that the current secondary education curriculum does not place enough value on environmental protection. Students therefore lack the knowledge required to advance environmental sustainability. It is necessary to raise awareness about the development of a curriculum that can support environmental quality promotion and pollution reduction in the future. According to the estimated renewable energy coefficient, which is negative and significant at the 1% level of significance, a 1% increase in renewable energy consumption will lead to a 0.1% decrease in CO_2 in Malaysia. The study's findings provided information on Malaysia's potential use of renewable energy in the effort to reduce CO2 emissions. The expansion of renewable energy, according to Afroz and Muhibbullah (2021) is a crucial component of Malaysia's efforts to reduce CO_2 emissions. The DOLS findings demonstrate that Malaysia's GDP, wealth disparity, and human capital all increase CO_2 emissions, whereas only the use of renewable energy sources reduces Malaysia's CO_2 emissions. We also used various statistical tests to determine the model's fitness. It is seen that the values of R^2 and adjusted R^2 are, respectively, 0.9983 and 0.9961, indicating that the estimated model of this study is well-fitted. It means that variation in the independent variables explains variation in the dependent variables in 99.9% of cases.

Robustness of The Estimated DOLS Model

To further assess the validity of the DOLS results, this study evaluated CCR and FMOS regression. Tables 6 and 7 show the estimated CCR and FMOS results. The robustness of the DOLS estimate was confirmed by the estimated FMOS and CCR findings. Similar to the DOLS model, it is found that the GDP coefficient is positive and significant at the 1% level of significance. Additionally, the coefficients of income inequality and human capital are positive and significant at the 1% level of significance, just like in the DOLS model. The anticipated FMOS and CCR results further supported the idea that Malaysia's renewable energy sources reduce its CO_2 emissions. Finally, the models' good fit is supported by the R^2 and adjusted R^2 values from CCR and FMOLS. The normality, heteroscedasticity, and serial correlation of the residuals are tested using a variety of diagnostic tests in this study. Table 8 presents the outcomes. The residuals are discovered to be normally distributed, and serial correlation and heteroscedasticity are not issues. Figure 7 also displays the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive (CUSUMQ), which show that the residual values are within the range of confidence intervals at the level of significance of 5%. This demonstrates the stability of the estimated model.

Estimated Results of Granger Causality

The Granger causality test is a statistical hypothesis test for determining whether one-time series is useful for forecasting another. If probability value is less than any level, then the hypothesis would be rejected at that level. The results of pairwise Granger causality is reported in Table 9. The causal relationship is indicated by different direction for instance, if the direction follows left to right, $LnGDP \rightarrow InCO_2$, it indicates that economic growth affect CO_2 emission in the model. Furthermore, if the direction follows right to left, $LnGDP \leftarrow LnCO_2$, it indicates CO_2 causes economic growth. Lastly, if the direction follows no causal relationship, $LnGDP \neq LnCO_2$, it indicates that GDP and CO2 does not affect each other. The estimated results of pairwise granger causality test suggest that there is unidirectional causality from LnGDP to $LnCO_2$, LnHC to $LnCO_2$, $LnCO_2$ to LnINEQ, LnHC to LnGDP and LnINEQ to LnRE. Based on the findings of this study, it can be inferred that improving human capital will have an impact on economic growth, which in turn will raise CO_2 emissions in this nation. Additionally, income inequality has been linked to a decrease in the usage of renewable energy, as well as a rise in CO2 emissions.

Conclusion and Recommendation

This study investigates the potential for economic growth, income inequality, human capital, and the use of renewable energy to assist Malaysia in meeting the goals of the Paris Agreement for reducing carbon emissions. Time series data from 1980 to 2018 has been used to examine the dynamic effects of the factors. In the current study, ADF, DF-GLS, and P-P unit root tests were used to record the order of integration of the series. The DOLS estimator was used to capture the long-term effects of Malaysia's economic growth, income inequality, human capital, and renewable energy sources on CO_2 emissions. We use the FMOLS and CCR tests to determine how reliable the DOLS estimate is. A paired Granger causality test was used to look into the relationship between the selected variables in more detail. Empirical data shows that increasing the use of renewable energy benefits Malaysia's environmental quality but long-term environmental degradation is adversely affected by economic growth, income inequality, and human capital.

The results have highlighted how essential equitable income distribution is to the long-term viability of the environment. Better budget allocations for clean energy production may result from a more equitable income distribution, and circumstances may arise that make it possible to allocate more money for research and development (R & D) in the clean energy sector. The equitable distribution of wealth may therefore indirectly reduce environmental pollution by boosting the production of clean energy due to the detrimental effects of income redistribution in the absence of regulations promoting the use of renewable energy sources (Uddin et al. 2020). Fair justice in economic distribution balances the distribution of political power in the country, mirroring environmental policies and preventing the relaxation of environmental policy protection. People in high-income countries are more likely to participate in environmental preservation efforts as well as have higher levels of general environmental awareness and behavior. The pairwise Granger causality results demonstrate that economic growth is one of the drivers of renewable energy use because it provides inputs for the development of renewable energy technology and infrastructure. But if there is pollution because of rapid economic growth, it will also negatively impact worker productivity. As a result, the poor get poorer, and the income inequality gap widens. This will obstruct both economic advancement and government efforts to promote the creation of renewable energy sources. However, it is unable to help Malaysia lessen its reliance on burning fossil fuels. As a result, it is believed that economic inequality and human capital are the main factors that could influence the CO_2 emissions in Malaysia, and that appropriate regulations must be put in place. The results of paired Granger causality are shown in Figure 7.

Limitation of the Study

Like earlier studies, the current study has some limitations. This study can be extended to a number of countries in addition to the one it was done for using panel data. However, the findings might also be supported by proxy analyses of other income inequality measures. For both a single country and a group of nations, it is possible to look into the relationship between income inequality, human capital, renewable energy and various pollution proxies.

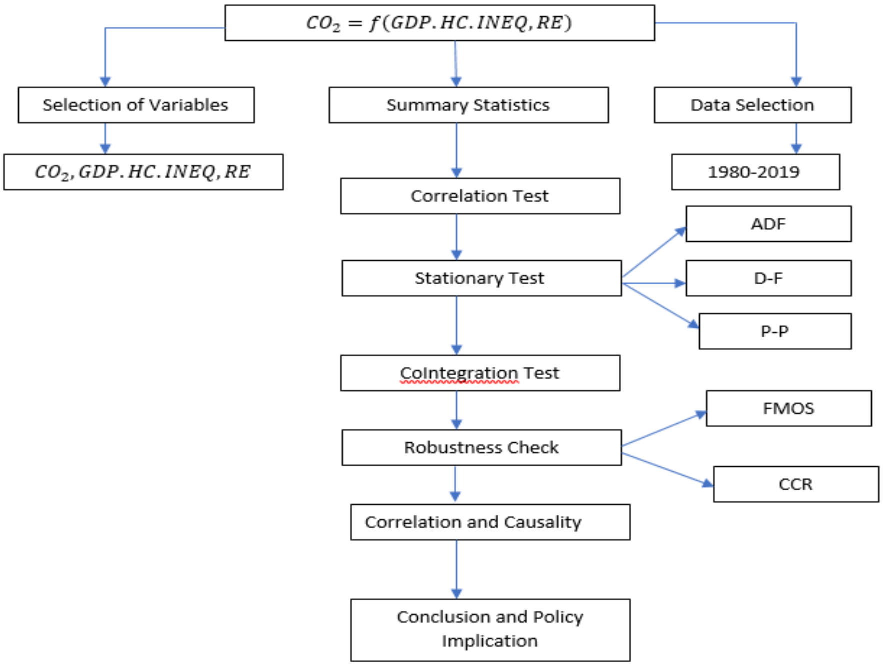

Figure 1. Flowchart of Econometric Methodology

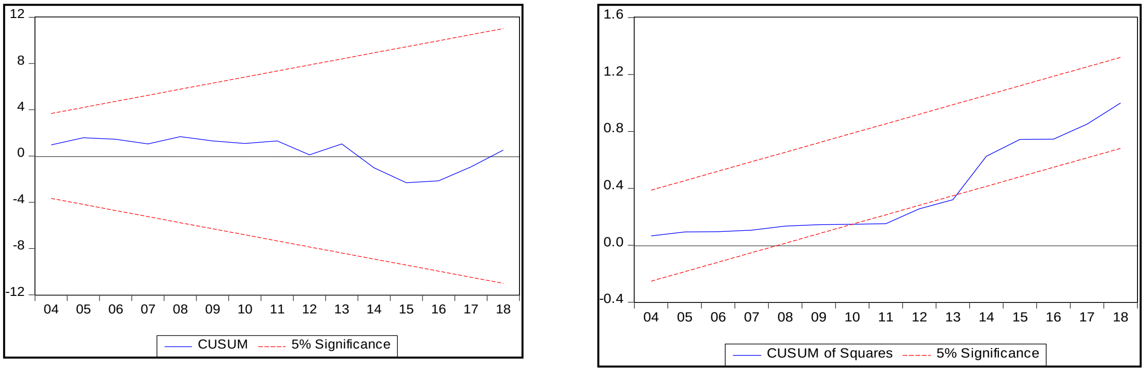

Figure 2. Graph of CUSUM and CUSUMQ

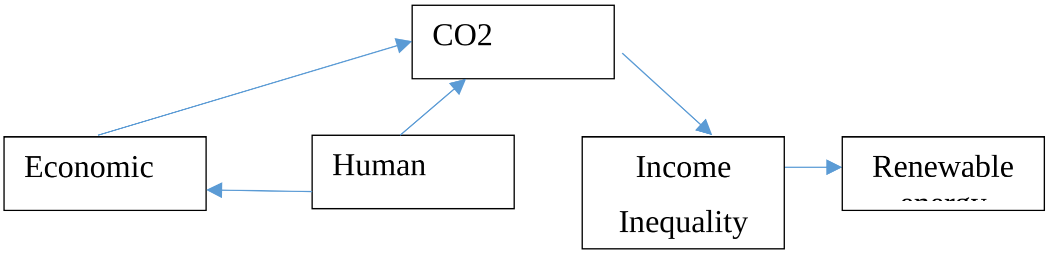

Figure 3. Results of Pairwise Granger Causality

Table 1. Data and Measurements

Variables	Acronym	Data Source	Log	Scales
CO2 emission	CO2	World Bank Development Indicators	LnCO2	Metric tons of oil equivalent
Per Capita Gross Domestic Product	GDP	World Bank Development Indicators	LnGDP	Constant 2010 US$
Human Capital	HC	Penn World Table version 10.0	LnHC	Years of schooling and returns to education
Income Inequality	INEQ	World Wealth and Income Database (WWID)	LnINEQ	Fraction (Between 0 and 1)
Renewable energy consumption	RE	BP World Energy Statistical Review 2017	LnRE	Millions of tons of oil

Table 2. Descriptive Statistics of the Variables

	LNCO2	LNGDP	LNHC	LNINEQ	LNRE
Mean	8.031016	3.775152	0.395332	-0.34766	0.263156
Median	8.093865	3.80203	0.411103	-0.33578	0.266905
Maximum	8.445073	4.05746	0.488355	-0.32349	0.281166
Minimum	7.447663	3.480922	0.250628	-0.39502	0.236098
Std. Dev.	0.322004	0.175589	0.071395	0.025757	0.016022
Skewness	-0.45676	-0.17525	-0.52824	-0.99244	-0.44287
Kurtosis	1.796123	1.807482	2.062424	2.434965	1.647488
Jarque-Bera	3.80638	2.574916	3.325356	7.098359	4.356356
Probability	0.149092	0.275971	0.18963	0.028748	0.113248
Sum	321.2406	151.0061	15.81327	-13.9062	10.52625
Sum Sq. Dev.	4.043782	1.202434	0.198793	0.025874	0.010011
Observations	40	40	40	40	40

Table 3. Results of Correlation Analysis

	LNCO2	LNGDP	LNGDP2	LNHC	LNINEQ	LNRE
LNCO2	1.000	0.990	0.987	0.993	-0.746	0.805
LNGDP	0.990	1.000	1.000	0.985	-0.804	0.841
LNGDP2	0.987	1.000	1.000	0.983	-0.813	0.844
LNHC	0.993	0.985	0.983	1.000	-0.763	0.847
LNINEQ	-0.746	-0.804	-0.813	-0.763	1.000	-0.845
LNRE	0.805	0.841	0.844	0.847	-0.845	1.000

Table 4. Results of Unit Root Test

		LnCO2	LnGDP	LnHC	LnINEQ	LnRE
ADF	Level	-1.6313	-0.4853	-2.7080**	-0.7790	-2.014
	First difference	-7.3013***	5.2162***	-0.9687	-2.7412**	-4.412***
DF-GLF	Level	0.0912	0.7842	-0.5050	-0.6951	-0.972
	First difference	-7.1797***	-5.2432***	-0.4084	-2.7186***	-4.401***
P-P	Level	-1.8240	-0.4895	-8.3700***	-0.0751	-1.762
	First difference	-7.1969***	-5.2162***	-0.9687	-2.8312**	-4.441***

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

Table 5. Estimated Results of DOLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP	3.201	0.101	31.545	0.000
LNGDP^2	-0.306	0.037	-8.364	0.000
LNINEQ	0.318	0.112	2.839	0.031
LNHC	2.853	0.439	6.498	0.000
LNRE	-0.147	0.039	-3.804	0.002
R-squared	0.998	Mean dependent var		8.040
Adjusted R-squared	0.996	S.D. dependent var		0.296
S.E. of regression	0.018	Sum squared resid		0.006
Long-run variance	0.001			

Table 6. Estimated Results of FMOS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP	3.094	0.049	62.708	0.000
LNGDP2	-0.281	0.020	-14.294	0.000
LNHC	2.641	0.241	10.967	0.000
LNINEQ	0.178	0.249	0.715	0.480
LNRE	-0.154	0.023	-6.809	0.000
R-squared	0.995259	Mean dependent var		8.035
Adjusted R-squared	0.994684	S.D. dependent var		0.309
S.E. of regression	0.022524	Sum squared resid		0.017
Long-run variance	0.000264			

Table 7. Estimated Results of CCR

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP	4.140	1.855	2.232	0.033
LNGDP2	-0.431	0.234	-1.843	0.075
LNHC	2.731	0.415	6.574	0.000
LNINEQ	0.045	0.222	0.202	0.841
LNRE	-0.157	0.023	-6.898	0.000
C	-1.877	3.626	-0.518	0.608
R-squared	0.994	Mean dependent var		8.035
Adjusted R-squared	0.993	S.D. dependent var		0.309
S.E. of regression	0.025	Sum squared resid		0.020
Long-run variance	0.000			

Table 8. Results of Diagnostics Tests

Diagnostic test	Coefficient	P-Valiu	Decision
Jarque–Bera test	1.66	0.435	Normal Distribution
Breusch–Godfrey LM test	1.323	0.292	No serial correlation
Breusch–Pagan–Godfrey test	0.746	0.73	No heteroscedasticity exists

Table 9. Estimated Results of Pairwise Granger Causality

Null Hypothesis:	F-Statistic	Prob.	Decision on Null Hypothesis	Causality Direction
LNGDP does not Granger Cause LNCO2	3.357	0.047	Reject	$LnGDP \rightarrow LnCO_2$
LNCO2 does not Granger Cause LNGDP	0.936	0.403	Accept	
LNHC does not Granger Cause LNCO2	6.576	0.004	Reject	$LnHC \rightarrow LnCO_2$
LNCO2 does not Granger Cause LNHC	1.213	0.310	Accept	
LNINEQ does not Granger Cause LNCO2	0.078	0.925	Accept	$LnCO_2 \rightarrow LnINEQ$
LNCO2 does not Granger Cause LNINEQ	4.142	0.025	Reject	
LNRE does not Granger Cause LNCO2	2.017	0.150	Accept	$LnRE \neq LnCO_2$
LNCO2 does not Granger Cause LNRE	0.948	0.398	Accept	
LNHC does not Granger Cause LNGDP	4.712	0.016	Reject	$LnHC \rightarrow LnGDP$
LNGDP does not Granger Cause LNHC	0.316	0.731	Accept	
LNINEQ does not Granger Cause LNGDP	0.945	0.399	Accept	$LnINEQ \neq LnGDP$
LNGDP does not Granger Cause LNINEQ	2.088	0.140	Accept	
LNRE does not Granger Cause LNGDP	1.023	0.371	Accept	$LnRE \neq LnGDP$
LNGDP does not Granger Cause LNRE	2.401	0.107	Accept	
LNINEQ does not Granger Cause LNHC	0.581	0.565	Accept	

Null Hypothesis:	F-Statistic	Prob.	Decision on Null Hypothesis	Causality Direction
LNHC does not Granger Cause LNINEQ	2.086	0.140	Accept	$LnINEQ \neq LnHC$
LNRE does not Granger Cause LNHC	0.134	0.875	Accept	$LnRE \neq LnHC$
LNHC does not Granger Cause LNRE	1.026	0.370	Accept	
LNRE does not Granger Cause LNINEQ	0.302	0.742	Accept	$LnINEQ \rightarrow LnRE$
LNINEQ does not Granger Cause LNRE	3.517	0.042	Reject	

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