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RESEARCH ARTICLE

Investigating possibility of achieving sustainable development goals through renewable energy, technological innovation, and entrepreneur: a study of global best practice policies

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Abstract

This study is anchored on the global best practice policies for achieving sustainable goals for Malaysia. Malaysia is among the countries that made commitment at 2015 United Nations Climate Change Conference to reduce its carbon emissions by 2030. This is expected to contribute to the country's sustainable development. Malaysian quarterly data of 1992Q1–2019Q4 with relevant policy-based instruments (renewable energy policy, technological innovations, financial development, and entrepreneur activities) are adopted in our study for explicit and clear insight on the subject. Different scientific and analytical methods are equally applied in this study, but the focus and emphasis are laid on the findings from linear (dynamic ordinary least square, DOLS) and non-linear autoregressive distributed lag (NARDL) and Granger causality. Findings from both NARDL and DOLS confirmed the positive shocks of renewable energy policy, technological innovations, financial development, and entrepreneur activities are mitigating carbon emissions. Also, inverted U shape of EKC hypothesis is found for Malaysia. Findings from Granger causality support the findings from both estimates by establishing both feedback and unidirectional causal nexus among the instruments. From the finding myms, policy-based instruments are mitigating carbon emissions in Malaysia; thus, it will be a very good idea to frame policies around these instruments.

Keywords Renewable energy policy · Technological innovation · Financial development · Entrepreneur · Symmetric and asymmetric methods · Malaysian sustainable development goals

Introduction

Entrepreneurship has long been recognized as a tool for boosting economic progress. It creates job opportunities, increases productivity, stimulates innovative technology, and aids in the development of the economy through the use of taxes and foreign exchange (Stel et al., 2005). Malaysian government has urgently examined its entrepreneurship education and training program to stimulate economic activity and promote employment growth. Entrepreneurship education is becoming an essential part of the curriculum at Malaysian higher education institutions (Ismail et al., 2009). Entrepreneurship increased life efficiency by offering access to latest technology and services, allowing individuals to equip and employ latest technology to raise efficiency and productivity, thereby strengthening economies. This, for instance, has aided the agricultural and industrial sectors to use technological innovation to support the economy, enhance productivity, imports, and exports (Schumpeter, 2002). According to the Global Entrepreneurial Monitor

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(GEM), entrepreneurial activities have the potential to help different economies reduce poverty and control current economic challenges by reallocating resources from previous economic projects to more productive and effective ones through a country's high number of skilled entrepreneurs (GEM, 2008). Moreover, activities directly related to entrepreneurship can increase job creation possibilities and re-ignite an era of invention, both of which are necessary for industrial and economic growth.

However, while entrepreneurship in Malaysia has numerous benefits, it also has some negativities, such as environmental pollution, corruption, and ethical related concerns. These challenges, however, can be controlled with appropriate planning and strategic alliances. Presently, despite the fact that many governments have paid more attention to the issue of environmental contamination, the problem persists. Environmental pollution and climate change have been identified as the most significant global issues. Environmental degradation has had a detrimental impact on economic sustainability for a long time, and efforts have been made around the world to lessen its impact on future sustainable development. Few individuals consider entrepreneurship to be one of the solutions to environmental problems (York and Venkataraman 2010; Jiang et al., 2018). Nevertheless, numerous research considered entrepreneurship as one of the key factors responsible for environmental pollutions (Cohen and Winn 2007; Riti et al 2015). Activities such as entrepreneurial activities, industrial activities, agriculture, and transportation equipment all contribute to environmental pollution through the over use of energy resources, which raises emissions. These activities commonly consume energy resources and emit emissions, which have a negative impact on the quality of the environment.

Malaysia was ranked 8th in Asia and 33rd overall in the 2020 Global Innovation Index (GIL). Malaysia is now the 2nd most innovative country in Asia, after China (the Global Innovation Index 2020). Technological innovation is one of the most important elements in an economy, as it improves economic growth, efficiency and production, mobility, and living standards. Many economies have been impacted by technological innovation in their industrial and energy sectors, as well as entrepreneurial activity and agriculture. According to Anam Ahmed (2019), the application of technology innovations lessens the cost of production. Technological innovation plays an important part in attaining environmental sustainability by combating climatic disasters and reducing greenhouse gas (GHG) emissions and other energy-related problems (Shan et al 2021). Innovation has a huge potential to influence environmental sustainability by applying new technologies. Majority of the studies support the fact that technological innovation (*TI*) minimizes environmental pollutions (Shan et al 2021). Consequently, the unavailability of technological innovation and clean energy causes negative impacts of energy use on environmental development. Technologies employed primarily in the service sectors or industrial activities usually consume energy resources and discharge emissions that are detrimental to the environmental. Malaysia, which is one of the fastest developing economies in South Asia, is reliant on fossil resources such as oil, gas, and coal to sustain its rapid economic expansion.

To this end, the aim of this study is to investigate the possible best policies to achieve the Malaysian 2030 climate goal of curbing carbon emissions. To achieve the objective of our study, we adopt relevant and policy based instruments to the economy of Malaysia like energy (renewable) policy, technological innovation, and financial development and entrepreneur activities. The interactions of the above mentioned instruments with carbon dioxide emissions will determine the country's environmental performance. Hence, the breakdown of the objective of our study is as follows: (a) Is energy policy through renewable energy capable of mitigating carbon emissions? (b) Is technological innovation policy through research and development capable of reducing carbon emissions? (c) Is financial development policy capable of reducing carbon emissions? (d) Is entrepreneurial activities affecting the movement of carbon emissions? The justification of the listed objectives will be based on the interactions of the listed instruments with carbon emissions. The uniqueness and novelty of our work is the quantification of the interaction of entrepreneurial activities on Malaysian environment. This will contribute to the existing literature by paving way for more studies on the impact of entrepreneurial activities on sustainable development. We employed different scientific approaches with our focus and emphasis on dual analyses of linear and non-linear findings on the nexus among environmental quality, entrepreneurial activities, and technological innovation with the help of financial development, economic performance, and renewable energy for Malaysia. This empirical study differs from previous studies not only in terms of time span, but also in terms of technique and explanatory variables included in the study. Based on the researcher's knowledge of the earlier studies, this study is the first of its kind covering the relationship between entrepreneurial activities, *TI*, and environmental quality. This study adds to the previous studies on the entrepreneurship, *TI*, and the impact on environmental degradation in Malaysia. As a result, this study is driven to investigate the major causes that contribute to environmental deterioration in Malaysia in order to propose a number of recommendations to alleviate the environmental strain that the region is experiencing.

The remainder of the study is organized as follows: The following part is a review of the literature, "Data and methodology" section is the proposed data and methodology, "Empirical results and discussion" is the empirical results, and conclusion and policy implications are reported in the last section.

Literature review

The link between entrepreneurship, technical innovation, financial development, and CO_2 emissions has attracted the interest of policymakers and academics alike. Some of the studies support the positive relationship between the variables, while others indicated negative or neutral relationship. In order to carry the discussion further, this study will look into some of the past investigations, such as the relationship between entrepreneurship, technological innovations, economic growth, renewable energy, and financial development and CO_2, respectively.

Entrepreneurship and CO_2 emissions

Nakamura and Managi (2020) designated the effect of entrepreneurship on the environment varies across countries, and part of their findings stated that in high-income economies, the effects of entrepreneurial activities on ecological pollution are low compared to low-income economies which causes more pollution. Omri and Afi (2020) explored the role of entrepreneurship and government spending on education on the environment of developing countries and discovered that while entrepreneurship improves economic growth, it has a negative impact on the environment by contributing to increased environmental pollution. Government funding for education minimizes pollution. Youssef et al. (2018) investigated the contributions of entrepreneurship, innovation, and economic performance in achieving environmental growth and sustainability in Africa. The study observed that both formal and informal entrepreneurships contribute to the degradation of environmental quality. However, as compared to formal entrepreneurship, informal entrepreneurship generates more environmental damage. Dhahri and Omri (2018) assessed how entrepreneurship enhances economic productivity and environmental sustainability in developing countries. They found that entrepreneurship helps to improve production and social conditions but, unfortunately, posed a harmful impact on the environment. Hansin et al. (2017) suggests through their findings that Turkey needs to take advantage and create more opportunities for innovation to attract more entrepreneurial firms. Employing the fully modified least squares model (FMOLS), Riti et al. (2015) demonstrated that entrepreneurship has a tremendous impact on environmental sustainability in Nigeria, as well as a positive association between entrepreneurship and CO_2 emissions due to the regular usage of fossil fuels, which produce a large amount of CO_2. Cohen and Winn (2007) investigated how entrepreneurship affects environmental quality. The study indicates that entrepreneurship contributes to environmental damage and concludes that sustainable entrepreneurship can limit emissions and improve environmental quality by enabling innovative technology in various sectors.

Technological innovation and CO_2 emissions

Technological innovation is critical to economic growth. However, it has both positive and negative effects on environmental quality. The negative consequences have damaged the environment by damaging water, air, and health, as well as depleting natural resources. Ali et al. (2016), applying the autoregressive distributed lag (ARDL) model, examines the relationship among technological innovation, financial development, and CO_2 emissions in Malaysia from 1985 to 2012. The results indicated a positive impact of *TI* on environmental development, showing that an increase in new technology would reduce pollution in the environment. The results also revealed that a rise in financial development and economic growth reduces emissions and, hence, increases the quality of the environment in the long run. Ullah et al. (2021) examined the symmetric or asymmetric effects of technology innovation on carbon emissions for Pakistan from 1990 to 2018. The result reflects the long-run asymmetric effects of technology and environmental degradation in Pakistan. Ali et al. (2019) applied the ARDL model from 1985 to 2016 to examine the effects of *TI* and energy use on Malaysian environmental development. The outcome of the study shows that improvement in *TI* will boost environmental quality. Demir et al. (2019) discovered that domestic innovation minimizes the impact of CO_2 emissions in Turkey by intensifying development. Iqbal et al. (2021) used the augmented mean group (AMG) approach to investigate the role of technological innovation, export diversification, renewable energy consumption, and fiscal decentralization in reaching carbon neutrality targets for OECD nations from 1970 to 2019. According to the findings, renewable energy consumption and technological innovation ensure environmental quality, while economic expansion has an impact on emissions. Also, Ibrahim and Ajide (2021) investigated the impact of technology, trade, and renewable and non-renewable energy on environmental quality in G-7 nations from 1990 to 2019. The findings revealed that technical advancement and renewable energy lessen CO_2 emissions. Bai et al. (2020) researched if economic inequality has an influence on the impact of renewable energy technology innovation (RETI) on environmental deterioration in China. According to the results, RETI tends to enhance environmental pollution in high-income inequality gab. Liu et al. (2021) used Chinese data of from 1995 to 2017 to investigate the impact of FDI, technology, renewable energy, and commerce on environmental degradation in China. The findings suggest that GDP and FDI had a positive effect on CO_2 emissions, whereas renewable energy and technology have a negative effect on carbon emissions. Renewable energy and technology development minimizes emissions and enhances environmental quality.

Economic growth and CO_2 emissions

Several studies have conducted various assessments over the past decades to investigate the relationship between economic performance and environmental quality for a variety of countries and areas. Some of them obtained the findings that a growth in GDP degrades the environment. Zhang et al. (2021) confirmed that economic growth has a positive influence on CO_2 emissions using the Maki cointegration and wavelet coherence tests. This implies that as Malaysia's economy grows, so will environmental degradation. Nurgazina et al. (2021), using the ARDL approach from 1978 to 2018, explored the role of economic growth, financial development, and energy consumption on environmental degradation in Malaysia. The result confirmed that all the variables influence CO_2 emissions. According to Malik (2021), economic growth has a significant impact on environmental degradation. The finding confirmed that economic expansion raises CO_2 emissions. Philip et al. (2021) examined the asymmetric effects of FDI and growth on environmental degradation. Their findings verified the positive influence of Turkey's real GDP per capita on the environment. Similarly, Alola et al. (2019) used the ARDL model to analyze the importance of achieving sustainability in terms of reducing the amount of deterioration in the environment of EU nations from 1997 to 2014. They found that growth in real GDP improves environmental quality, while others, however, have shown a negative relationship between economic performance and the environment.

Renewable energy and CO_2 emissions

Renewable energy consumption is an important part of any nation's environmental and economic sustainability in order to increase productivity while maintaining environmental quality. Several research have been conducted to investigate the link between renewable energy use and environmental sustainability. Some of the findings indicated a significant relation, while others discovered a negative relationship between energy usage and environmental quality. Mahalik et al. (2021) explored the influence of renewable and non-renewable energy usage, as well as urbanization, in reducing environmental degradation. The result of the study showed that renewable energy use lowers carbon emissions through improving environmental quality, whereas non-renewable energy consumption and economic expansion raise emissions. Alola et al. (2019) investigated the impact of renewable energy, non-renewable energy, and trade on environmental deterioration using the ecological footprint for 16 EU economies from 1997 to 2014. The analyses confirmed that non-renewable energy degrades environmental quality, whereas renewable energy improves it. Jebli and Youssef (2017) and Liu et al. (2017), on the contrary, revealed that the long-run relationship between renewable energy and CO_2 emissions is positive, implying that increasing renewable energy increases CO_2 emissions.

Financial development and CO_2 emissions

Financial development is vital in improving economic growth by providing funding for project investment, such as establishing transportation networks and energy, which ensures that the economy and the environment are less susceptible to harmful effects. Depending on a country's level of growth, financial development plays an essential role in lowering CO_2 emissions by reducing pollution. Several studies have been conducted to investigate the impact of financial development on environmental conditions. Some of the studies indicate favorable benefits of financial development on the environment, while others indicate negative effects depending on the financial institutions and economic growth of a country. Ye et al. (2021) applied the ARDL approach from 1987 to 2020 to explore the influence of financial development on environmental quality of Malaysia. The study indicates that financial development increases environmental degradation and confirmed the EKC hypothesis. Godil et al. (2020) employed ecological footprints rather than CO_2 emissions to investigate the asymmetric influence of financial development, tourism, and globalization on Turkey's environmental quality. According to the ARDL findings, financial consumption has a negative impact on the environment. Njoku et al. (2020) investigated the symmetric and asymmetric effects of financial development on environmental degradation in Nigeria. The linear model results show that financial development has a positive effect on environmental deterioration through increasing emissions, while finding from the nonlinear model reflects a drop in CO_2 emissions. However, according to Xiaoxin and Qiang (2020), increase in financial development provides more high technologies that improve energy efficiency and environmental sustainability. Destek (2017) found the negative effect of financial development on energy consumption. The study suggests that investment in the energy sector can enhance energy efficiency and improve environmental clean technologies. Similarly, Shahbaz et al. (2013) explore the influence of financial development on environmental degradation in Malaysia. Their findings suggest that financial development lessens CO_2 emissions, while energy and economic growth improve emissions.

This study will also contribute to the literature on the role of entrepreneurial activities and financial development on the environment and economic growth. This research will also help us to understand the importance of renewable energy consumption in reducing emissions.

Data and methodology

As it is mentioned in previous sections, this study aims to examine the symmetric and asymmetric long-run and short-run relationships among environmental quality (CO_2), entrepreneurial activities (*ET*), and technological innovation (*TI*) with the help of financial development (*F*), economic performance (*Y*), and renewable energy (*R*) for Malaysia. Environmental quality is indicated with carbon dioxide emission and measured in kilogram per 2010 US$ of gross domestic product (GDP). Environmental quality is used as dependent variable in our estimation. Moreover, total number of newly registered businesses is used to measure entrepreneurial activities in Malaysia. Technological innovation is indicated with the summation of patent applications done by residents and non-residents (Cetin, 2021). Also, financial development is used as an explanatory variable in our estimation and indicated with domestic credit to private sector as percentage of gross domestic product (GDP) of Malaysia. While economic performance is measured as constant 2010 US$, renewable energy consumption as percentage of total final energy consumption is utilized to highlight the importance of using renewable energy sources for environmental quality. Due to the availability of entrepreneurial activities data, the period covered is 1992Q1–2019Q4, quarterly basis. The data, except for entrepreneurial activity, are obtained from World Bank World Development Indicators Database (WDI) (2021). The entrepreneurial activity data was acquired from the official website of Companies Commission of Malaysia (www.ssm.com.my).

In order to get robust results for our estimation by decreasing the skewness and increasing the normal distribution of the variables, all investigated variables are transformed into logarithmic forms. The Jarque–Bera test was employed to test the validity of normality assumption for all investigated variables. Hence, the following equation (Eq. 1) was developed to examine the general association among variables.

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln ET_t + \beta_2 \ln Y_t + \beta_3 \ln TI_t + \beta_4 \ln F_t + \beta_5 \ln R_t + \varepsilon_t \tag{1}$$

where $\ln CO_{2t}$ indicates for environmental quality level in period t; $\ln ET_t$ denotes entrepreneurial activities in period t; $\ln Y_t$ shows economic performance in period t; and $\ln TI_t$ stands for technological innovation level in period t. Moreover, $\ln F_t$ depicts financial development in period t, and $\ln R_t$ stands for renewable energy consumption level in period t. Moreover, α_0 stands for the intercept, while, β_i's are the coefficients of the independent variables. The residuals of the empirical estimation were represented by ε_t in the model.

Traditional time series techniques were not used for our estimations. These techniques are not able to distinct the positive and negative shocks and capture their effect on dependent variable. Therefore, since entrepreneurial activities and research and development activities are very sensitive to economic and political changes, non-linear autoregressive distributed lag model (NARDL) is employed to capture the systematic adjustment of the variables and their asymmetric relationships with environmental quality in Malaysia. The NARDL model, developed by Shin et al. (2014), can distinct the shocks and capture the effects of positive and negative changes on explanatory variables. It can also eradicate the problems caused by endogeneity and serial correlations in estimation. Thus, Eq. 1 was extended to capture the effect of positive and negative shocks of explanatory variables on environmental quality and presented below.

$$\begin{aligned} CO_{2t} &= \alpha_0 + \beta_1 lnET_t^+ + \beta_2 lnET_t^- + \beta_3 lnY_t^+ + \beta_4 lnY_t^- \\ &+ \beta_5 lnTI_t^+ + \beta_6 lnTI_t^- + \beta_7 lnF_t^+ + \beta_8 lnF_t^- + \beta_9 lnR_t^+ + \beta_{10} lnR_t^- + \varepsilon_T \end{aligned} \tag{2}$$

Here, + and – signs depict the positive and negative changes of on the explanatory variables, which can be synthesised in partial sum process. The process is shown below.

$$\begin{aligned} lnET_t^+ &= \textstyle\sum_{i=1}^t \Delta \ln ET_i^+ = \sum_i^t \\ lnET_t^- &= \textstyle\sum_{i=1}^t \Delta \ln ET_i^- = \sum_i^t \\ lnY_t^+ &= \textstyle\sum_{i=1}^t \Delta \ln Y_i^+ = \sum_i^t \\ lnY_t^- &= \textstyle\sum_{i=1}^t \Delta \ln Y_i^- = \sum_i^t \\ lnTI_t^+ &= \textstyle\sum_{i=1}^t \Delta \ln TI_i^+ = \sum_i^t \\ lnTI_t^- &= \textstyle\sum_{i=1}^t \Delta \ln TI_i^- = \sum_i^t \\ lnF_t^+ &= \textstyle\sum_{i=1}^t \Delta \ln F_i^+ = \sum_i^t \\ lnF_t^- &= \textstyle\sum_{i=1}^t \Delta \ln F_i^- = \sum_i^t \\ lnR_t^+ &= \textstyle\sum_{i=1}^t \Delta \ln R_i^+ = \sum_i^t \\ lnR_t^- &= \textstyle\sum_{i=1}^t \Delta \ln R_i^- = \sum_i^t \end{aligned} \quad \begin{aligned} &max(\Delta \ln ET_i, 0) and min(\Delta \ln ET_i, 0) \\ &max(\Delta \ln Y_i, 0) and min(\Delta \ln Y_i, 0) \\ &max(\Delta \ln TI_i, 0) and min(\Delta \ln TI_i, 0) \\ &max(\Delta \ln F_i, 0) and min(\Delta \ln F_i, 0) \\ &max(\Delta \ln R_i, 0) and min(\Delta \ln R_i, 0) \end{aligned} \tag{3}$$

The dynamics of short run and long run can be figured out as follows.

$$\begin{aligned} \Delta lnCO_{2t} &= \alpha_0 + \delta_1 CO_{2t-1} + \beta_1^+ lnET_{t-1}^+ + \beta_2^- lnET_{t-1}^- + \theta_3^+ lnY_{t-1}^+ + \theta_4^- lnY_{t-1}^- + \varphi_5^+ lnTI_{t-1}^+ + \varphi_6^- lnTI_{t-1}^- + \gamma_7^+ lnF_{t-1}^+ + \gamma_8^- lnF_{t-1}^- + \\ &\phi_9^+ lnR_{t-1}^+ + \phi_{10}^- lnR_{t-1}^- + \textstyle\sum_{i=1}^{p-1} \delta lnCO_{2t-i} + \sum_{i=0}^{q-1} \begin{pmatrix} \vartheta_1^+ \Delta lnET_{t-1}^+ + \vartheta_2^- \Delta lnET_{t-1}^- + \\ \vartheta_3^+ \Delta lnY_{t-1}^+ + \vartheta_4^- \Delta lnY_{t-1}^- + \vartheta_5^+ \Delta lnTI_{t-1}^+ + \vartheta_6^- \Delta lnTI_{t-1}^- + \\ \vartheta_7^+ \Delta lnF_{t-1}^+ + \vartheta_8^- \Delta lnF_{t-1}^- + \vartheta_9^+ \Delta lnR_{t-1}^+ + \vartheta_{10}^- \Delta lnR_{t-1}^- \end{pmatrix} + \varepsilon_t \end{aligned} \tag{4}$$

Equation4 can be developed to capture the long-run steady-state relation in estimation by adding error correction term. This can be shown as follows.

In Eq. 5, the long-run dynamics of explanatory variables are seized with their level form, while the short-term

$$\Delta ln\mathrm{CO}_{2t} = \alpha_0 + \delta_1 \mathrm{CO}_{2t-1} + \beta_1^+ lnET_{t-1}^+ + \beta_2^- lnET_{t-1}^- + \theta_3^+ lnY_{t-1}^+ + \theta_4^- lnY_{t-1}^- + \varphi_5^+ lnTI_{t-1}^+ + \varphi_6^- lnTI_{t-1}^- + \gamma_7^+ lnF_{t-1}^+ + \gamma_8^- lnF_{t-1}^- + \phi_9^+ lnR_{t-1}^+ + \phi_{10}^- lnR_{t-1}^- + \sum_{i=1}^{p-1} \delta ln\mathrm{CO}_{2t-i} + \sum_{i=0}^{q-1} \begin{pmatrix} \vartheta_1^+ \Delta lnET_{t-1}^+ + \vartheta_2^- \Delta lnET_{t-1}^- + \\ \vartheta_3^+ \Delta lnY_{t-1}^+ + \vartheta_4^- \Delta lnY_{t-1}^- + \vartheta_5^+ \Delta lnTI_{t-1}^+ + \vartheta_6^- \Delta lnTI_{t-1}^- + \\ \vartheta_7^+ \Delta lnF_{t-1}^+ + \vartheta_8^- \Delta lnF_{t-1}^- + \vartheta_9^+ \Delta lnR_{t-1}^+ + \vartheta_{10}^- \Delta lnR_{t-1}^- \end{pmatrix} + \psi ECT_{t-1} + \varepsilon_t \quad (5)$$

dynamics are captured with their differenced (Δ) form. The direction and magnitude of the effect of positive and negative shocks of explanatory variables on the deterioration level of environment can be examined by the values of $\sum_{i=0}^{q-1}(\vartheta_i^+)$ and $\sum_{i=0}^{q-1}(\vartheta_t^-)$. Besides that, the existence of cointegration relationship can be tested by using the Bounds test and Wald test under the hypothesis of H_0: β_i's = θ_i's = 0 and H_0: β_i's = θ_i' ≠ 0.

Accordingly, the long-run coefficients of the NARDL estimation results were confirmed by utilizing symmetric estimation technique, i.e., dynamic ordinary least squares (DOLS) model. The consistency and goodness of fit for the NARDL model was affirmed by employing the stability tests of CUSUM (cumulative sum of recursive residuals) and CUSUMsq (cumulative sum of recursive residuals squares). Consequently, the causal relationship among investigated variables was examined with Granger causality test.

Table 1 Stationarity test results

Variables	*ADF*		*PP*	
	Level	**Δ**	**Level**	**Δ**
lnCO_2	−0.81	3.72**	−0.04	−5.29***
ln*ET*	−1.86	−9.10***	−1.84	−4.85***
ln*Y*	−0.57	−3.01**	−1.51	−4.93***
ln*TI*	−1.26	−4.15***	−1.72	−5.11***
ln*F*	−1.66	−3.52**	−1.63	−4.66***
ln*R*	−1.73	−3.68**	−2.18	−4.81***

(1) All variables were tested with only intercept. (2)*** and ** depict for the significance level at 1% and 5%, respectively. Source: authors' computation

Empirical results and discussion

The symmetric and asymmetric long-run and short-run relationships of entrepreneurial activities and technological innovation with environmental quality are examined for Malaysia incorporating with economic performance, renewable energy consumption, and financial development for the period of 1992Q1–2019Q4, quarterly basis. To this end, the traditional unit root tests have been employed to check the stationarity level of the variables. For this purpose, augmented Dickey-Fuller (Dickey and Fuller, 1979) test and Phillips and Perron (1988) test have been utilized. The results, given in Table 1, indicates that all investigated variables are stationary at their first differenced form and integrated order 1.

Consequently, as a pre-condition of employing NARDL model, Bounds test were engaged to examine the long-run steady-state relationship among investigated variables. Hence, Table 2 provides the details about estimation outcomes and endorses the cointegration relationship among variables. In other words, the null hypothesis of no cointegration relationship exists among investigated variables that have been rejected since the calculated *F*-statistics (5.27) is greater than the upper critical bound at 1% significance level (4.68).

After the confirmation of cointegration relationship among investigated variables, the magnitude and directions of positive and negative effects of independent variables have been examined by utilizing NARDL model. The estimation outcomes are elaborated in Table 3 below.

The estimation outcomes demonstrate that, although the positive and negative shocks of explanatory variables have different magnitudes and directions in terms of the effect on dependent variable, all explanatory variables are statistically

Table 2 Bounds test results

K	Calculated *F*-stat	1%		5%		10%	
		L_B	U_B	L_B	U_B	L_B	U_B
5	5.27	3.41	4.68	2.62	3.79	2.26	3.35

Source: authors' computation

L_U upper critical bound, L_B lower critical bound

Table 3 Estimation output

Var	Coeff	Std. error	*t*-stat	*P*-value
Short-run coefficients				
D(lnET+)	−0.034***	0.013	−2.636	0.0098
D(lnET−)	0.042**	0.029	2.427	0.0159
D(lnF+)	−0.190*	0.098	−1.930	0.0566
D(lnF−)	−0.136**	0.057	−2.350	0.0209
D(lnTI+)	−0.042**	0.018	−2.317	0.0226
D(lnTI−)	−0.012*	0.006	−1.795	0.0758
D(lnR+)	−0.083**	0.034	−2.408	0.0180
D(lnR−)	−0.067*	0.035	−1.905	0.0598
D(lnY+)	0.309**	0.169	1.826	0.0310
D(lnY−)	0.069**	0.225	2.310	0.0257
ECT(−1)	−0.109***	0.027	−3.976	0.0001
Long-run coefficients				
lnET+	−0.313**	0.128	−2.441	0.0165
lnET−	0.069*	0.172	3.403	0.0687
lnF+	1.708***	0.527	3.240	0.0017
lnF−	−1.240**	0.486	−2.548	0.0125
lnTI+	−0.158*	0.080	−1.958	0.0532
lnTI−	−0.112*	0.062	−1.792	0.0763
lnR+	−0.762**	0.338	−2.256	0.0264
lnR−	−0.610**	0.342	−3.782	0.0479
lnY+	0.828**	0.459	3.800	0.0350
lnY−	0.636**	0.017	4.315	0.0159
C	−0.390***	0.066	−5.896	0.0000

Source: authors' computation

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

significant at different significance level. Therefore, they can be accounted as significant determinants of environmental quality function and satisfy our theoretical assumptions. Furthermore, in detail, the coefficient of ECT(−1) in short-run estimation is negative and statistically significant at 1% significance level. This indicates that 10.9% of disequilibrium in environmental quality level can be mended in the short run given the independent variables in Malaysia. Also, a 1% increase in entrepreneurial activities in Malaysia will cause a 0.034% decrease in CO_2 emission in short run and 0.313% in the long run, respectively. This indicates that a rise in entrepreneurial activities will increase environmental quality in both terms since they need to adapt changing economic structures and use environmentally friendly technologies. Therefore, Malaysian government and policymakers should encourage entrepreneurial activities, while set restricted and well-developed policies to operate environmentally friendly. However, a 1% decline in the negative shocks on the entrepreneurial activities will lead to 0.042% and 0.069% decrease in environmental quality in the short run and the long run, respectively. Thus, it can be said that a reduction in entrepreneurial activities in Malaysia will rise the emission level and cause significant rise in deterioration level of environment. This may be due to continuation of using traditional technologies in production and other economic activities which cause greater CO_2 emission and deteriorate the environment. Therefore, the government and policymakers should continuously observe the global economic downturns and support start up to help them survive in competitive market. Together with, besides having positive effect on environmental quality, it will lead to greater economic activities in the country and provide alternative products with higher quality to the consumers with lower prices. This will also cause greater multiplier effect in economy which will boost economic performance. These findings follow the suggestion by Nakamura and Managi (2020) on the impact of entrepreneur activities on environment of developed countries but contradict his views on the impact of entrepreneur on developing country. From our finding, the impact of positive shock of entrepreneur on Malaysian environment contradicts the findings from Omri and Afi (2020) for developing countries, Youssef et al. (2018) for Africa, and Dhahri and Omri (2018) for developing countries, while the impact of negative shock of entrepreneur on Malaysian environment supports the findings of the listed studies. This is more reason of adopting dual approaches—NARDL and DOLS. NARDL will give a comprehensive insight on the analysis in a decomposed manner which exposes both the positive and negative impacts on the dependent variables.

On the other hand, financial development was found as significant determinant for environmental quality in Malaysia. A 1% rise in financial development will cause 0.19% decline in the deterioration level of environment in short run. Besides, this value was accounted as 1.708% in the long run. This demonstrates that the development in finance sector will contribute to sustain the environmental quality and decrease the CO_2 emission with several ways. One of the reasons can be that ease to access to finance leads economic actors to purchase environmentally friendly and energy-saving technologies and emit less CO_2 to the environment. Moreover, a 1% decline in the level of financial development will contribute to CO_2 emission level by 0.136% in the short run and 1.240% in the long run. This will cause the greater deterioration in environment and reduction in environmental quality. This finding supports the findings from Xiaoxin and Qiang (2020) and Destek (2017) but contradicts the findings from Ye et al. (2021) for Malaysia and Godil et al. (2020) for Turkey.

Furthermore, research and development activities (R&D) targeted to improve environmental quality for sustainability by emitting less CO_2. Thus, R&D activities are mostly supported by government, environmentalists, and associations. To observe the role of R&D activities on environment in Malaysia, technological innovation was used in our estimation and its asymmetric and symmetric impact on environment was examined for the long run and the short run. The results indicate that technological innovation in Malaysia will lead to improve environmental quality by 0.042% in the short run and 0.158% in the long run for every 1% increase. However, a 1% decline in these activities will cause 0.012% decline in environmental quality in the short run and 0.112% in the long run. Therefore, the government, environmentalists, and associations should create funds for research and development activities and continuously guide and financially support technological innovation in order to improve environmental quality. This finding supports the finding from Ullah et al. (2021) for Pakistan, Iqbal et al. (2021) for OECD, Ali et al. (2019) for Malaysia, and Demir et al. (2019) for Turkey.

In addition, renewable energy sources are accounted as the remedy for environmental sustainability and quality. Thus, in environmental sustainability conferences, e.g., Kyoto Protocol and Paris agreement, the importance of the environmental sustainability and the quality was highlighted and some targets are set and restrictions imposed on countries, such as keeping an increase in global heat at 1.5–2 °C by 2020. Thus, countries intensively invest on renewable energies and try to rise their environmental quality. However, countries' self-benefits and targets sometimes drill the rules and restrictions of these agreements and reduce the priority of environmental sustainability. For instance, since Malaysia targeted to become a developed country by 2030 and believes the goal is reachable despite COVID-19's dire economic impact, it prioritized the sustainable economic growth to the environment. To this end, it fastened the economic productivity. Thus, as it was also proved with our estimation, with less consideration on negativities on environment, for every 1% increase in economic performance, it will cause an increase in CO_2 emission level and decrease the environmental quality. In details, a 1% increase in economic performance will lead to decline in environmental quality in Malaysia by increasing CO_2 emission by 0.309% in the short run and 0.828% in the long run, on average. Also, on average, a 1% decline in economic performance will improve environmental quality by 0.069% and 0.636% in the short run and in the long run, respectively. Together with, a 1% increase in renewable energy usage in total energy consumption will cause 0.083% reduction in CO_2 emission in the short run and 0.762% in the long run, on average. However, a 1% reduction in the use of renewable energy sources will degrade environmental quality by 0.067% and 0.61% in the short run and in the long run, respectively. This demonstrates that the long-run benefit from the use of renewable energy in case of environmental quality is greater compared to short run. Therefore, although the investment on renewable energy sources needs significant budget, the higher the investment in potential renewable energy sources will decrease the use of traditional energy sources, e.g., oil and coal, and reduce the energy dependency of country, while improving environmental quality in the long run. These findings from the perspective of renewable energy support the findings from Mahalik et al. (2021), Udemba (2021a) for Chile, and Alola et al. (2019), while the findings from the economic growth support the findings from Zhang et al. (2021) for Malaysia, Nurgazina et al. (2021) for Malaysia, Alola et al. (2019), Udemba and Yalçıntaş (2021) for Algeria, and Udemba (2021b) for UAE.

To affirm the outcomes of the NARDL estimates, the symmetric estimation technique, i.e., dynamic ordinary least squares (DOLS) method was utilized. In Table 4, the outcomes affirm the NARDL and show that all the explanatory variables are significant determinants of environmental quality function and support our theoretical assumptions. The coefficients show that, except economic performance, 1% rise in explanatory variables will cause a reduction in CO_2 emission and improve the environmental quality. In details, 1% rise in entrepreneurial activities will reduce the CO_2 emissions in Malaysia by 0.079%, on average, and improve the environmental quality. Also, 1% rise in financial development level will cause 0.164% improvement in environmental quality. Furthermore, technological innovation and the use of renewable energy will cause 0.031% and 0.163% improvement in environmental quality, on average, respectively. On

Table 4 DOLS estimation output

Var	Coeff	Std. error	*t*-stat	*P*-value
lnET	−0.079**	0.035	−2.247	0.0267
lnF	−0.164***	0.046	−3.570	0.0005
lnTI	−0.031***	0.008	−3.621	0.0005
lnR	−0.163*	0.083	−1.959	0.0528
lnY	1.810***	0.120	4.288	0.0000
lnY^2	−0.349***	0.079	−4.375	0.0000
C	−2.324***	0.124	−4.179	0.0001
R-squares	0.819	Adjusted *R*-squared		0.809

Source: authors' computation

***, **, and * indicate 0.01, 0.05, and 0.10 significance levels, respectively

Table 5 Diagnostic test results

Tests	Statistics	*P*-value
BG-LM test	1.498	0.2288
BPG	1.675	0.0787
RESET	1.003	0.3182
ARCH	0.355	0.6946
Jarque–Bera test	1.385	0.4561

Source: authors' computation

the other hand, most importantly, the inverted U-shaped environmental Kuznets curve hypothesis has been affirmed in Malaysian economy. This indicates that at the first phase, 1% rise in the economic performance in Turkey will lead to contribute to the degradation level by 1.810% on average and after a threshold level, for every 1% increase in economic performance will cause 0.349% decline in CO_2 emission level and improve environmental quality.

Table 5 gives the details about the tests for the reliability of the estimated model. According to the tests, our model is free of serial correlation and heteroscedasticity problems Breusch-Godfrey LM (BG-LM) test our model is free of autocorrelation problem. Moreover, the results of Breusch-Pagan (BPG) and ARCH tests show the validity of homogeneous distribution of our model, while Ramsey RESET test and Jarque–Bera test designate that our model is properly specified and the normality is valid for our estimation, respectively.

Additionally, CUSUM (Fig. 1) and CUSUMSQ tests (Fig. 2) were employed to test the stability of the model. The results proves that the model is stabile since the plots are located within the 5% critical bounds.

Finally, Granger causality analysis has been employed to examine the causal relationship among investigated variables. In Table 6, the outcomes indicate the bidirectional causal relationship of environmental quality with entrepreneurship and renewable energy use. Moreover, entrepreneurial activities also have feedback causal relationship with financial development and economic performance, while financial development has another bidirectional causal relationship with renewable energy use. Moreover, another feedback causal relationship was investigated among economic performance and technological innovation. On the other hand, the results show that the unidirectional causal relationships run from financial development, technological

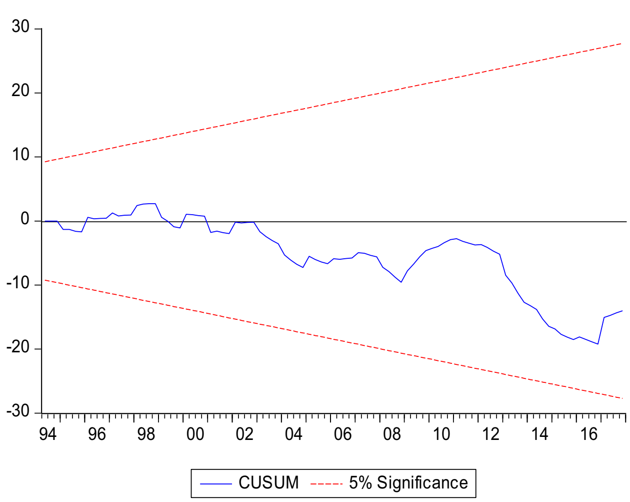

Fig. 1 CUSUM test result. Source: authors' computation

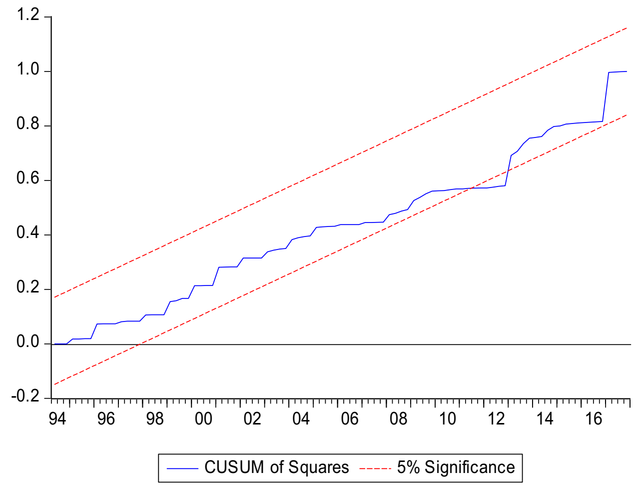

Fig. 2 CUSUMSQ test result. Source: authors' computation

Table 6 Granger causality test

Null hypothesis:	*F*-statistic	Prob
lnET ≠ > LN CO_2	2.97007	0.0450
LN CO_2 ≠ > lnET	2.52214	0.0263
LNF ≠ > LN CO_2	3.18641	0.0069
LN CO_2 ≠ > LNF	1.66240	0.1390
LNTI ≠ > LN CO_2	3.12245	0.0255
LN CO_2 ≠ > LNTI	0.80824	0.5661
LNR ≠ > LN CO_2	3.94587	0.0464
LN CO_2 ≠ > LNR	3.97905	0.0440
LNY ≠ > LN CO_2	3.53715	0.0174
LN CO_2 ≠ > LNY	0.49118	0.8135
LNF ≠ > lnET	3.77904	0.0141
lnET ≠ > LNF	3.91794	0.0128
LNTI ≠ > lnET	0.12299	0.9933
lnET ≠ > LNTI	0.59689	0.7321
LNR ≠ > lnET	0.67499	0.6701
lnET ≠ > LNR	0.75364	0.6081
LNY ≠ > lnET	3.27883	0.0152
lnET ≠ > LNY	3.54511	0.0033
LNTI ≠ > LNF	2.12779	0.1615
LNF ≠ > LNTI	0.63200	0.7043
LNR ≠ > LNF	4.70531	0.0003
LNF ≠ > LNR	3.01698	0.0097
LNY ≠ > LNF	1.08786	0.3755
LNF ≠ > LNY	3.59660	0.0173
LNR ≠ > LNTI	1.36592	0.2366
LNTI ≠ > LNR	0.35455	0.9056
LNY ≠ > LNTI	3.96553	0.0453
LNTI ≠ > LNY	2.36950	0.0356
LNY ≠ > LNR	0.11346	0.9946
LNR ≠ > LNY	1.32765	0.2527

≠> stands for ''does not granger cause''. Source: authors' computation innovation, and economic performance to environmental quality. Additionally, another unidirectional causal linkage runs from financial development to economic performance. These outcomes affirm the importance of technological innovation, entrepreneurial activities, economic performance, financial development, and renewable energy use on environmental quality for the short term and long term.

Conclusion and policy recommendation

This is a scientific and analytical study of the global best policy practice to initiate an inclusive sustainable development for the Malaysia. Malaysia is among the countries that made commitment at 2015 United Nations Climate Change Conference to reduce its carbon emissions per unit of GDP by 2030. This is expected to contribute to the country's sustainable development. According to the United Nation's definition, sustainable development goals involve achieving progressive economic development (with emphasis on the good economic welfare, health, and education of the masses) and good quality and environmental performance. In a bid to unravel the best policies that will aid Malaysia achieve its inclusive sustainable development goals, we test Malaysian environmental performance with some policy based instruments such as energy policy (renewables), technological innovation (R&D), financial development, and entrepreneurial activities.

For clear and direct insight from this study, we adopt a dual scientific analysis of both symmetric (DOLS) and asymmetric (NARDL) approaches with Granger causality test. This is done by comparing the results and findings from the different approaches in a way of robust check policy direction on how to improve the environmental lapses. Findings from both NARDL and DOLS confirmed the ability of renewable energy, technological innovation, and financial development and entrepreneur activities to aid Malaysian authority to achieve its sustainable development goals (SDGs). This is seen when the positive shocks of the listed instruments are seen mitigating carbon emissions which is in line with the country's 2030 target of reducing carbon emission. The same pattern is repeated in the output of DOLS with the listed instruments having negative relationship with CO_2 which points towards positive impact on Malaysian environment. Further into our findings is the establishment of inverted U shape of EKC hypothesis for Malaysia. This presents developmental relationship between Malaysian economic growth and environment. It supposes that at the initial stage of Malaysian economic growth, the economic activities had adverse effect towards its environmental performance until a certain point where relationship is upturned to impact positive on the environment. For the purpose of double checking the findings from the linear and non-linear estimates, findings from Granger causality support the findings from both estimates by establishing both feedback and unidirectional causal nexus among the instruments. Hence, bidirectional causal relationship is found among environmental quality with entrepreneurship and renewable energy use, entrepreneurial activities with financial development and economic performance, financial development with renewable energy use, economic performance, and technological innovation. On the other hand, the results show that the unidirectional causal relationships run from financial development, technological innovation, and economic performance to environmental quality.

From the findings, instruments like renewable energy, technological innovation, and entrepreneur are all pointing towards mitigating carbon emissions in Malaysia; thus, it will be a very good idea to frame policies around these instruments. Malaysia through its Ministry of Energy, Science, Technology, Environment, and Climate Change (MESTECC) has adopted some policies cum programs such as incorporating and expansion of Malaysian Green Technology Corporation (GreenTech Malaysia) towards achieving its climate goal. This policy is targeted on mitigating CO_2 from energy use, water consumption of buildings, and common areas and from vehicles that use fossil fuels. Even increasing of carbon sequestration from protecting and supplementing green spaces is among the policies aligned with MESTECC. Also, through this program, Low Carbon Cities Framework (LCCF) was supported with lots of effort in curbing emissions by the Malaysian authorities. Specific policy of development and promotion of green technology as a focal point of socioeconomic growth which falls in line with its green technology master plan of 2017 to 2030 is developed and pursued by the authorities. Again, agenda behind the LCCF was to get carbon-intensive cities involved in solving the problem of high greenhouse emissions.

Having seen from our findings the good signs of Malaysia achieving its sustainable development through the listed instruments, the following policies can be incorporated with the already existing policies of Malaysia: (a) diversification and boosting of renewable energy through deregulation and expansion of the sector. This will get both the private and public players actively involved in the sector through investment; (b) to enhance and encourage more private hands in the renewable energy, government subsidies are advised to cut tax and more credits to renewable energy sector; (c) boosting of technological innovations through public funding of research and development (R&D) will equally contribute in expanding and development of renewable energy sector; (d) policies to encourage financial institutions to release fund for investment are equally advised. Also, entrepreneur activities are found mitigating carbon emission, and this suggests the ability of controlling poor environment through entrepreneur and merchant's activities.

Malaysian authorities can monitor and regulate entrepreneur activities through environmental tax to avoid accelerating carbon emission beyond the manageable level. This could be done by placing a ceiling on which the companies under entrepreneur control are not allowed to exceed in emissions.

Conclusively, the findings and the policies listed in our study are very important and relevance to other countries in the category of Malaysia. This study has implication to other emerging and developing economies especially in the region of Asia continent. Our study and its findings have not closed the chapter of investigating this topic; hence, the topic is still open for research especially with other related instruments in energy-environment-economic growth nexus.

Author contribution Authors collaborate for this paper in each section. Asst. Prof. Dr. Firat Emir developed the theory and performed the computations and verified the analytical methods. Asst. Prof. Dr. Edmund Ntom Udemba significantly contributed to each section for academic writing of the text, conclusion part, and the policy suggestions. Dr. Lucy Davou Philip mainly contributed to the introduction and literature part of the study. All authors discussed the results and contributed to the final version of the manuscript. All authors read and approved the final manuscript.

Data availability Data sources are outlined in the "Data and methodology" section and will be available on demand.

Declarations

Ethics approval and consent to participate The authors are giving their ethical approval and consent for this paper to be published in your Journal if found publishable.

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