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Can green finance and energy provide a Glimmer of hope towards sustainable environment in the midst of chaos? An evidence from Malaysia

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A R T I C L E I N F O

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A B S T R A C T

Sustainable development has many dimensions, such as clean energy, green growth, and sustainable industry. Green finance has a key role in realizing these targets. The core focus of the existing paper is to demystify the influences of green finance, green energy on environmental dynamics in Malaysia covering the timeframe from 1990 to 2018. To this end, we employ the QARDL technique to peruse the effect of green finance, renewable energy, and economic growth on CO_2 emissions and ecological footprint separately. By doing so, we crosscheck the empirical outcomes and inspect the consistency of the analysis. Firstly, empirical results show that the ecological footprint model yields similar results to the CO_2 emissions model in terms of statistically significant quantile ranges and the magnitude of the coefficients. According to the overall results, GDP increases environmental degradation while green finance and renewable energy have a mitigating role. Finally, we confirm a significant EKC hypothesis for Malaysia. Based on these findings, we recommend Malaysian policymakers focus on energy efficiency, realize financial reforms and promote green energy through the financial system to achieve the 2050 net-zero emission target.

1. Introduction

Carbon-neutral states the balancing of the carbon dioxide emissions of an individual, household, company, or country in a year through carbon dioxide elimination technologies [1]. This activity is also known as net-zero emissions. To reach net-zero emissions, carbon neutrality requires balancing emissions using the technologies of carbon capture, storage, and conversion for a specific timeline [2]. In Paris Agreement, the 197 nations have committed to keeping global warming between 1.5 °C and 2 °C. This consensus continued at COP27 in Sharm el-Sheikh, Egypt, in 2022. The Nationally Determined Contributions (NDCs) mechanism was established in the Paris Agreement, which explains how much each country will achieve emission reduction. Many countries have set net-zero emission targets by 2050 through the NDCs system. This goal is substantial reaching net-zero emission targets and achieving sustainable development goals (SDGs). Therefore, achieving these targets requires several advancements and collaborations in all sectors from the industry to finance.

Finance sector's role for economic growth and environmental sustainability is undeniable. A sound financial sector can contribute to environmental quality through the energy sector's technological innovations [3] and encourage firms to adopt low-carbon and climate-resilient technologies [4,5]. For example, in accordance with Gianfrate and Peri [6], green bonds have properties being an essential method for mobilizing financial welding to satisfy the Paris Agreement's carbon mitigation targets. Therefore, financial sustainability can increase economic growth and environmental quality [7,8]. Investments in the renewable energy sector may expand thanks to the green finance policies by the governments [9]. However, the financial sector can also negatively affect the environment because it can finance investments in

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energy-intensive sectors through cheap loans, which causes an increase in energy consumption and emissions [10]. Particularly, developing countries may ignore the environment and use the financial sector as a driver to boost economic growth. Therefore, there is no consensus on the relationship between financial sustainability and environmental quality. Financial sustainability, green finance, is a phenomenon that combines finance and business with an environmentally friendly attitude, and it is a new financial approach integrating environmental quality with economic profit [11]. In addition, it covers the components of the financial system, such as the Green Climate Fund and other financial tools for clean investments [12]. Recently, several studies also have aimed to find out the influence of green finance on environmental quality in different aspects [13,14]. These studies generally claim that green finance could contribute to solving environmental issues and ease the realization of net-zero targets. For instance, Lee et al. [15] claim that green finance encourages the use and production of renewable energy through financial services such as loans and incentives. Another advantage of finance sector is to ease to reach a turning point mentioned in Environmental Kuznets Curve (EKC) hypothesis through providing financial resources to green investments.

Environmental studies generally focus on the EKC hypothesis to observe whether environmental quality increases as income increases. According to Kuznets [16], while income inequality increases initially in the economic development process, it decreases after reaching a threshold level. Inspired by this hypothesis, Grossman and Krueger [17] found a similar affiliation between income and environment. In this context, the EKC hypothesis refers that environmental pollution increases initially and then begins to decrease during economic development [18,19].

As it is known, at the COP26 meeting in Glasgow, Malaysia declared to decrease the intensity of emissions by 45 % by 2030 and achieve net-zero emissions before 2050 [20]. These targets requires substantial reductions in fossil fuels. Fig. 1, Figs. 2 and 3 present an overview to energy outlook of Malaysia regarding sector wise energy demand, energy consumption by type and CO_2 emissions by years. In the following sections, we will discuss how it is possible to achieve net-zero targets despite the energy mix of Malaysia.

As it is sen in Fig. 1, energy demand is Malaysia has been increasing over the years and industry and transport sectors constitute the majority of the energy demand. Fig. 2 depicts energy mix in Malaysia. Fig. 3 also proves the increasing trend of CO_2 emissions.

According to Fig. 2, it is seen that fossil fuel consumption which triggers greenhouse gas emissions and lead to environmental degradation has been increasing gradually since 1990.

From the last few years, the energy demand of Malaysian economy is increasing day-by-day (See Fig. 1), and for meeting this demand, the Malaysian economy is highly depends on non-renewable energy consumption (See Fig. 2), which results in the form of more CO_2 emissions (See Fig. 3) and environmental degradation.

In environmental researchs, CO_2 emissions are commonly utilized as a stand-in for environmental pollution. Although CO_2 emissions is the most utilized indicator representing environmental pollution, in fact, it represents air quality. However, the ecological footprint indicator has recently attracted researchers' attention [21–23]. The term "ecological footprint" was initially exploited in 1996 by Wackernagel and Rees to delineate the amount of domain required for a sustainable population. This indicator focuses on several aspects of environmental pollution while considering all production and consumption activities [24]. Therefore, ecological footprint serves better than many environmental indicators by providing a wide perspective [25]. The motivation of this study is to help the Malaysian government tackle climate change and attain net-zero targets by 2050.

This study scrutinises the influence of green finance and green energy on environmental degradation by using the framework of the EKC hypothesis for Malaysia during 1990–2018. Present study contributes to the existing literature in many ways. Firstly, this study uses two separate models by including CO_2 emissions and ecological footprint as dependent variables for comparing the influence of sustainable finance, green energy, and income on environmental quality through different mirrors. Secondly, we use the QARDL bound testing approach to demystify the

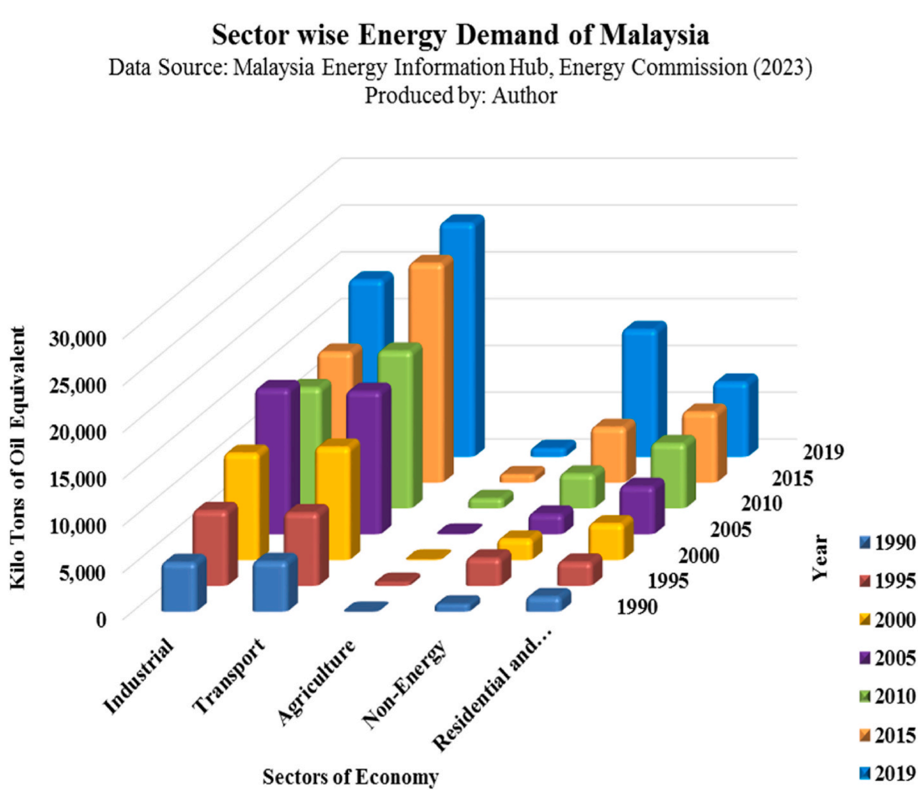

Fig. 1. Sector wise Energy Demand in Malaysia (1990–2019).

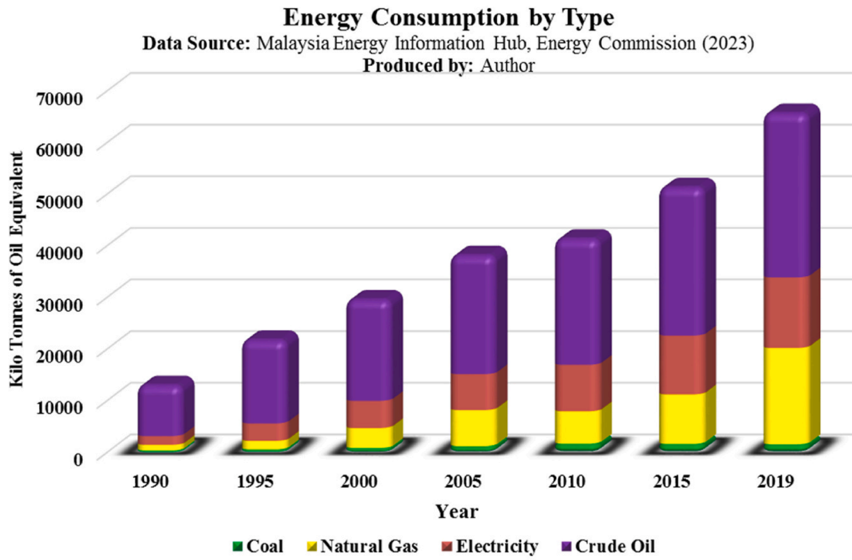

Fig. 2. Energy consumption by type (1990–2019).

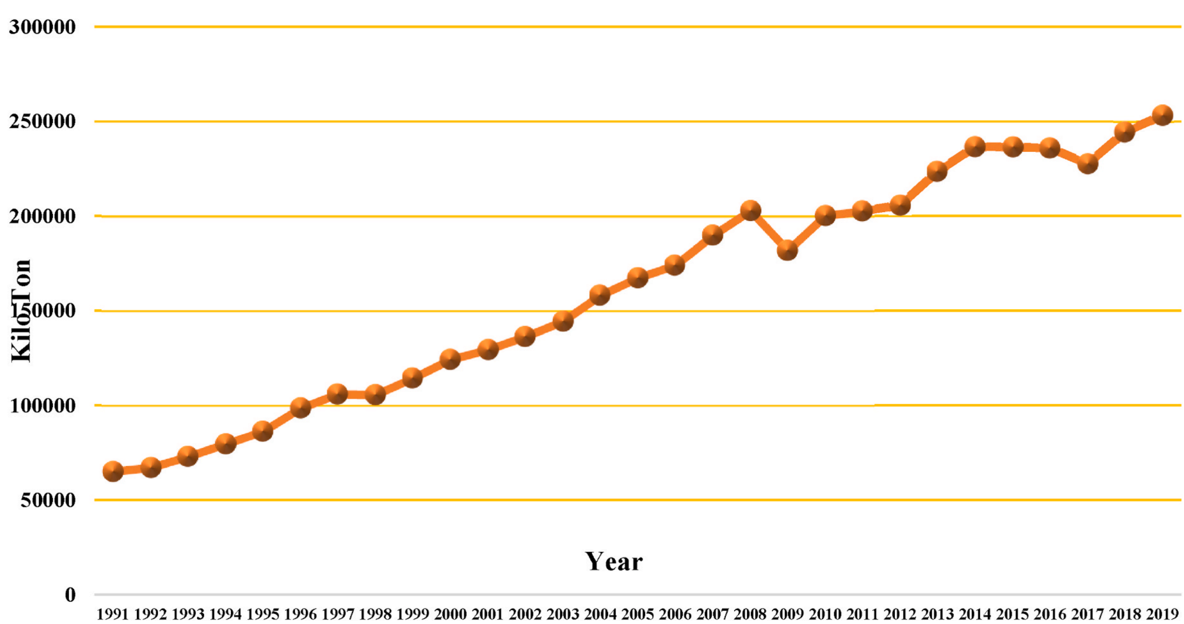

Fig. 3. Trend of CO_2 emissions in Malaysia (1990–2019).
Source: World Bank. Produced by the authors.

long-run relationship, which gives robust results in small samples. QARDL method reveals the association between the variables in different quantiles; in this way, it shows whether the regression equation coefficients estimated in different quantiles differ significantly [26,27]. Therefore, the QARDL method has been taken attention by studies analyzing the determinants of ecological footprint [28,29] and CO_2 emissions [30]. Thirdly, this study suggests specific policy recommendations for Malaysia to reach the net-zero emission target and achieve sustainable growth by 2050. This study also discusses possible risks for Malaysia's 2050 net-zero targets. Minimizing the risks we have discussed will ease the net zero emissions target. We consider the current energy mix as the most serious risk since the energy demand of the Malaysian economy is still largely met by fossil fuels. Therefore, this study reveals that green finance could play a strategic role in promoting environmental sustainability through developments such as financial reforms and incentive mechanisms.

The current study is organized under three main headings. The first part gives theoric background on financial sustainability environmental issues. The second part presents literature. The third part demonstrates methodology and reports empirical findings. Finally, we discuss empirical findings and suggest some policy recommendations for Malaysia in the Conclusion.

2. Literature

The EKC hypothesis is typically tested in environmental studies, allowing researchers to track environmental quality changes during the economic development process (Jahanger et al., 2023). However, the effect of financial sustainability on environmental indicators such as CO_2 emissions [31,32], ecological footprint [33–35] and load capacity factor [36,37] has initiated newly stand out.

In the literature, studies generally examine the financial development on environmental quality and found a positive (Shahbaz, 2013; [33,35]) or negative [38,39] relationship between the variables. While the positive relationship is generally referred to advanced financial systems and providing cheap resources to environmentally friendly investments (Majeed, 2010), the adverse effect of financial development is attributed to providing affordable resources to dirty industries, which leads to high emissions [40]. However, the concept of financial sustainability serves a broader purpose. Chowdhury et al. [41], examined the sub-components of green finance in order to show how broad impact it has. They underlined the importance green buildings, renewable and environmentally friendly product to fight against climate change. When it comes to green finance, renewable comes to mind first. However, the dimension of green finance along with agriculture, construction, transportation, banking, energy and many other sectors. Financial sustainability does not directly affect the environment but improves environmental pollution by supporting green enterprises and projects [42]. Wang and Zhi [11] investigated the impact of green finance on environmental sustainability. They focused on two aspects of green finance: market mechanism and policy formulation. In this context, they claim that market mechanism could mitigate environmental degradation in case policymakers adopt effective regulations. King and Lenox [43] examined 65 American manufacturing firms between the period 1987 and 1996. According to the findings, although there is a affirmative connection between environmental quality and financial valuations, the characteristics of firms and their strategic positions are essential for this relationship. Therefore, the study underlines the perfect time for the green payments. Schaltegger and Synnestvedt (2002) explained two critical views in terms of the environmental performance of the firms. While the first view claims that environmental performance leads to additional cost and decreases the profit of the firms, the second view defends that it contributes to profits by triggering cost savings and sales. Therefore, there is reason to believe that the style of environmental management plays a critical role on environmental sustainability.

The effect of financial sustainability on environmental sustainability varies based on the financial infrastructure. Many studies positively determine the effect of financial sustainability on environmental sustainability. Using the baseline ordinary least squares regression, Khan et al. [44] found that financial sustainability decreases ecological footprints in the Asian region. They suggested that government should promote climate investing. Sadiq et al. [45] reached a similar empirical finding. They claimed it is crucial to reduce emissions and promote green economic development to boost green finance and renewable energy. Sharif et al. (2022) also demonstrate that financial sustainability and green technology innovation increase environmental quality using the panel ARDL method for the G7 countries. The outcomes point out countries might achieve the SDG-7 and SDG-13 goals by embracing green funding and the policies of green technology. Yang et al. [46] conducted empirical study of the G7 countries. The results assert that clean economy, financial sustainability, and clean energy contribute to the environmental, social, and governance pillars in G7 countries. Chin et al. [47] assert that financial sustainability contributes to environmental sustainability and promotes economic expansion. The paper suggests that governments and the corporate sector should collaborate to support the green transition to improve economic growth, enhance sustainable development, and achieve SDGS by 2030. Kirikkaleli and Adebayo [35] investigate the relationship of political risk with environmental quality for Brazil employing a dynamic ARDL approach. The findings put forward that policies enclosing green innovation, social globalization, economic development, green finance, and political risk will promote environmental sustainability. Meo and Karim [31] employed Quantile on quantile regression (QQR) model for the top ten countries that encourage financial sustainability. Findings reveal that financial sustainability enhances environmental sustainability. However, they highlighted that the relationship between the variables varies within the range of different quantiles since each country has different market green finance market conditions. Nevertheless, they claim that green financing is an essential strategy for sustainability. Zhang [48] determined that environmental performance is a key factor between financial sustainability and economic performance. He claimed that firms that engage in and benefit from green financing cause less environmental pollution in OECD countries. Sun et al. [49] discusses the relationship between financial sustainability and carbon neutrality. The study claims that financial sustainability policies in renewable energy could be essential to increase environmental quality in China. Jian and Afshan [50] conducted a similar study for the G10 countries in the carbon-neutral framework. They investigated the importance of green financing and green technologies to achieve carbon neutrality by using the CS-ARDL approach. They confirmed the EKC hypothesis and found that green financing and green technologies contribute to reaching carbon neutral economy. Employing Pedroni and Kao cointegration tests, Zhou et al. [42] analysed financial sustainability impact on economic development and environmental quality. Confirming the EKC hypothesis, they found that financial sustainability could moderate the link between economic development and the environment through a win-win mechanism. Recently, Bakry et al. [51] found that green finance and renewable energy mitigate environmental pollution in 76 developing countries by confirming the EKC hypothesis. The moderating impact of renewable energy and green finance also supported by Rasoulinezhad & Taghizadeh-Hesary [52] for the top ten green finance supporting countries. When it comes to E−7 countries, Wang et al. [34] revealed that there are some barriers for green energy efficiency. Inadequate government and private investment in the energy sector is one of these barriers for environmental sustainability. On the other side, Asian countries is are examined by Liu [53], to see the relationship between green finance and renewable energy. The results show that there is link between green finance, green economy and renewable energy. The study claims that technological progress contribute to sustainable production and consumption as mentioned by sustainable development goals (SDGs).

From all the above discussion, we conclude that there are several studies, which investigate the impact of finance development on environmental quality. However, the role of green finance on environmental degradation is still relatively unexplored. Previous studies suggest that financial sector can reduce environmental pollution by increase investment in green energy projects. To validate this argument, this study investigates the impact of green finance on environmental degradation for Malaysia in order to suggest suitable policies for achieving carbon neutrality targets. Past literature mainly focuses on the emission reduction and increase environmental quality. However, we discuss the findings specifically in the context of the probability to achieve net-zero emissions by 2050 which was declared by Malaysia. This paper tries to contribute to the literature within the framework of the research gap in net-zero target studies.

3. Data and methodology

3.1. Data

The existing paper is targeted at exploring the dimensions of green finance and green energy on environmental pollution in Malaysia for the period from 1990 to 2018 by using six variables, four of which are independent and two of which are different-dependent variables. We decided to examine Malaysia as a sample country since Malaysian policymakers declared long-term environmental strategies and set an ambitious target to achieve net-zero emission target by 2050. Many developing countries hesitate to realize net-zero emission targets even by 2050. For instance, as one of the important developing countries, Türkiye declared its net-zero emission target year as 2053 [54]. Therefore, we choose Malaysia to observe the impact of green finance on CO2 emissions and ecological footprint and we aim to examine whether green finance could be a policy tool for Malaysian policymakers.

Besides, the econometric analysis, undergirded by a robust strategy, seeks to instantiate the validity of the EKC hypothesis, as clearly given with the two-different quadratic functional structures of (1) and (2), below.

$$CO2_t = f\left(GDP_t, GDP_t^2,\ SFIN_t, RENE_t \right) \tag{1}$$

$$EFP_t = f\left(GDP_t, GDP_t^2,\ SFIN_t, RENE_t \right) \tag{2}$$

Five dissimilar databases were accessed to bring together the paper's datasets. The first quadratic model, (1), encapsulates one of the different-dependent variables of $CO2_t$ which presents the carbon emissions in metric tons per capita taken from the British Petroleum Statistical Review of World Energy. The second one is defined for the variable of EFP_t which shows the ecological footprint comes from the Global Footprint Network. In the paper, the variables considered on the explanatory variable side consist of GDP_t which is gross domestic product per capita drawn from the database of World Bank, gross domestic product squared, GDP_t^2, and $SFIN_t$ which is the investment in renewable energy measured in billions $ obtained from International Renewable Energy Agency (IRENA). Moreover, the last explanatory variable, $RENE_t$, based on the database of OECD statistics, mentions to consumption of renewable energy. Table 1 presents the complete details of the data, similarly the graphical presentation of data is given in Figs. 4 and 5. Inspection time frame overlays a data set converted from annual data set to quarterly data via the quadratic match-sum method, like in for the period 1995–2020. In the analysis, we preferred to use the approach of the quadratic match-sum, for the sake of leaving the problem of small sample behind and adjusting the seasonality problem automatically [55,56]. To lessen the hassle of heteroscedasticity and skewness, all series are changed to the natural logarithms.

Table 2 unrolls the nuance in the statistical details of the series. Prior statistics on the means of the variables show that RENE has the highest value, 2,588, while the lowest one is SFIN, 1.914. Likewise, the mean for the indicators of environmental pollution reveals as 1.989 for CO_2 emissions, and 1.953 for EFP, with a standard deviation in the order of 0.848 and 0.613. The Jarque-Bera (JB) statistic motivates the handling of the quantile-based technique as a correct econometric strategy by affirming the out-of-normality in the data set. The graphs of the frequency distribution of the data also confirms that the data is not-normally distributed (see Fig. 6).

The pair-wise correlation matrix of variables in Table 3 discloses that the strength and directions of the relationships among all series are positive. Obtained positive correlation coefficients imply that the strength of the pair-wise relationships varies from 0.237 to 0.379.

3.2. Methodology

This analysis simultaneously probes the productiveness of green finance and green energy on environmental pollution while seeking confirmation for the hypothesis of EKC in Malaysia. Undoubtedly, the basis of a solid econometric analysis is based on the correct determination of the integration order of the variables at the beginning. That's why the application of the test of unit root, which is the first step, is very important in terms of demonstrating a strong process performance of the econometric method.

Taking advantage of using the two most central proxies of the environment's quality, including ecological footprint and carbon emissions, we employ the strategy of Quantile ARDL (QARDL), which enables parameters to differ across the quantiles even considering outliers, heterogeneity, and skewness in the dependent variable. The Quantile regression models are more flexible models compared to least squares models since they make no assumptions about the distribution of the estimated error terms (Lv & Xu, 2016). In the least square method, estimations are made based on the conditional average of the response of the dependent variable to the independent variables. However, the quantile regression model allows estimating different quantiles of the conditional median [57]. This model also provides robust results even when classical econometric assumptions fail [58].

Fresh techniques, which incrementally substitute traditional econometric techniques based on the mean regressed methodologies, suffix different dimensions to the analyses carried out. QARDL, which tries to divulge the asymmetrical (nonlinear) behaviours of variables in models for both the short- and long-run, is one of them. The technique uncovers robust estimation while yielding quantile-based outcomes. Its knack for examining dynamics at low, median, and higher quantile levels allows the method to disclose much more information than conventional ones.

QARDL model for the τth quantile of $CO2_t$ conditional on the information set of $\theta_{t\text{-}1}$, which permits both short- and long-run coefficients to be heterogeneous from one quantile to another with the range of quantiles switching from zero to one ($0 > \tau < 1$), is constructed as under:

$$Q_{CO2_t} = \alpha(\tau) + \sum_{i=1}^{p} \beta_i(\tau)\Delta CO2_{t\text{-}i} + \sum_{i=0}^{q1} \gamma_i(\tau)\Delta GDP_{t\text{-}i} + \sum_{i=0}^{q2} \delta_i(\tau)\Delta GDP^2{}_{t\text{-}i} + \sum_{i=0}^{q3} \vartheta_i(\tau)\Delta SFIN_{t\text{-}i} + \sum_{i=0}^{q4} \varphi_i \Delta RENE_{t\text{-}i}$$

$$\alpha_1(\tau)CO2_{t-1} + \alpha_2(\tau)GDP_{t-1} + \alpha_3(\tau)GDP^2_{t-1} + \alpha_4(\tau)SFIN_{t-1} + \alpha_5(\tau)RENE_{t-1} + \epsilon_t(\tau) \tag{3}$$

$$Q_{EFP_t} = \alpha(\tau) + \sum_{i=1}^{p} \beta_i(\tau)\Delta EFP_{t\text{-}i} + \sum_{i=0}^{q1} \gamma_i(\tau)\Delta GDP_{t\text{-}i} + \sum_{i=0}^{q2} \delta_i(\tau)\Delta GDP^2{}_{t\text{-}i} + \sum_{i=0}^{q3} \vartheta_i(\tau)\Delta SFIN_{t\text{-}i} + \sum_{i=0}^{q4} \varphi_i \Delta RENE_{t\text{-}i}$$

$$\alpha_1(\tau)EFP_{t-1} + \alpha_2(\tau)GDP_{t-1} + \alpha_3(\tau)GDP^2_{t-1} + \alpha_4(\tau)SFIN_{t-1} + \alpha_5(\tau)RENE_{t-1} + \epsilon_t(\tau) \tag{4}$$

Here, in Equation (3), $\epsilon_t(\tau)$ is described as $CO2_t\text{-}Q_{CO2_t}[\tau|\theta_{t\text{-}1}]$ as in Kim and White [59]. The selected quantiles of the analysis for determining both short- and long-run relationships comprise τ, 0.05, 0.10, 0.20, 0.30, 0.40 0.50, 0.60, 0.70, 0.80, 0.90, and 0.95. Also employing the Δ method, the cumulative short-run impact of the previous CO_2 emissions or EFP on the current CO_2 emissions or EFP is gauged. We followed the same econometric strategy to measure the cumulative short-run impact of the previous and current level of the GDP, GDP^2, SFIN, and RENE on the current levels of CO_2 emissions or EFP. After all, we perform the test of Wald to audit the nonlinear short- and long-run impacts of GDP, GDP^2, SFIN, and RENE on both CO_2 and EFP, separately.

In order to ascertain all conceivable scenarios where there is a one-way, two-way, or no causality relationship between the variables for two-different models, the last part of the empirical analysis of the study is concluded with the Granger-causality in quantiles test demystifying nonlinear causal relationships in all conditional quantiles.

Table 1
Data Description.

Variable Name	Sign	Measurement Scale	Data Source
CO_2 Emissions	CO_2	Metric Tons Per Capita	BP-Statistics (2023)
Ecological Footprint	EFP	Global hectare per capita	Global Footprint Network (2023)
Economic Growth	GDP	GDP per capita (constant US Dollar 2015)	World Bank (2023)
Green Finance	SFIN	Investment in renewable energy measured in billions US dollar	IRENA (2023)
Renewable Energy Consumption	RENE	Kilo tonnes oil equivalent	OECD (2023)

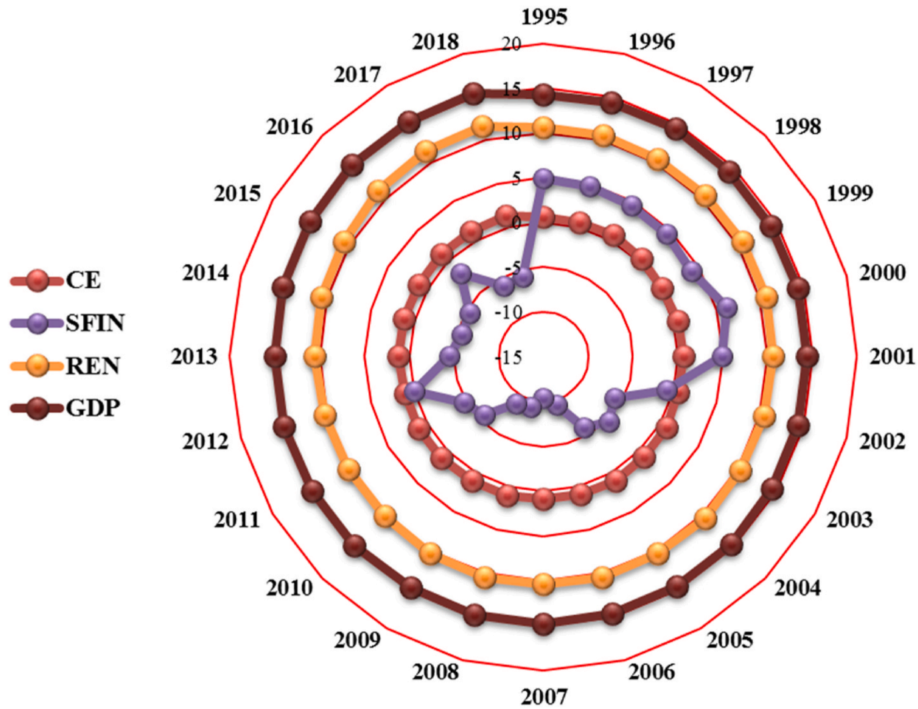

Fig. 4. Data of Model 1 (CO2 Emissions).

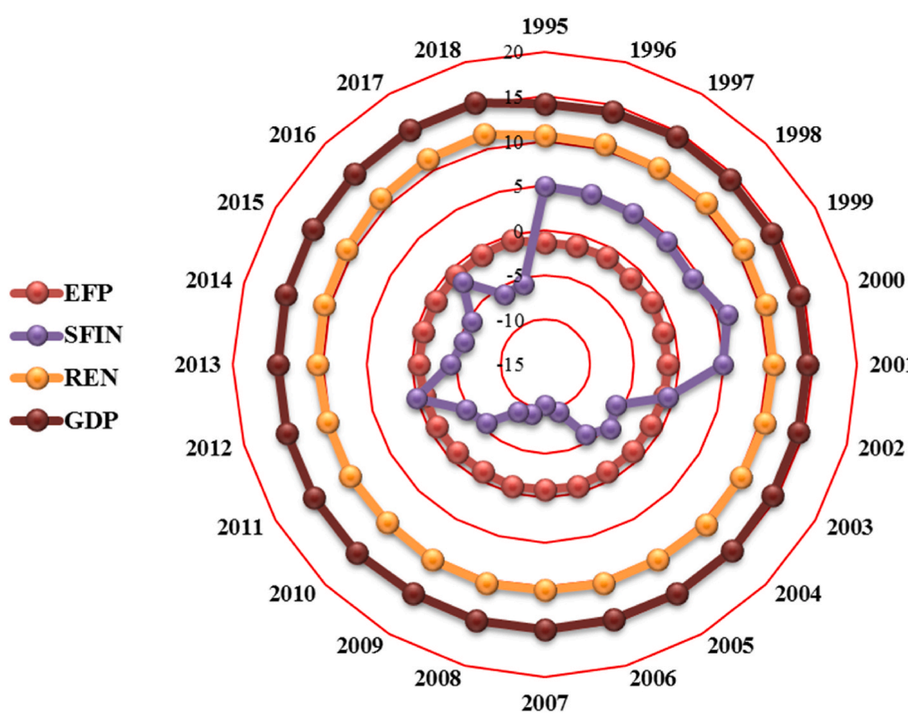

Fig. 5. Data of Model 2 (Ecological Fooprint).

4. Results and discussion

To reveal deeper statistical evidence of the time series that is the subject of the related research, determining the integration order of the variables is one of the most crucial initial stages of econometric analysis. The most basic econometric strategy that facilitates and makes this process the most healthy is the unit root test. The test furnishes two important advantages to time series analysis: the first is to lead the testing despite unit root issues, and the second is to discover the integration order. However, tests such as Zivot and Andrews [60] (ZA) can take the analysis to the next level by allowing to identify the presence of structural breaks in the time series.

The upshot of the assessment in which we investigated the presence of unit root in series by taking advantage of a test such as ZA besides a traditional procedure, such as the Augmented Dickey-Fuller (ADF) test, is given in Table 4. Both ADF and ZA test statistics imply that shocks have permanent effects on the level values of the variables. It can be clearly said that the variables exhibit properties that do not belong to a

Table 2
Results of Descriptive statistics.

Variables	GDP_t	$SFIN_t$	$RENE_t$	CO_{2t}	EFP_t
Mean	2.515	1.914	2.588	1.989	1.953
Maximum	3.045	2.834	2.812	2.912	2.828
Minimum	1.843	1.857	1.869	1.811	1.838
Std. Dev.	0.696	0.942	1.120	0.848	0.613
J-B Stats	17.962***	15.059***	16.397***	17.689***	13.751***

***, $p < 0{,}01$."Source: Author Estimation".

stationary series at level I(0). More specifically, taking the first difference yields all variables the property of being stationary at I(1) level under both ADF and ZA tests. Under all these results, the order of integration of CO2, EFP, SFIN, RENE, GDP, and GDP^2 is confirmed as I(1).

The outcomes of quantile-based from QARDL are provided in Table 5. The econometric evidence going on from lower pollution levels to higher ones in Table 4 belongs to the model handled for CO_2 emissions, the first representative of environmental pollution. Having highly significant negative error correction coefficients (ECM) in the range of 0.09%–0.145 % for each quantile confirms a reversion to the long-run equilibrium among CO_2 emissions and other variables for Malaysia.

As for the long-run relationship, the quantile-based estimated coefficients of GDP are positive and significant for the first three lower CO_2 emissions levels, i.e., 0.05 (0.213), 0.10 (0.266), and 0.20 (0.211). Also, the results for the last four high CO_2 levels ranging from 0.70 to 0.95 confirm the long-run positive impact of GDP on CO_2 emissions. At the 10th quantile, a 1 % change in GDP leads to a 0.266 % highest-rise in CO_2 emissions, whereas the positive effect decreases to 0.195 %, the lowest one, at the 80th quantile. The estimated coefficients of 30th,

Table 3
Results of pair-wise correlation.

Variables	GDP_t	$SFIN_t$	$RENE_t$	CO_{2t}	EFP_t
GDP_t	1.000				
$SFIN_t$	0.379	1.000			
$RENE_t$	0.375	0.282	1.000		
CO_{2t}	0.251	0.281	0.327	1.000	
EFP_t	0.237	0.351	0.248	0.345	1.000

"Source: Author Estimation"

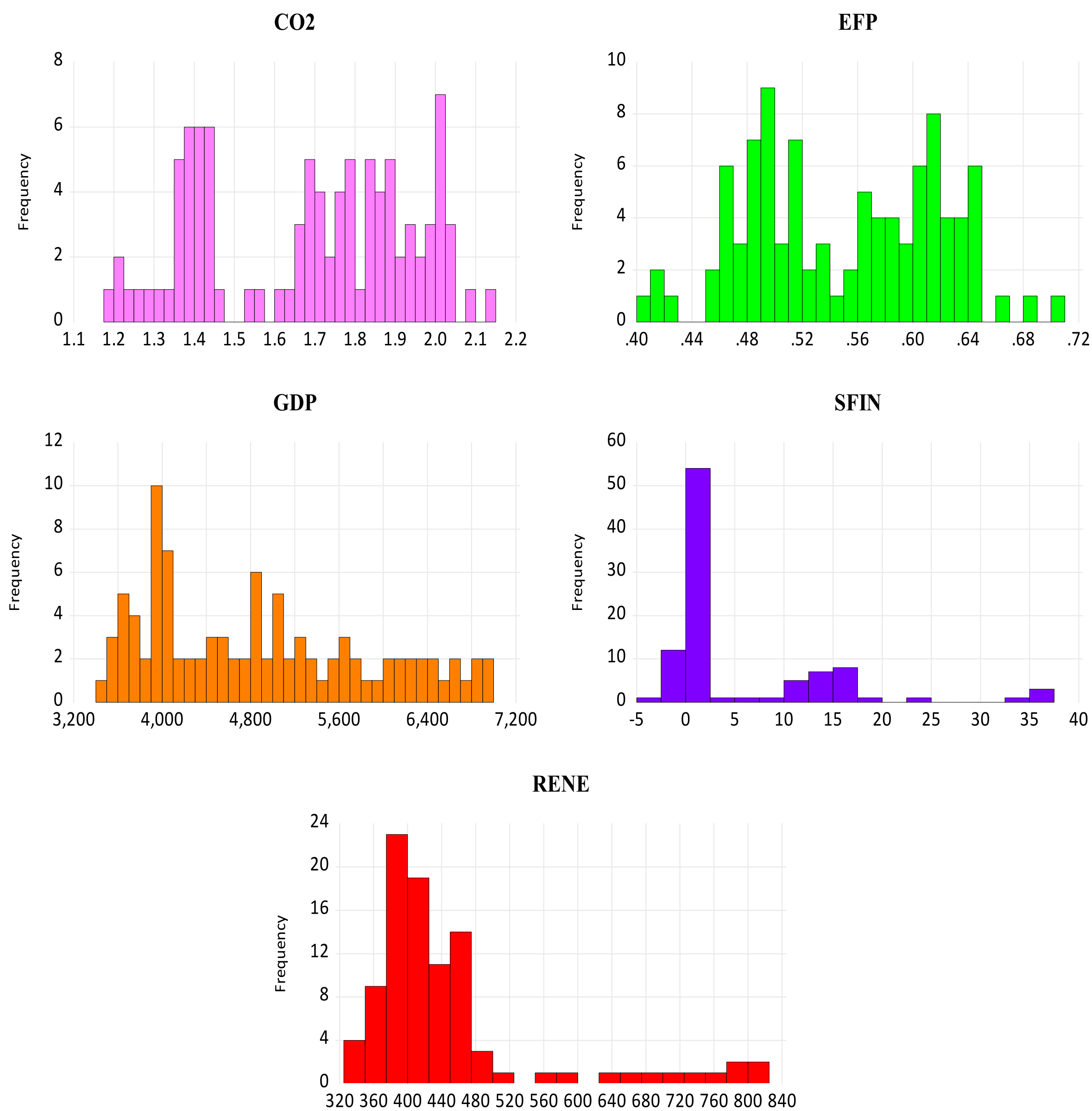

Fig. 6. Frequency distribution of the data.

Table 4
Results of Traditional and Structural Break Unit root test.

Variables	ADF (Level)	ADF (Δ)	ZA (Level)	Break Year	ZA (Δ)	Break Year
C02	−1.389	−4.075***	0.021	2013 Q1	−6.296***	2011 Q2
EFP	−1.140	−6.408***	−1.715	2011 Q3	−4.225***	2009 Q2
SFIN	−1.185	−5.772***	−0.714	2001 Q2	−9.229***	2014 Q1
RENE	−1.262	−6.189***	0.280	2007 Q1	−3.788***	2002 Q1
GDP	1.487	−5.064***	−2.094	2009 Q4	−9.446***	2012 Q3
GDP2	−0.230	−5.799***	1.020	2006 Q1	−3.309***	2008 Q4

Note: ***, $p < 0{,}01$.
Source: Author Estimation

40th, 50th, and 60th quantiles, however, put forward no statistically significant long-run effect of GDP on CO_2 emissions. As come to the short-run dynamics, the results indicate current CO_2 emissions have been affected significantly and also highly positively by their own past levels except for 30th, 40th, 50th, and 60th quantiles. Moreover, the short-run dynamics show that the previous and current changes in GDP impact CO_2 emissions positively and significantly for the same quantiles as in the long-run, while the impact is insignificant for the 30th-60th quantiles. The statistically highly significant and negative sign estimation of GDP^2 at the lower and higher quantiles endorses the EKC hypothesis for Malaysia in the long-run (See Fig. 7). These results agree with the preceding results of Jahanger et al. [61], Awan et al. [62], which prove the environmental revival effects of GDP^2 by lowering pollutants in Malaysia. Moreover, the short-run validity of the EKC hypothesis is confirmed by the findings.

The long-run estimated parameter of SFIN yields significant negative impacts on CO_2 emissions. The highest negative effect is sighted at the 90th quantile with the coefficient of −0.279 which implies a one percent change in SFIN cause a 0.279 % mitigation in CO_2 emissions. Although the estimated long-run coefficients for SFIN are negative in middle level quantiles between 0.30 and 0.60, they are not statistically significant. The current CO_2 emissions in Malaysia are negatively and significantly impacted by the previous cumulative changes in SFIN except for the range of 30th and 60th quantiles. Under these results, integration of financial sustainability with an environmentally friendly attitude can be an active tool for policymakers to bringing environmental sustainability to the next level in Malaysia for all term. The negative relationship of SFIN with CO_2 emissions is within consonance with Sun et al. [49] and Jian and Afshan [50].

As come to RENE, it has a significant impact on CO_2 emissions. In the long-run, this impact has been observed as being negative for the lower CO_2 emissions levels of 0.05–0.20 and higher pollution levels of 0.70–0.95. RENE leads to mitigating environmental pollution in Malaysia. The curative-contemporaneous effect of RENE on environmental pollution prevails in the short-run for the same quantile ranges as in the long-run. However, with one difference, the magnitude of the effect on CO_2 between the short- and the long-run is dissimilar. Highest long-run mitigating effect on environmental pollution is recorded as −0.292 under the highest quantile, 95th, while the highest short-run mitigating effect is realized as −0.086 under the 20th quantile.

Table 6 portrays the nonlinear long- and short-run effects of independent variables of GDP, GDP2, SFIN, and RENE, while the dependent variable is EFP. First, it is worth noting that most of the findings from the EFP model yield similar results to the CO_2 emission model, both in terms of statistically significant quantile ranges and the magnitude of the coefficients. The obtained highly statistically significant negative ECM, around the 0.097%–0.146 %, across all quantile in the EFP model do not differ much from the previous model in terms of magnitude. However, we observe that the error correction coefficients at the highest quantiles in the EFP model are slightly higher compared with the CO_2 model. Likewise, the ECM results affirm that the short-run imbalances return toward equilibrium value in the long-run.

The long-run relationship of GDP with EFP is also positive and significant for majority of the quantiles, except for the 30th, 40th, 50th, and 60th. The estimated long-run coefficient of 70th quantile is now the highest one, which indicates a 1 % change in GDP results in a 0.279 % increase in EFP. The lowest long-run impact of GDP on EFP is observed at the quantile of 20th, with the coefficient of 0.197. With regard to the short-run dynamics, the findings depict that, with the exception of the 30th, 40th, 50th, and 60th quantiles, current EFP has been significantly and also extremely positively influenced by its own prior levels. The significantly positive past changes in GDP do not have consistent values

Table 5
Results of quantile autoregressive distributed lag (QARDL) for carbon emissions.

Quantiles	Constant	ECM	Long-Run Estimation				Short-Run Estimation				
(τ)	$\alpha_*(\tau)$	$\rho_*(\tau)$	$\beta_{GDP}(\tau)$	$\beta^2_{GDP}(\tau)$	$\beta_{SFIN}(\tau)$	$\beta_{RENE}(\tau)$	$\varphi_1(\tau)$	$\omega_0(\tau)$	$\lambda_0(\tau)$	$\theta_0(\tau)$	$\acute{\varepsilon}_0(\tau)$
0.05	0.040	−0.125***	0.213***	−0.259***	−0.235***	−0.216***	0.402***	0.039***	−0.072***	−0.049***	−0.039***
	(0.044)	(-3.877)	(3.390)	(-3.921)	(-3.015)	(-3.515)	(3.362)	(4.857)	(-4.416)	(-4.523)	(-3.109)
0.1	0.079	−0.109***	0.266***	−0.272***	−0.251***	−0.277***	0.040***	0.087***	−0.081***	−0.072***	−0.047***
	(0.070)	(-4.888)	(4.945)	(-3.495)	(-3.976)	(-4.886)	(3.495)	(3.598)	(-4.516)	(-4.211)	(-4.296)
0.2	0.049	−0.137***	0.211***	−0.296***	−0.273***	−0.199***	0.440***	0.099***	−0.031***	−0.064***	−0.086***
	(0.029)	(-4.955)	(3.449)	(-4.301)	(-3.975)	(-4.022)	(3.211)	(3.100)	(-4.529)	(-4.884)	(-3.567)
0.3	0.014	−0.090***	0.239	−0.278	−0.240	−0.235	0.499	0.096	−0.066	−0.090	−0.073
	(0.036)	(-3.373)	(1.562)	(-1.429)	(-1.326)	(-1.355)	(1.351)	(1.541)	(-1.472)	(-1.238)	(-1.498)
0.4	0.043	−0.118***	0.200	−0.297	−0.201	−0.245	0.529	0.081	−0.069	−0.078	−0.085
	(0.010)	(-4.499)	(1.515)	(-1.262)	(-1.504)	(-1.442)	(1.365)	(1.571)	(-1.370)	(-1.466)	(-1.579)
0.5	0.086	−0.102***	0.241	−0.199	−0.245	−0.279	0.415	0.042	−0.055	−0.087	−0.042
	(0.053)	(-3.648)	(1.373)	(-1.440)	(-1.454)	(-1.487)	(1.568)	(1.348)	(-1.361)	(-1.263)	(-1.535)
0.6	0.035	−0.097***	0.193	−0.229	−0.244	−0.223	0.536	0.051	−0.079	−0.090	−0.045
	(0.078)	(-4.430)	(1.576)	(-1.537)	(-1.418)	(-1.247)	(1.514)	(1.517)	(-1.499)	(-1.288)	(-1.553)
0.7	0.086	−0.145***	0.208***	−0.241***	−0.231***	−0.256***	0.412***	0.038***	−0.055***	−0.087***	−0.033***
	(0.053)	(-4.740)	(4.737)	(-4.997)	(-3.082)	(-4.850)	(4.751)	(3.170)	(-3.153)	(-4.346)	(-4.454)
0.8	0.069	−0.092***	0.195***	−0.275***	−0.215***	−0.209***	0.429***	0.094***	−0.080***	−0.090***	−0.041***
	(0.010)	(-4.844)	(3.942)	(-3.252)	(-4.734)	(-4.171)	(3.237)	(4.707)	(-4.303)	(-3.092)	(-4.220)
0.9	0.064	−0.091***	0.242***	−0.293***	−0.279***	−0.192***	0.428***	0.059***	−0.052***	−0.084***	−0.045***
	(0.043)	(-3.717)	(3.963)	(-3.259)	(-4.453)	(-4.958)	(4.221)	(3.550)	(-4.252)	(-4.133)	(-3.319)
0.95	0.045	−0.107***	0.205***	−0.273***	−0.241***	−0.292***	0.427***	0.094***	−0.095***	−0.067***	−0.046***
	(0.069)	(-4.561)	(3.267)	(-4.501)	(-4.260)	(-4.859)	(4.252)	(4.057)	(-3.314)	(-4.277)	(-3.396)

Note: ***, $p < 0{,}01$. "Source: Author Estimations".

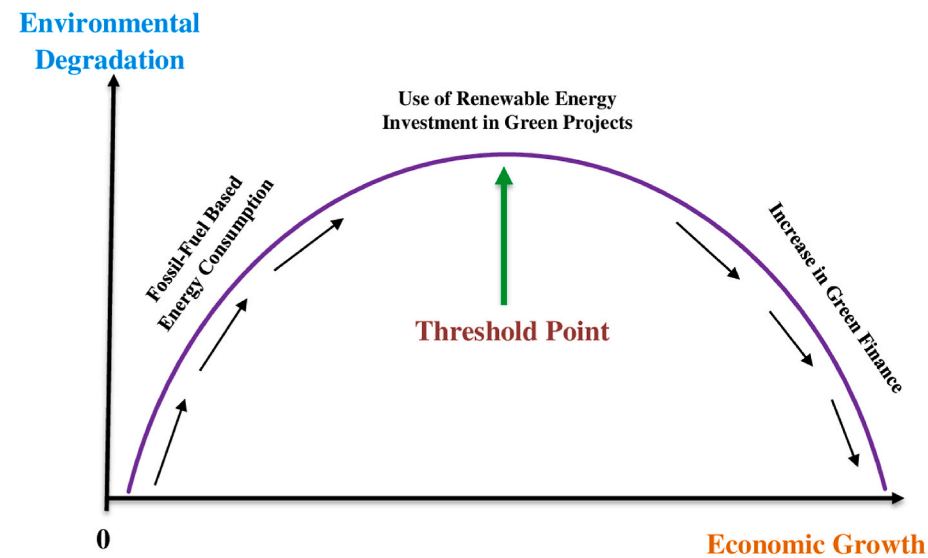

Fig. 7. Environmental Kuznets curve in Malaysian Economy
Produced By: Author.

Table 6
Results of quantile autoregressive distributed lag (QARDL) for ecological footprint.

Quantiles	Constant	ECM	Long-Run Estimation				Short-Run Estimation				
(τ)	$\alpha_*(\tau)$	$\rho_*(\tau)$	$\beta_{GDP}(\tau)$	$\beta^2_{GDP}(\tau)$	$\beta_{SFIN}(\tau)$	$\beta_{RENE}(\tau)$	$\varphi_1(\tau)$	$\omega_0(\tau)$	$\lambda_0(\tau)$	$\theta_0(\tau)$	$\acute{\epsilon}_0(\tau)$
0.05	0.074	−0.097***	0.266***	−0.211***	−0.258***	−0.231***	0.508***	0.068***	−0.081***	−0.057***	−0.035***
	(0.052)	(-4.265)	(4.347)	(-4.963)	(-4.828)	(-4.711)	(3.040)	(3.498)	(-4.269)	(-3.010)	(-3.170)
0.1	**0.041**	**−0.140*** **	**0.198*** **	**−0.201*** **	**−0.227*** **	**−0.213*** **	**0.092*** **	**0.088*** **	**−0.093*** **	**−0.079*** **	**−0.077*** **
	(0.043)	(-4.103)	(3.938)	(-4.458)	(-4.493)	(-4.634)	(3.434)	(4.857)	(-3.879)	(-3.964)	(-4.902)
0.2	**0.033**	**−0.146*** **	**0.197*** **	**−0.288*** **	**−0.255*** **	**−0.251*** **	**0.486*** **	**0.087*** **	**−0.097*** **	**−0.091*** **	**−0.072*** **
	(0.043)	(-4.419)	(4.118)	(-3.250)	(-3.152)	(-3.474)	(3.108)	(4.284)	(-3.741)	(-3.392)	(-4.070)
0.3	**0.044**	**−0.135*** **	**0.249**	**−0.293**	**−0.255**	**−0.207**	**0.501**	**0.074**	**−0.043**	**−0.069**	**−0.070**
	(0.058)	(-4.218)	(1.384)	(-1.276)	(-1.548)	(-1.529)	(1.569)	(1.502)	(-1.299)	(-1.365)	(-1.462)
0.4	**0.052**	**−0.099*** **	**0.259**	**−0.260**	**−0.274**	**−0.257**	**0.418**	**0.049**	**−0.049**	**−0.034**	**−0.078**
	(0.050)	(-4.925)	(1.263)	(-1.392)	(-1.261)	(-1.454)	(1.236)	(1.577)	(-1.305)	(-1.333)	(-1.358)
0.5	**0.083**	**−0.118*** **	**0.216**	**−0.259**	**−0.248**	**−0.246**	**0.511**	**0.083**	**−0.043**	**−0.043**	**−0.034**
	(0.046)	(-4.243)	(1.580)	(-1.360)	(-1.395)	(-1.289)	(1.298)	(1.537)	(-1.585)	(-1.340)	(-1.599)
0.6	**0.080**	**−0.103*** **	**0.212**	**−0.222**	**−0.256**	**−0.256**	**0.504**	**0.048**	**−0.031**	**−0.068**	**−0.065**
	(0.015)	(-4.706)	(1.333)	(-1.540)	(-1.435)	(-1.482)	(1.549)	(1.589)	(-1.530)	(-1.267)	(-1.596)
0.7	**0.065**	**−0.117*** **	**0.279*** **	**−0.255*** **	**−0.203*** **	**−0.207*** **	**0.412*** **	**0.051*** **	**−0.069*** **	**−0.072*** **	**−0.083*** **
	(0.083)	(-4.834)	(4.590)	(-3.300)	(-3.350)	(-4.565)	(4.004)	(4.698)	(-3.889)	(-4.340)	(-3.126)
0.8	**0.077**	**−0.140*** **	**0.227*** **	**−0.191*** **	**−0.239*** **	**−0.252*** **	**0.449*** **	**0.094*** **	**−0.070*** **	**−0.040*** **	**−0.037*** **
	(0.043)	(-3.344)	(3.043)	(-4.728)	(-3.864)	(-3.800)	(3.024)	(3.635)	(-3.366)	(-4.394)	(-4.782)
0.9	**0.073**	**−0.135*** **	**0.208*** **	**−0.239*** **	**−0.264*** **	**−0.221*** **	**0.506*** **	**0.046*** **	**−0.076*** **	**−0.073*** **	**−0.065*** **
	(0.085)	(-3.878)	(4.506)	(-4.589)	(-4.952)	(-3.831)	(4.322)	(4.656)	(-4.777)	(-4.029)	(-3.965)
0.95	**0.048**	**−0.125*** **	**0.220*** **	**−0.211*** **	**−0.254*** **	**−0.211*** **	**0.484*** **	**0.076*** **	**−0.035*** **	**−0.034*** **	**−0.098*** **
	(0.073)	(-3.884)	(3.321)	(-4.172)	(-4.149)	(-3.355)	(4.628)	(3.383)	(-3.641)	(-4.099)	(-3.437)

"Note: ***, $p < 0{,}01$.""Source: Author Estimations".

across the quantiles of 0.05 and 0.20, and also between 0.70 and 0.95.

On the other hand, except for the 30th, 40th, 50th, and 60th quantiles, the GDP^2 cointegration parameters signify the validity of the EKC hypothesis for Malaysia in the EFP model. The short-run validity of the EKC hypothesis is also among the results confirmed for the model. The EFP model's findings regarding the validity of the EKC hypothesis likewise show findings that are in line with the aforementioned papers. But, for the Malaysian economy, the short-run result differs from the results of Suki et al. [63], which supports its findings with the argument that it may take time for potential investments to translate into materialistic returns, and fails to establish the validity of the EKC in the short-run. It is possible that the advantage of the econometric approach used in the present paper reveals itself. The fact that QARDL, an advanced econometric technique, is likely to have enabled the validity of the hypothesis to be captured more easily by providing a detailed analysis for each quantile dynamic.

As far as SFIN is concerned in the EFP model, financial sustainability indicates a negative relationship with EFP in the long-run at the lower pollution levels of 0.05–0.20, and also higher pollution levels of 0.70–0.95. In parallel with the previous model of CO_2 emissions, the highest negative and statistically significant effect is observed in the 90th quantile, with the coefficient of −0.264. Middle quantiles such as 30th, 40th, 50th, and 60th are the quantile ranges in which we can observe no both long- and short-run effects of SFIN on EFP. However, the contemporaneous changes of SFIN on current changes in the value of EFP in the highest quantiles (70th-95th) are lower than the contemporaneous impacts of SFIN on current changes in the value of CO_2 emissions for the same quantiles. These findings suggest that the increase in SFIN promotes environmental quality by reducing ecological footprints.

Among the variables considered for the EFP model, the ultimate role of impact examined belongs to RENE. As seen from Table 5, RENE negatively influences EFP in Malaysia. The long-run effects are statistically significant at the lower level (0.05–020) and at the higher level (0.70–0.95) of EFP. The diminishing pollution effects of RENE are observed in the short-term as well as long-term. The negatively and significantly accumulated past and lagged value of RENE on the current and lagged level of EFP shows itself in the short-term, as in the quantiles with a significant relationship in the long-run. The magnitude of the short-run EFP-reducing effect of RENE is greater in the highest quantiles, unlike the CO2 model. The diminishing pollution effects of RENE is observed in the short and long term.

After performing the QARDL, the consistency in the both long- and short-run parameters in models of CO_2 emissions, and also EFP is tested employing the Wald test. Table 7 illustrates that the null hypothesis of the parameter constancy of the speed of adjustment is rejected at a 1 % significance level for the models of CO_2 emission and EFP. The asymmetric long-run effect of GDP, GDP^2, SFIN, and RENE on CO_2 emissions is proved by the Wald-statistics. From Tables 6 and it also seen that the cointegrating parameters for GDP, GDP^2, SFIN and RENE, and EFP are dynamic across the various quantiles. Similarly, in both empirical models, the short-run coefficients of GDP, GDP^2, SFIN, and RENE indicate the significant values of coefficients and have failed to accept the null hypothesis of linearity with CO_2, and also with EFP.

The analysis is finally completed with the Granger-causality in quantiles test by Troster [64], the results of which are depicted in Tables 8 and 9. The results of Table 8 present strong statistical evidence for bi-directional causal relationships among CO_2 emissions and GDP, SFIN, and RENE, separately, for all quantiles. The quantile-based causality results do not differ for the EFP model as in the previous model. As can be seen from Table 9, EFP has a two-way causality relationship with GDP, SFIN and RENE, supported by a high level of significance in all quantiles.

Overall results show that our findings are supported by the studies conducted by Ref. [49,50,61,62]. Bakry et al. [51], Rasoulinezhad & Taghizadeh-Hesary [52] and Liu [53] also found that green finance and renewable energy have a mitigating role in environmental degradation. However, we found some studies captured different results. For instance, the short-run outcome for the Malaysian economy is different with the study conducted by Suki et al. [63]. They do not confirm the EKC hypothesis in the short-run and claim that potential investments may take time to transform into tangible rewards.

Table 7
Results of the Wald Test for the constancy of parameters.

Variables	Wald-statistics CO2	Wald-statistics EFP
ρ	9.328*** [0.000]	17.078*** [0.000]
β_{GDP}	13.976*** [0.000]	13.877*** [0.000]
β_{GDP2}	12.003*** [0.000]	16.118*** [0.000]
β_{GFIN}	12.212*** [0.000]	10.654*** [0.000]
β_{RENE}	10.577*** [0.000]	15.590*** [0.000]
φ_1	17.834*** [0.000]	11.441*** [0.000]
ω_0	13.245*** [0.000]	11.679*** [0.000]
λ_0	17.964*** [0.000]	12.041*** [0.000]
θ_0	14.374*** [0.000]	16.623*** [0.000]
$\acute{\varepsilon}_0$	17.095*** [0.000]	12.720*** [0.000]

Note: ***, p < 0,01.

Table 8
Granger causality in quantile test results for carbon emissions.

Quantiles	$\Delta CO2_t$ ↓ ΔGDP_t	ΔGDP_t ↓ $\Delta CO2t$	$\Delta CO2t$ ↓ $\Delta SFIN_t$	$\Delta SFINt$ ↓ $\Delta CO2t$	$\Delta CO2t$ ↓ $\Delta RENE_t$	$\Delta RENE_t$ ↓ $\Delta CO2t$
[0.05–0.95]	0.008	0.008	0.006	0.004	0.001	0.003
0.05	0.010	0.006	0.004	0.003	0.004	0.001
0.1	0.010	0.009	0.005	0.006	0.009	0.004
0.2	0.006	0.006	0.007	0.009	0.004	0.001
0.3	0.002	0.005	0.001	0.004	0.008	0.009
0.4	0.004	0.003	0.010	0.002	0.009	0.009
0.5	0.006	0.003	0.003	0.006	0.006	0.007
0.6	0.002	0.004	0.001	0.005	0.008	0.009
0.7	0.008	0.004	0.001	0.008	0.005	0.002
0.8	0.007	0.004	0.006	0.004	0.009	0.008
0.9	0.007	0.005	0.002	0.007	0.008	0.008
0.95	0.004	0.007	0.002	0.008	0.001	0.008

Source: Authors Estimation.

Table 9
Granger causality in quantile test results for ecological footprint.

Quantiles	ΔEFP_t ↓ ΔGDP_t	ΔGDP_t ↓ $\Delta EFPt$	$\Delta EFPt$ ↓ $\Delta SFIN_t$	$\Delta SFINt$ ↓ $\Delta EFPt$	$\Delta EFPt$ ↓ $\Delta RENE_t$	$\Delta RENE_t$ ↓ $\Delta EFPt$
[0.05–0.95]	0.002	0.006	0.006	0.008	0.003	0.004
0.05	0.006	0.008	0.003	0.003	0.007	0.009
0.1	0.005	0.006	0.008	0.009	0.004	0.002
0.2	0.002	0.009	0.004	0.009	0.004	0.002
0.3	0.002	0.008	0.004	0.004	0.009	0.002
0.4	0.005	0.008	0.007	0.002	0.001	0.008
0.5	0.007	0.007	0.007	0.009	0.009	0.006
0.6	0.005	0.009	0.007	0.004	0.003	0.005
0.7	0.008	0.006	0.003	0.007	0.003	0.004
0.8	0.005	0.002	0.006	0.009	0.009	0.009
0.9	0.009	0.004	0.004	0.005	0.006	0.006
0.95	0.005	0.007	0.009	0.004	0.005	0.005

Source: Authors Estimation.

5. Conclusion and policy recommendations

One of the essential components of sustainable development is green finance, since a sound financial sector may improve the environmental [44,65]. Financial development stimulates the financial markets, economic growth, and sustainable development. However, the financial sector might lead to environmental pollution or environmental quality by affecting energy consumption patterns [66]. Similarly, this study is an attempt to investigate whether green financing might be one of the solutions for Malaysia to achieve net zero targets by 2050. In doing so, we investigate the impact of green finance, green energy, and income on environmental quality by using the data of Malaysia during 1990–2018. The empirical finding shows that green finance and green energy reduces the environmental degradation. The results also confirm the presence of EKC-hypothesis in Malaysian economy. These results suggest that green finance may be utilized as a policy instrument for combating the issue of climate change and achieving carbon neutrality targets in Malaysia.

As it is known, the financial market can mainly promote dirty investments and lead to higher environmental pollution through increasing energy consumption [10]. However, with a sound financial system, Malaysia has an advantage in tackling environmental issues. Since the advanced financial sector promotes businesses to use clean technology and provides resources for eco-friendly projects, countries with effective financial markets may have better environmental conditions [8,67]. In addition, financial development has a facilitating function for companies to access clean and advanced technology that increases energy efficiency and reduces environmental pollution [46] and encouraging domestic production and clean investments [68]. Therefore, Malaysia should realize more financial reforms to establish a low-carbon financial system. For instance, creating energy funds to support projects in clean energy could be among the solutions. However, the initial cost of clean energy remains high in many nations. For this reason, financial development has great importance for the advancement of renewable energy through financial services and technology [69]. Therefore, green finance can improve environmental quality by promoting renewable energy.

Malaysia has several disadvantages in terms of its economic growth structure. Economic growth still leads to higher environmental pollution in Malaysia. In addition, we capture the inverted-U shaped EKC hypothesis. Therefore, energy efficiency must be increased to moderate adverse effect of economic growth in Malaysia [70]. Loganathan et al. (2014) determined that the policy of carbon taxation is unsuccessful at reducing environmental pollution in Malaysia. Malaysia needs to produce long-term sustainable growth and taxation policies. Policymakers should also combine growth and environmental policies. In this way, transition to low-carbon economy could be started. Otherwise, Malaysia cannot reach its middle and long term targets: lowering the intensity of emissions by 45 % by 2030 and achieving carbon neutrality before 2050. In this context, promoting renewable energy is an essential hot topic for Malaysia like the other countries.

Malaysia's share of energy consumption reveals that Malaysia need more ambitious efforts to achieve net-zero target. According to Energy Institute (2023), in 2022, gas (36.76 %), oil (35.7 %) and coal (19.39 %) generate 91.85 % of primary energy consumption. However, hydropower (6.31 %), solar (0.53 %) and other renewables (0.27 %) constitutes only 7.11 % of primary energy consumption. The majority of the energy demand is still met by fossil-fuels in Malaysia. As a growing economy, energy demand has been increasing in Malaysia. These energy facts reveal that it would become more challenging to achieve the 2050 net-zero target unless Malaysian politicians do not take urgent action. Policymakers should focus on middle and long-term energy conversation and energy efficiency policies. Another challenge is that Malaysia has already achieved fossil fuel substitution from dirty to clean in a certain extent. What does this mean? As it is known, in addition to renewable energy policies, a conversion between fossil fuels can also be effective in reducing greenhouse gas emissions. What is meant by this conversation is that the transition from coal, the dirtiest fuel, to natural gas. When Malaysian energy consumption shares are examined, it is seen that natural gas consumption is 37 % and coal consumption is 19 %. In this case, achieving an additional emission reduction by switching from coal to natural gas is limited. However, coal consumption of 19 % is still very high and reducing it will make significant contributions to reducing emissions and achieving the net zero target.

The limitation of this study is not considering sub-components of green finance. By focusing green investments in detail and observing the most efficient mechanisms may indicate specific and attainable policies for countries. Using Fourier cointegration method, researchers may obtain empirical findings considering structural breaks. In this context, any paper examining the sub-components of green finance will contribute to the environmental sustainability literature.

CRediT authorship contribution statement

Arshian Sharif: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, preparation, Supervision, Project administration. **Emrah Sofuoglu:** Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, preparation. **Sinem Kocak:** Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, preparation. **Ahsan Anwar:** Conceptualization, Methodology, Writing – original draft, preparation, Supervision, Project administration, All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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