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Economic complexity and environmental sustainability in eastern European economy: Evidence from novel Fourier approach

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ABSTRACT

Globally, economies have become complex and new technologies have transformed and facilitated the modernization of economies. In the previous literature, economic complexity approach has become one of the popular tools in the development and innovation studies of economic geography. Researchers have found that green technology and eco-innovation approaches should be used to decisively reduce the effects of carbon emission on the environment. However, debates about the impact of economic complexity on environment remain unsettled since some emerging production technologies have far-reaching pollution effects. This study explored the impacts of economic complexity on environmental sustainability in Turkey using the novel Fourier-based approaches, namely: Fourier Augmented Dickey-Fuller (FADF) and Fourier autoregressive-distributed lag (FARDL) models. The Fourier-based approaches indicated that all variables (economic complexity index (ECI), GDP, energy consumption, and CO_2 emission (CO_2E)) are cointegrated in the long run. Additionally, the FARDL model implied that (i) in the long run, the effect of ECI (as a proxy for economic complexity), GDP (as a proxy for economic growth), and energy consumption on CO_2E (as a proxy for environmental quality) is important; (ii) economic complexity decreases environmental degradation in Turkey; and (iii) economic growth and energy consumption negatively affect environmental quality. The results also showed that economic complexity could be used as a policy tool to tackle environmental degradation. The findings also revealed that the fossil fuel-based economy will continue to expand and undermine Turkey's efforts to meet its net zero emission target by 2053. Therefore, policy-makers should take actions and establish diversified economic, environmental, and energ strategies. For policy insights, the Turkish governments can use the combination of tax exemptions and technical support systems to support knowledge creation and the diffusion of environmentally friendly technologies The governments can also impose strict environmental regulations on the knowledge development phases.

1. Introduction

Today, most nations are facing various impacts of intensified economic growth, including deteriorating health, food crisis, and global

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warming (He et al., 2021). Given these associated problems, environmental degradation has recently emerged at the forefront of global policy debates. Additionally, several international organizations have spoken out immensely against the difficulties produced by global warming, arguing that the difficulties are mostly connected to growth-related environmental damage (Can and Gozgor, 2017). Towards dealing with environmental degradation, global economy entities have committed to voluntarily communicating and transparently declaring their emission inventories. Historically, with little success in the delivery of the Kyoto Protocol in 1997 and the Copenhagen Accord in 2009, the Council of Parties COPs, 2015 was established at Paris (France) to lead the policy discussions of global climate. Instructively, some countries have forthwith agreed to regulate their growth-related pollution and control greenhouse gas emissions well below 2 °C (Ellis and Henderson, 2017; Pata, 2018a; Kirikkaleli et al., 2020; Sharif et al., 2020; Kirikkaleli and Adebayo, 2021; Shan et al., 2021; Abbasi et al., 2022a; Awan et al., 2022; Bandyopadhyay et al., 2022; Irfan et al., 2022; Zhang et al., 2022; Zhao et al., 2022; Zhou et al., 2022).

To improve environmental quality at regional scales, researchers found that economic complexity can serve as the most effective pathway. Economic complexity is used to refer to the complexity (including changes in approaches to production and their capability) of an economy in the growth trajectory. According to Becker and Murphy (1992), "complexity" entails various resources needed for a unit of production. At national scales, the complexity level is determined by knowledge diversity and their efficient application (Hausmann et al., 2014). Due to how energy and economic growth relate, economic complexity explains changes in carbon emissions at both national and global scales (Neagu and Teodoru, 2019). Economic Complexity Index (ECI) is viewed as a complete assessment economic progress of economies since it includes product variety, skill, education, and accessibility (Hidalgo and Hausmann, 2009). However, debates have occurred on whether the economic complexity of each nation is aiming to reducing pollution, given that cement, steel, and petrochemical production industries contribute to 30.00% of global greenhouse gas emissions and are difficult to abate. However, proponents argue that power plants could be redesigned to use residual process gas, or the efficiency of industrial processes could be improved to reduce emissions. Several scholars claim, economic complexity and environmental quality are interlinked; such that the initial stages of development focuses on the limited production of primary goods with less polluted intensity. However, as the level of knowledge advances, resources are exploited for higher production using technology, leading to environmental degradation. Eventually, the production structure and technologies (e.g., cleaner production) have changed, which thereafter help to reduce the externality of environmental pollution. To validate this claim about economic complexity, researchers in Turkey assess the nature and state of its development, sophistication, and pollution degrees (Yilanci and Pata, 2020; Chu, 2021).

With a population of 84.34×10^6, Turkey has recognized the scale of global environmental degradation and climate change as an emergency requiring policy action. The country has planned to neutralize carbon emissions, committed to Paris Agreement, and declared her plans towards realizing net zero emissions goal by 2053. Supporting the four core objectives of COP 26 at Glasgow (the United Kingdom), Turkey called for all nations' agreement on a more aggressive carbon-reduction plan. Towards catching up in the global race to net zero emissions' goal, the United Nations Development Programme (2021) has committed to assisting Turkey in meeting the new climate obligations and net zero emissions targets. In 2020, Turkey was the number 19th economy in the world for her GDP records (current USD); placed 29th in global exports; and ranked 23rd in total global imports. Its economy ranked 87th in GDP per capita (current USD) out of 127 economies, as one of the world's most complex economies. With very limited investments in research, development, and technology, Turkey witnessed a fall in export earnings (i.e., 2.08×10^{10} USD by the end of 2022), given an import value of 3.07×10^{10} USD, and recorded a negative trade balance of 0.90×10^{10} USD. On environmental performance, the country ranked the 176th in 2022 with an Environmental Performance Index (EPI) score of 26.30. EPI is a score of ecosystem vitality, health, and climate policy of economies. Air pollution is serious in Turkey, usually recorded from the transportation sector. For this reason, Etokakpan et al. (2020) warned that the rate of Turkey's economic progress requires serious controls to avoid environmental catastrophes. By investigating Turkey's long-term solutions to carbon emission, Pata (2018b) discovered that Turkeys rate of economic output does not mimic the Environmental Kuznets Curve (EKC) framework; although experts believe that renewable energy could reduce CO_2 emission (CO_2E) (Etokakpan et al., 2020; Chu, 2021).

Achieving net zero emission target is vital for the planet and future generations. However, while developed countries have the technological capacity and financial power to implement low-carbon policies, developing and less-developed countries still need support to mitigate carbon emissions. Reducing carbon emission in developed countries is insufficient for environmental sustainability since many developing countries are major emitters, such as India, Russia, Brazil, China, Mexico, and Turkey. Turkey is a rising star among developing countries in terms of economy, industrial capacity, and dynamic population. Therefore, as an important developing country, Turkey's achievement of reaching the net zero emission target will strengthen the international fight against the climate crisis. This paper contributes to the existing academic literature by demonstrating that developing countries could tackle environmental degradation by focusing on economic complexity in the case of Turkey. Turkey has declared many policies by submitting her Intended Nationally Determined Contributions report as required by the Paris Agreement. Towards fulfilling this obligation, Turkey has charged the energy, industry, transport, agriculture, and forestry minstries for the period 2021 to 2030 (UNFCCC, 2015 climate report). Governments generally explain their mitigation policies in these fields. However, emission gaps may emerge even if emission is decreased in these fields (Sofuoğlu and Kirikkaleli, 2022). This study argues that economic complexity could be used as policy tool to close carbon emission gaps of an economy.

The objective of this study is to discover whether it is possible for Turkey to use economic complexity as a policy tool towards achieving net zero emission target by 2053 as declared at COP 27 in the Arab Republic of Egypt. Based on the information above, this paper proposes specific policy implementations to mitigate carbon emissions by Turkey in 2030; and to similarly achieve net zero emissions target by 2053. The paper aims to augment discussions on linkages between economic complexity and environmental quality to help policy action. To achieve this objective, economic growth and energy use are controlled, since both have historically been found to impact on carbon emissions of an economy. Given that studies on economic complexity are limited, this paper is the first to evaluate correlations between the complexity of economies and environmental performance using Fourier Augmented Dickey-Fuller (FADF) and Fourier autoregressive-distributed lag cointegration (FARDL) models in Turkey.

2. Literature review

This section reviews studies on economic complexity, economic output, primary energy utilization, and carbon emission by investigating whether the complexity of Turkey could moderate carbon emissions, given its current rate of economic output and energy use.

2.1. Economic complexity and environment sustainability

Greenhouse gases and climate change are the developing apprehensions which have heightened attentiveness to environmental deprivation and its consequences. Several researchers have scrutinized the relationship between ECI and CO_2E. Towards verifying the EKC hypothesis in France, Can and Gozgor (2017) found that ECI can reduce CO_2E, contrary to the result found in European Union countries, where ECI increases CO_2E. Doğan et al. (2019) studied relations between ECI and CO_2E in the USA and validated the EKC hypothesis, indicating a U-shaped correlation between them. They similarly found that ECI raises CO_2E in low-income states but helps to lessen the negative environmental impact of developed economies. As reported by Boleti et al. (2019), ECI minimizes environmental pollution by improving certain air quality parameters, including illusive chemicals and CO_2E. Neagu and Teodoru (2019) studied ECI and fossil fuel consumption in a certain context, demonstrating an inconsistent impact on CO_2E. In this study to test the EKC hypothesis using relations between ECI and CO_2E in 6 European Union economies, Chu (2021) found that ECI exerts a positive effect on CO_2E and an inverted-U shape relations between ECI and CO_2E.

Although ECI provides comprehensive perspectives on the diversity of economy's export market and connectivity (Doğan et al., 2020), critics question the reliability of the claim (Caldarelli et al., 2012). ECI has vast knowledge of the advantages of 128 countries through comparative analysis of their export, which is a key advantage (Hidalgo and Hausmann, 2009). It is worth noting that ECI can describe cross-country disparities in GDP and predict financial activity. Abbasi et al. (2021) recently examined the relationship among ECI, tourism, GDP, and CO_2E using data from the top 18 economic complexity states during the period of 1990–2019. By using the cross-sectionally Autoregressive distributed lag (CS-ARDL) and Dumitrescu-Hurlin (DH) causality tests, they confirmed heterogeneity of cross-section-unit bond and panel slope; whereas there is long- and short-run relations among ECI, GDP, and CO_2E. Chu et al. (2023) found that while ECI initially leads to environment degeneration, it eventually improves environment quality in Emerging Seven (E7) countries. Another study indicated that both export quality and ECI promote sustainable growth in member countries of Organisation for Economic Co-operation and Development (Shahzad et al., 2022). The positive impact of ECI on environmental quality also was confirmed in both Group of Seven (Murshed et al., 2022) and Middle East and North Africa (MENA) countries (Saud et al., 2023).

2.2. Primary energy use and carbon emission

Studies analyzing relationship between energy usage and carbon emission have historically found relations between resource use and environmental pollution. Rahman (2020) discovered resource use in European Union to negative impact on CO_2E in in both G7 countries and Turkish economy by using Fully Modified Ordinary Least Squares approach. Using an ARDL model, scholars have found energy consumption has influence on carbon emission in both the short- and long-term in China, India, Turkey, and Indonesia (Ozturk and Acaravci, 2013; Shahbaz et al., 2013). Destek et al. (2016) investigated CO_2E in European Union countries, as well as 10 other Central and Eastern European (CEEC) nations, and suggested that these countries agree with the EKC hypothesis. According to outcomes of the FMOLS estimates, Destek et al. (2016) found that energy use intensify environmental pollution in the European Union. Furthermore, Dong et al. (2017) explored the nexus between energy use and CO_2E using Granger causality and Augmented Mean Group (AMG) estimators in Brazil, Russia, India, China, and South Africa (BRICS) from 1985 to 2016, and found two-way causality between energy use and CO_2E. Destek and Aslan (2020) used both AMG and panel bootstrap causality estimators to explore the multivariate relations among disaggregated renewable energy consumption, economic growth, and climate variation in G7 countries between 1991 and 2014. The outcomes indicated that a rise in green energy utilization results in falling CO_2E in France, Germany, Japan, and the United States. However, they found that any rise in hydroelectricity consumption had detrimental environmental consequences in Italy and Turkey. Bélaïd and Youssef (2017) employed the ARDL estimator to analyze green energy and nonrenewable energy use in Algeria between 1980 and 2012. The outcomes indicated that both renewable energy and nonrenewable energy use caused an increase in CO_2E. Further, Chen et al. (2019) revealed that coal and non-fossil fuel create a rise in carbon emissions in China from 1995 to 2012. More important, notwithstanding the relationship between energy utilization and carbon emission was significant for economy, the analysis failed to emphasize their impact on economic growth. Destek and Okumus (2019) investigated environmental pollution in 10 rising markets from 1982 to 2013 using real income, foreign direct investment, energy use, and ecological footprint using second-generation panel data. The outcomes indicated that both rising FDI and energy consumption led to an intensification of environmental pollution.

2.3. Economic growth and environmental pollution

Several studies have looked at the nexus between economic output and CO_2E (Usman et al., 2019; Iqbal et al., 2021; Abbasi et al., 2022b). The results continue to conflict, which might be attributed to methodological modifications, chronology, and national charactieritics. According to recent studies (Usman et al., 2019; Iqbal et al., 2021; Abbasi et al., 2022b; Addai et al., 2023), the outcomes are inconclusive. Some studies suggested unidirectional causation between economic output and CO_2E, while others indicated a bidirectional causal relationship between them. Akadiri et al. (2018) utilized bootstrap Granger causality approach to investigate tourism, globalization, GDP, and CO_2E in 16 islands from 1995 to 2014, and validated income and output assumptions in particular nations. The study additionally found a feedback effect between economic output and CO_2E. Cerdeira Bento and Moutinho (2016) revealed a linkage among CO_2E, green energy use and rising real GDP in Italy from 1960 to 2011, based on panel assimilation methodology (i.e., ARDL model). The outcomes indicated a negative connection among the selected variables in the short run. Further, Granger causality approach indicated a long-term and one-direction linkage between the rise of real GDP and CO_2E. Moreover, Iram et al. (2020) found that energy productivity is correlated with carbon emissions. They also found that economic output is linked to environmental productivity. Instructively, Katircioglu et al. (2020) investigated pollution associated with tourism in Northern Cypru (Turkey) from 1977 to 2015; and the ARDL model revealed that tourist activities have an acceptable and considerable but inelastic influence on CO_2E. Another study by Seetanah et al. (2019) on the impact of economic output and financial sector growth on environmental destruction in 12 islands from 2000 to 2016. While the outcomes validated the EKC hypothesis, it also indicated that GDP growth is negatively related to CO_2E. However, financial sector development has an indirect effect on carbon emissions during the period of 2000–2016.

Until now, there are no studies analyzing the implications of ECI, GDP growth, and energy consumption on environmental sustainability, especially in Turkey. Several previous studies (Abbasi et al., 2020, 2022b; Bandyopadhyay et al., 2022; Zheng et al., 2022) have identified the reasons for the environmental degradation in different countries and locations. Therefore, this research analyzes the effect of ECI, GDP, and energy consumption on CO_2E in Turkey.

3. Materials and methods

3.1. Data sources

This empirical research examined the linkage between economic complexity and environmental quality in Turkey, while controlling economic growth and energy use. CO_2E (as a proxy for environmental quality), economic complexity, GDP (as a proxy for economic growth), and energy consumption (EC) are included to the model. CO_2E serves as the highest emitting gas in greenhouse gas emission and is obtained from the World Bank database (https://data.worldbank). Energy consumption was obtained from Statistical World Review of Energy. Data of economic growth that serves as an economic and industrial activity determining the levels of CO_2E of an economy, were collected from the World Bank. ECI was sourced from Growth Lab (https://atlas.cid.harvard.edu/rankings). All variables were logged to avoid scaling issues. The detailed data sources and descriptive statistics of variables are reported in Tables 1 and 2, respectively.

3.2. Motivations for model development

Previous literature validated that the environment deteriorates with economic growth. Economy complexity explained the variations in increased income and economic growth trajectories and their implications on environmental degradation (Hidalgo and Hausmann, 2009). Several studies have found that environmental degradation is shaped by economic complexity and income is significant (e.g., Romero and Gramkow, 2021). Economic growth is completely enhanced by transforming from simple technologies to advance technological applications, and the impact of the complexity of economies on production technology has become a reality (Swart and Brinkmann, 2020). Given these theoretical and empirical expositions, this study adopted both the EKC hypothesis and the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) for the empirical model to be estimated. This is because, firstly, income and environmental degradation are related according to the EKC hypothesis. Secondly, environmental degradation is driven by population, rising income, and technology, according to the STIRPAT model. To assess effects of economic complexity on CO_2E in Turkey, this study controlled economic output and energy consumption as both of them are found to equally contribute to environmental degradation. The empirical model is shown in Equation (1):

$$CO_2E_t = ECI_t + GDP_t + EC_t + e_t, \tag{1}$$

where, EC stands for the energy consumption (J); t is the time; and e_t is the error term.

3.3. Augmented Dickey-Fuller (ADF) and Fourier ADF (FADF) unit root test

The integration order of interest variables was checked using the FADF unit root with breakpoints approach and the ADF model after

Table 1
Description of data sources.

Data	Source	Period
Per capita CO_2 emission (CO_2E; t)	https://ourworldindata.org/	1995–2020
Per capita GDP (USD)	https://data.worldbank.org/indicator/NY.GDP.PCAP.KD	
Energy consumption (J)	https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html	
Economic complexity index (ECI)	https://atlas.cid.harvard.edu/rankings	

Table 2
Descriptive statistics of CO_2E, ECI, energy consumption, and GDP.

Statistic	CO_2E (t)	ECI	EC (J)	GDP(USD)
Mean	10.54	–1.20	13.42	9.03
Median	10.65	–0.77	13.94	9.03
Maximum	10.87	–0.41	14.41	9.40
Minimum	8.54	–2.62	6.66	8.66
Standard deviation	0.44	0.78	1.89	0.25
Skewness	–3.86	–0.63	–3.07	0.14
Kurtosis	18.41	1.82	10.78	1.60
Jargue-Bera	321.66	3.23	106.42	2.21
Probability	0.00*	0.20	0.00*	0.33

Note: *, significance at 1% level.

reviewing the descriptive statistics. Time series of unit roots have historically been computed in a variety of ways by different researchers. If variables are integrated to varying degrees, it is impossible to test for cointegration with traditional cointegration methods. The paper uses unit root test of the FADF and ADF models as they can provide more reliable results than traditional approaches, allowing cointegration analysis regardless of integration order, i.e., I(0), I(1) or mixed (Becker et al., 2004; Enders and Lee, 2012). Even though the unit root with structural breaks test normally produces misleading results, bootstrapping does not (Enders and Lee, 2012). The null hypothesis (Eq. (2)) was formed to check unit roots for both the ADF model with breaks and FADF model:

$$x_t = \mu + P_{x-1} + e_t, \tag{2}$$

where, x_t is interest variables; μ is constant; and P_{x-1} is parameter slope(s) for lagged and dependent variables, and becomes 1 in case of unit root. The unit roots alternative to ADF and FADF models with break points are presented in Equations (3) and (4):

$$x_t = \mu + \delta\beta_t + \mathrm{DU}_t + \theta D(T_B)_t + e_t, \tag{3}$$

where, δ is the slope parameter for the structural break dummy; and β indicates the slope parameter for the trend. The null hypothesis in Equation (3) implies existence of unit root in x_t; implying that x_t is breakpoint stationary. In vase of one-break, DU_t is the indicator dummy variable for a mean shift which occurs at time T_B. Whenever a structural break occurs, T_B is the breakpoint; DU_t=1, if $t > T_B$ and DU_t=0, if otherwise. For the one-time break dummy, θ in Equation (3) is slope parameter. $D(T_B)$ is the corresponding trend shift variable; $D(T_B)_t$=1 if t=T_B and $D(T_B)_t$=0 if otherwise (Yaya et al., 2021).

$$x_t = \mu + \beta_t + \gamma_1 + \sin\left(\frac{2\pi kt}{N}\right) + \gamma_2 + \cos\left(\frac{2\pi kt}{N}\right) + e_t, \tag{4}$$

where, γ in the Fourier function is the slope parameter; γ_1 is amplitude of the frequency component; γ_2 is displacement of the frequency component; k is the Fourier frequency; N is the number of observations; and sin ($2\pi kt$) and cos ($2\pi kt$) capture breaks (or unattended nonlinearity) in the deterministic term, because Fourier expansion can approximate absolutely integrable functions with accuracy.

Having re-written these models in error correction form and by including the augmentation component (Yaya et al., 2021), we tested these equations for the FADF model with breaks and ADF model in Equations (5) and (6), respectively:

$$\Delta x_t = \mu + \beta_t + \gamma_1 \sin\left(\frac{2\pi kt}{N}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{N}\right) + (\rho - 1)x_{t-1} + \sum\nolimits_{i=1}^{\rho} c_i \Delta x_{t-1} + \varepsilon_t, \tag{5}$$

where, ρ is lag length for augmentation through the minimum information criteria; c is slope parameter of augmented components; and i ranges from 1 to ρ. Beckeret al. (2004) mentioned that selecting higher frequencies can create stochastic parameter variability, while low frequencies could interfere with the stationarity or nonstationarity test.

$$\Delta x_t = \mu + \beta_t \delta \mathrm{DU}_t + \theta D(T_B)_t + (\rho - 1)x_{t-1} + \sum\nolimits_{i=1}^{\rho} c_i \Delta x_{t-1} + \varepsilon_t. \tag{6}$$

Rejection of a null hypothesis does not mean the test or regression model is invalid. A model fitness test (F-statistic) is done as proposed by Furuoka (2017). When the structural break is absent, the ADF model regression is restricted. The FADF model considers structural breaks in the model. When there are breaks or structural changes, the spectral density function moves to zero frequencies.

3.4. Fourier autoregressive-distributed lag (FARDL) model

The FARDL model has been used by several researchers for many years. Recent investigations indicated that long-run relationships exist between positive and negative aspects of variables in FARDL model (Yilanci, 2019). Over the years, it has been found that variables are integrated through collective responses to shocks (Granger and Yoon, 2002). However, if variables behave differently when responding to economic shocks, they can be viewed as not integrated. The FARDL model provides an efficient and reliable interpretation of long-run equilibrium cointegration outcomes compared to the conventional ARDL model (McNown et al., 2018; Yilanci, 2019). The orthodox ARDL model allows for different integration orders. However, if stationarity is established at the first difference for the dependent variable, the bounds test (*F*- and *t*-statistics) is used for cointegration assessment (McNown et al., 2018). Pesaran et al. (2001), claim I(0) and I(1) are obtained from the for *F*- and *t*-statistical values. Valid conclusions about the *F*-statistic can be taken outside of the two critical bounds values; however, a threshold value must be set between the two bounds before judgments about cointegration can be reached.

The advantage with the bootstrap ARDL model is that critical values are based on the variable integration, which allows for the elimination of instabilities of bounds testing to determine the existence of cointegration using *F*-statistic (McNown et al., 2018). The bootstrap ARDL model was developed with critical values from bootstrap simulation, and by correctly applying resampling procedures, the bootstrap method yields better outcomes (Lin et al., 2018). With Fourier function, Yilanci and Pata (2020) detected structural variations within the model (Eq. (7)), as follows:

$$d(t) = \sum_{k=1}^{n} a_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} b_k \cos\left(\frac{2\pi kt}{T}\right), \tag{7}$$

where, $d(t)$ is a deterministic term; n indicates the total number of frequencies; a and b show the traditional different deterministic terms, including a constant with or without a linear term; and T is sample size. Single frequency value is used (Becker et al., 2006) as in Equation (8).

$$d(t) = \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right). \tag{8}$$

FARDL model for this study is (Eq. (9)).

$$\begin{aligned}\Delta CO_{2(t)} &= \beta_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \sin\left(\frac{2\pi kt}{T}\right) + \beta_1 \mathrm{CO}_{2(t-1)} + \beta_2 \mathrm{ECI}_{t-1} + \beta_3 \mathrm{GDP}_{t-1} + \beta_4 \mathrm{EC}_{t-1} \\ &+ \sum_{i-1}^{\rho-1} \varphi_i' \Delta \mathrm{CO}_{2(t-i)} + \sum_{i-1}^{\rho-1} \delta_i' \Delta \mathrm{ECI}_{t-i} + \sum_{i-1}^{\rho-1} \varphi_i' \Delta \mathrm{GDP}_{t-i} + + \sum_{i-1}^{\rho-1} \vartheta_i' \Delta \mathrm{EC}_{t-1} + e_t,\end{aligned} \tag{9}$$

where, the FARDL model is estimated using k values in the increments of 0.1 ($0 \leq k \leq 5$), and k is "the minimum sum of squared residuals, since Christopoulos and Leon-Ledesma (2011) suggested that integer frequencies imply temporary breaks while fractional frequencies imply permanent breaks". β_0 is constant term;, β_1, β_2, β_3, and β_4 are the coefficients of CO_2E, ECI, GDP, and energy consumption, respectively; and φ, δ, ϕ, and ϑ represent the coefficients of ΔCO_2E, ΔECI, ΔGDP, and ΔEC (energy consumption), respectively, The details of the FARDL model can be found in See Solarin (2019). The FARDL model is chosen since it can detect hidden nonlinearities in time series, including structural changes. Additionally, since hidden breaks and structural changes cause the spectral density functions to move to zero frequency, the approach utilizes low-frequency aspects of the Fourier approximation. This method also captures robust results in small samples.

In addition, this study used the Dynamic Ordinary Least Squares approach to determine the validity of the FARDL model.

4. Results and discussion

This empirical research examined linkages among CO_2E, ECI, GDP, and energy consumption in Turkey between 1995 and 2020 by applying the FARDL and ADF models. The FADF unit root test was the first to be applied to achieve the stated objectives. However, the outcomes indicated that the Fourier trigonometric terms are insignificant because ECI and GDP values are smaller than the critical values (Enders and Lee, 2012). Given these results, the paper applied a unit root test of the conventional ADF model suggested by Enders and Lee (2012; Table 3).

According to the test results of the ADF model, all variables except ECI were stationary at first difference. Only ECI was stationary at both level and first difference levels. To do bounds test of the FARDL model, the dependent variable must be established as stationary at first difference. The outcome, therefore, implied that long-run cointegration can be estimated. Table 4 shows the results of the FARDL model.

Outcomes of the FARDL estimates indicate that the F_a, T, and F_b statistics appear larger than the bootstrap critical values. This finding indicated that variables are, in the long run, cointegrated in Turkey. Given this result, the study further examined the long-term coefficients to explore the impact of independent variables (CEI, GDP, and energy consumption) on the dependent variable (CO_2E). Table 5

Table 3
Unit root test results of Fourier Augmented Dickey-Fuller (FADF) and Augmented Dickey-Fuller (ADF) models.

Variable	Frequency	FADF model	*F*-statistic	ADF model (level)	ADF model (at first difference)
CO_2E	1	–3.04	14.72*	0.11	–6.16*
ECI	1	0.99	0.36	–2.84*	–4.17*
GDP	3	0.33	0.41	2.39	–2.26**
Energy consumption	5	–5.44	17.17*	–0.18	–5.62*

Note: Critical values of the FADF model are 12.21, 9.14, and 7.78 at 10%, 5%, and 1% significance levels, respectively.
*, significance at the 1% level; **, significance at the 5% level.

shows the long-run estimated coefficients.

As clearly underlined in Ozgur et al. (2022), Addai et al. (2023), and Kirikkaleli (2023), the FARDL model provides efficient and reliable interpretation of long-run cointegration outcomes compared to the conventional ARDL model. The outcomes indicated that although ECI exerts a negative effect on CO_2E, both GDP and energy consumption increase CO_2E. This implied that a unit rise in GDP results in 0.85% increase in CO_2E. This result was consistent with the recent studies of Ahmed et al. (2022) and Mohsin et al. (2022). Similarly, a unit investment in energy consumption culminated in 0.20% rise in CO_2E. This outcome supported the early empirical findings of Haldar and Sethi (2021), Sahoo and Sahoo (2022), and Mukhtarov et al. (2023). These empirical outcomes were discussed in detail following the robust model tests.

Based on the findings, ECI had a negative effect on CO_2E. This meant that Turkey is progressing in its commitment to reducing carbon emissions as required by the UNFCC. Since 2012, Turkey has instituted regulatory measures for emission reduction and investment holding. Accordingly, all corporations must submit carbon footprint inventories to the governments. Additionally, Turkey formulated measures on alternative energy sourcing with several incentives, feed-in tariff measures, and funding to accelerate investment projects in renewable energy. Further, the government of Turkey established a carbon emission trading system as part of its overall energy strategies until 2023. This was a parallel measure to renewable energy investments. However, Turkey was yet to sign the Paris Agreement, the country committed to a 21.00% reduction of carbon emissions by 2030 through its Nationally Determined Contributions (NDCs) actions.

These revealing outcomes and recent practical policy actions by Turkey were significant. Available records indicated that notwithstanding the economic crisis and 10.00% unemployment rate in 2001, the Turkish economy has tripled amidst heavy investments in research and industry. Given the current emission trajectory, Turkey was warned to take serious emission measures through its NDCs actions. Available records showed that under a business-as-usual scenario, Turkey's carbon emission is estimated to triple from 430 $MtCO_2E$ in 2012 to 1175 $MtCO_2E$ in 2030. Given that ECI reduces carbon emission, Turkey can heavily invest in ECI if the country wants to meet the targets of the Paris Agreement of reducing carbon emission to 929 $MtCO_2E$ by 2030.

Similarly, energy consumption was generally validated positively affect CO_2E worldwide. The estimates indicated that Turkey's GDP and energy consumption led to increases in CO_2E, which support to several theories and empirical outcomes (e.g., Alola et al., 2019). This means positive shocks in GDP and energy consumption badly affect environmental quality in both the short- and long-run equilibrium, implying that Turkey should ensure the integration of GDP, environment, and energy policies. The government of Turkey can assist corporations in exploring renewable energy sourcing and to improve technology applications. To achieve SDG 7 of the United Nations, it is necessary for Turkey to find substitutes for fossil fuel consumption. Policy actions and projects are needed in areas such as greener and cleaner growth, job creation, and economic progress.

Research, development and innovative activities promote production of sophisticated and complicated products, which are linked to economic complexity. Therefore, increasing complexity means high level of technology and energy efficiency. Considering the positive impact of economic complexity, the outcomes are novel and promising. Improvements in economic complexity could promote structural economic restructuring (Neagu and Teodoru, 2019). When formulating its energy and economic policies, Turkey must consider the products' complexity and how they are manufactured. Such creative approaches might assist in achieving the nation's policy commitments to a greener environment, as well as avoiding climate crisis.

The FMOLS, DOLS and Canonical Cointegrating Regression (CCR) estimation results were generally similar to the FARDL model as the coefficient of ECI was negatively related to CO_2E; while GDP was positively related to CO_2E (Table 6). However, the coefficient of energy consumption was insignificant. The overall outcomes showed that although economic output has exacerbated environmental destruction, an increase in economic complexity could ameliorate it. Further, considering the three test results, it can be concluded that empirical results are robust and consistent.

5. Conclusions and implications

This study has assessed economic complexity and energy use effects of on environmental quality in Turkey from 1995 to 2020. The study was carried out to illustrate the contribution of economic complexity as key determinant factor of environmental quality in Turkey, using the FADF and FARDL models. The primary objectives for using the FARDL model were to detect long-run equilibrium relations among the four interest variables (i.e., CO_2E, ECI, GDP, and energy consumption). FARDL estimates indicated that: (i) in the long run, the effect of economic complexity, economic output, and energy consumption on environmental sustainability is important; (ii) economic complexity decreases environmental destruction in Turkey; and (iii) both economic output and energy use negatively affect the quality of the environment of Turkey. The outcomes of the traditional cointegration estimator (the ADF model) supported the

Table 4
Bounds test results of the Fourier autoregressive-distributed lag (FARDL) model.

Statistic	Frequency	Bootstrap critical value		
		10%	5%	1%
F_a	8.51**	3.80	5.12	8.06
T	–4.16**	–2.67	–3.18	–4.21
F_b	9.43***	4.09	5.57	8.90

Note: *, significance at the 1% level; **, significance at the 5% level; *** significance at the 10% level. F_a, the lagged value of the dependent and independent variables; F_b, the lagged value of the dependent variable; T, the lagged value of the independent variable.

Table 5
Long-run estimation results based on the FARDL model.

	ECI	GDP	Energy consumption
Coefficient	–0.23*	0.85*	0.20*
P-value	0.04	0.00	0.01

Note: *, significance at the 1% level. CEI, GDP, and energy consumption are the independent variables, and CO_2E is the dependent variable.

Table 6
Robustness check results of the independent variables.

	FMOLS			DOLS			CCR		
	ECI	GDP	Energy consumption	ECI	GDP	Energy consumption	ECI	GDP	Energy consumption
Coefficient	–0.25***	1.11*	0.01	–0.26*	0.87*	0.17**	–0.23	2.13*	–0.66*
P-value	0.08	0.00	0.80	0.03	0.00	0.02	0.10***	0.00	0.00

Note: *, significance at the 1% level; **, significance at the 5% level; ***, significance at the 10% level; FMOLS, Fully Modified Ordinary Least Square; DOLS, Dynamic Ordinary Least Squares; CCR, Canonical Cointegrating Regression.

outcomes of the FARDL model in this study. Turkey could assure sustainable growth by considering strategic energy policies. Further, a tax exemption or financial support system could be used by the Turkish government to support knowledge creation and diffusion of environmentally friendly technologies. It is vital that during the knowledge development process, the government could implement strict environmental regulations. It is possible to improve environmental quality by investing in cleaner production and green energy sourcing policies. Moreover, promoting renewable energy will also help to mitigate environmental pollution and ease achieve net zero emission target. In addition, policy-makers should declare long-term policies to subsidy clean technologies in Turkey, such as environmental patents, research and development activities, and energy efficiency. Financial institutions could allocate loans to energy-efficient projects, as well as commit more funding to renewable energy and clean energy projects to increase environmental sustainability. Therefore, green financing was another policy option to increase clean energy investments and trigger positive resilience of economic complexity.

Towards realizing sustainable development goals and net zero emission targets, Turkey needs to increase economic welfare and reduce emissions. An absolute decoupling between economic output and carbon emission is required in this case. Yet, achieving these goals is challenging, given Turkey's current fossil fuel policies. Turkey ratified the Paris Agreement before COP 26 and announced its net zero emission target in 2053. In this context, it prepared a roadmap for COP 27 in 2022 and updated its NDCs. Accordingly, after increasing emissions until 2030, Turkey has committed to achieving a net zero emission target in 2053. Unfortunately, it was unlikely to transition to a net zero emission target by 2053 since the economy and fossil fuel consumption will expand more. Furthermore, a fossil-based economy will continue to grow and make it more difficult to achieve the net zero emission target. Therefore, Turkey needs to review and adjust its medium and long-term economy, environment, and energy policies. In this way, the country will not miss the opportunity to move to a low-carbon economy. In this case, economic complexity might be one of the policy tools for Turkey to achieve its net zero emission target by 2053.

Authorship contribution statement

Emrah Sofuoğlu: conceptualization, formal analysis, software, data curation, investigation, and writing-original draft preparation. Kwaku Addai: writing-original draf and resources. Kashif Raza Abbasi: writing-original draft and Visualization. Dervis Kirikkaleli: writing-original draft, methodology, project administration, and supervision.

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.

References

Abbasi, K.R., Hussain, K., Abbas, J., et al., 2020. Analyzing the role of industrial sector's electricity consumption, prices, and GDP: a modified empirical evidence from Pakistan. Aims Energy 9, 21–49.
Abbasi, K.R., Lv, K., Radulescu, M., et al., 2021. Economic complexity, tourism, energy prices, and environmental degradation in the top economic complexity countries: fresh panel evidence. Environ. Sci. Pollut. Res. 28, 68717–68731.
Abbasi, K.R., Kirikkaleli, D., Altuntaş, M., 2022a. Carbon dioxide intensity of GDP and environmental degradation in an emerging country. Environ. Sci. Pollut. Res. 29 (56), 84451–84459.
Abbasi, K.R., Shahbaz, M., Zhang, J., et al., 2022b. Analyze the environmental sustainability factors of China: the role of fossil fuel energy and renewable energy. Renew. Energy 187, 390–402.
Addai, K., Genç, S.Y., Castanho, R.A., et al., 2023. Financial risk and environmental sustainability in Poland: evidence from novel Fourier-based estimators. Sustainability 15 (7), 5801. https://doi.org/10.3390/su15075801.

Ahmed, Z., Cary, M., Ali, S., et al., 2022. Moving toward a green revolution in Japan: symmetric and asymmetric relationships among clean energy technology development investments, economic growth, and CO_2 emissions. Energy Environ. 33 (7), 1417–1440.
Akadiri, S.S., Lasisi, T.T., Uzuner, G., et al., 2018. Examining the causal impacts of tourism, globalization, economic growth and carbon emissions in tourism island territories: bootstrap panel Granger causality analysis. Curr. Issues Tourism 23, 470–484.
Alola, A.A., Bekun, F.V., Sarkodie, S.A., 2019. Dynamic impact of trade policy, economic growth, fertility rate, renewable and nonrenewable energy consumption on ecological footprint in Europe. Sci. Total Environ. 685, 702–709.
Awan, A., Abbasi, K.R., Rej, S., et al., 2022. The impact of renewable energy, internet use and foreign direct investment on carbon dioxide emissions: a method of moments quantile analysis. Renew. Energy 189, 454–466.
Bandyopadhyay, A., Rej, S., Abbasi, K.R., et al., 2022. Nexus between tourism, hydropower, and CO_2 emissions in India: fresh insights from ARDL and cumulative fourier frequency domain causality. Environ. Dev. Sustain. 1–25.
Becker, G.S., Murphy, K.M., 1992. The division of labor, coordination costs, and knowledge. Q. J. Econ. 107 (4), 1137–1160.
Becker, R., Enders, W., Hurn, S., 2004. A general test for time dependence in parameters. J. Appl. Econom. 19 (7), 899–906.
Becker, R., Enders, W., Lee, J., 2006. A stationarity test in the presence of an unknown number of smooth breaks. J. Time Ser. Anal. 27 (3), 381–409.
Bélaïd, F., Youssef, M., 2017. Environmental degradation, renewable and nonrenewable electricity consumption, and economic growth: assessing the evidence from Algeria. Energy Pol. 102, 277–287.
Boleti, E., Garas, A., Kyriakao, A., et al., 2019. Economic complexity and environmental performance: evidence from a world sample. Environ. Model. Assess. 26, 251–270.
Caldarelli, G., Cristelli, M., Gabrielli, A., et al., 2012. A network analysis of countries' export flows: firm grounds for the building blocks of the economy. PLoS One 7 (10), 1–11.
Can, M., Gozgor, G., 2017. The impact of economic complexity on carbon emissions: evidence from France. Environ. Sci. Pollut. Res. 24, 16364–16370.
Cerdeira Bento, J.P., Moutinho, V., 2016. CO_2 emissions, nonrenewable and renewable electricity production, economic growth, and international trade in Italy. Renew. Sustain. Energy Rev. 55, 142–155.
Chen, Y., Wang, Z., Zhong, Z.Q., 2019. CO_2 emissions, economic growth, renewable and nonrenewable energy production and foreign trade in China. Renew. Energy 131, 208–216.
Christopoulos, D.K., Leon-Ledesma, M.A., 2011. International output convergence, breaks, and asymmetric adjustment. Stud. Nonlinear Dynam. Econom. 15 (3), 1–33.
Chu, L.K., 2021. Economic structure and environmental Kuznets curve hypothesis: new evidence from economic complexity. Appl. Econ. Lett. 28 (7), 612–616.
Chu, L.K., Doğan, B., Abakah, E.J.A., et al., 2023. Impact of economic policy uncertainty, geopolitical risk, and economic complexity on carbon emissions and ecological footprint: an investigation of the E7 countries. Environ. Sci. Pollut. Res. 30 (12), 34406–34427.
Destek, M.A., Balli, E., Manga, M., 2016. The relationship between CO_2 emission, energy consumption, urbanization and trade openness for selected CEECs. Res. World Econ. 7 (1), 52–58.
Destek, M.A., Okumus, I., 2019. Does pollution haven hypothesis hold in newly industrialized countries? Evidence from ecological footprint. Environ. Sci. Pollut. Res. 26, 23689–23695.
Destek, M.A., Aslan, A., 2020. Disaggregated renewable energy consumption and environmental pollution nexus in G-7 countries. Renew. Energy 151, 1298–1306.
Doğan, B., Saboori, B., Can, M., 2019. Does economic complexity matter for environmental degradation? An empirical analysis for different stages of development. Environ. Sci. Pollut. Res. 26, 31900–31912.
Doğan, B., Driha, O.M., Balsalobre Lorente, D., et al., 2020. The mitigating effects of economic complexity and renewable energy on carbon emissions in developed countries. Sustain. Dev. 29 (1), 1–12.
Dong, K., Sun, R.J., Hochman, G., 2017. Do natural gas and renewable energy consumption lead to less CO_2 emission? Empirical evidence from a panel of BRICS countries. Energy 141, 1466–1478.
Ellis, H., Henderson, K., 2017. The climate change challenge. Rebuilding Britain 55–64.
Enders, W., Lee, J., 2012. The flexible Fourier form and Dickey–Fuller type unit root tests. Econ. Lett. 117 (1), 196–199.
Etokakpan, M.U., Adedoyin, F.F., Vedat, Y., et al., 2020. Does globalization in Turkey induce increased energy consumption: insights into its environmental pros and cons. Environ. Sci. Pollut. Res. 27, 26125–26140.
Furuoka, F., 2017. A new approach to testing unemployment hysteresis. Empir. Econ. 53 (3), 1253–1280.
Granger, C.W., Yoon, G., 2002. Hidden Cointegration. University of California at San Diego, California, pp. 1–48.
Haldar, A., Sethi, N., 2021. Effect of institutional quality and renewable energy consumption on CO_2 emissions−an empirical investigation for developing countries. Environ. Sci. Pollut. Res. 28 (12), 15485–15503.
Hausmann, R., Hidalgo, C.A., Bustos, S., et al., 2014. The Atlas of Economic Complexity: Mapping Paths to Prosperity. Massachusetts Institute of Technology (MIT) Press, Massachusetts, pp. 1–69.
He, K., Ramzan, M., Awosusi, A.A., et al., 2021. Does globalization moderate the effect of economic complexity on CO_2 Emissions? Evidence from the top 10 energy transition economies. Front. Environ. Sci. 9, 778088. https://doi.org/10.3389/fenvs.2021.778088.
Hidalgo, A., Hausmann, R., 2009. The building blocks of economic complexity. Proc. Natl. Acad. Sci. USA 106 (26), 10570–10575.
Iqbal, N., Abbasi, K.R., Shinwari, R., et al., 2021. Does exports diversification and environmental innovation achieve carbon neutrality target of OECD economies? J. Environ. Manag. 291, 112648. https://doi.org/10.1016/j.jenvman.2021.112648.
Iram, R., Zhang, J.J., Erdogan, S., et al., 2020. Economics of energy and environmental efficiency: evidence from OECD countries. Environ. Sci. Pollut. Res. 27, 3858–3870.
Irfan, M., Salem, S., Ahmad, M., et al., 2022. Interventions for the current COVID-19 pandemic: frontline workers' intention to use personal protective equipment. Front. Public Health 9, 1–11.
Katircioglu, S., Saqib, N., Katircioglu, S., et al., 2020. Estimating the effects of tourism growth on emission pollutants: empirical evidence from a small island, Cyprus. Air Qual. Atmos. Health. 13, 391–397.
Kirikkaleli, D., Adedoyin, F.F., Bekun, F.V., 2020. Nuclear energy consumption and economic growth in the UK: evidence from wavelet coherence approach. J. Publ. Aff. 1–11.
Kirikkaleli, D., Adebayo, T.S., 2021. Do public-private partnerships in energy and renewable energy consumption matter for consumption-based carbon dioxide emissions in India? Environ. Sci. Pollut. Res. 28, 30139–30152.
Kirikkaleli, D., 2023. Does environmental tax matter for environmental degradation in The Netherlands? Evidence from novel Fourier-based estimators. Environ. Sci. Pollut. Res. 30, 57481–57489.
Lin, F.L., Inglesi-Lotz, R., Chang, T., 2018. Revisit coal consumption, CO_2 emissions and economic growth nexus in China and India using a newly developed bootstrap ARDL bound test. Energy Explor. Exploit. 36 (3), 450–463.
McNown, R., Sam, C.Y., Goh, S.K., 2018. Bootstrapping the autoregressive distributed lag test for cointegration. Appl. Econ. 50 (13), 1509–1521.
Mohsin, M., Naseem, S., Sarfraz, M., et al., 2022. Assessing the effects of fuel energy consumption, foreign direct investment and GDP on CO_2 emission: new data science evidence from Europe & Central Asia. Fuel 314, 123098. https://doi.org/10.1016/j.fuel.2021.123098.
Mukhtarov, S., Aliyev, F., Aliyev, J., et al., 2023. Renewable energy consumption and carbon emissions: evidence from an oil-rich economy. Sustainability 15 (1), 134. https://doi.org/10.3390/su15010134.
Murshed, M., Saboori, B., Madaleno, M., et al., 2022. Exploring the nexuses between nuclear energy, renewable energy, and carbon dioxide emissions: the role of economic complexity in the G7 countries. Renew. Energy 190, 664–674.
Neagu, O., Teodoru, M.C., 2019. The relationship between economic complexity, energy consumption structure and greenhouse gas emission: heterogeneous panel evidence from the EU countries. Sustainability 11 (2), 497. https://doi.org/10.3390/su11020497.
Ozgur, O., Yilanci, V., Kongkuah, M., 2022. Nuclear energy consumption and CO_2 emissions in India: evidence from Fourier ARDL bounds test approach. Nucl. Eng. Technol. 54 (5), 1657–1663.

Ozturk, I., Acaravci, A., 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ. 36, 262–267.
Pata, U.K., 2018a. The influence of coal and noncarbohydrate energy consumption on CO_2 emissions: revisiting the environmental Kuznets curve hypothesis for Turkey. Energy 160, 1115–1123.
Pata, U.K., 2018b. Renewable energy consumption, urbanization, financial development, income and CO_2 emissions in Turkey: testing EKC hypothesis with structural breaks. J. Clean. Prod. 187, 770–779.
Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. J. Appl. Econometrics 16 (3), 289–326.
Rahman, M.M., 2020. Environmental degradation: the role of electricity consumption, economic growth and globalisation. J. Environ. Manag. 253, 109742. https://doi.org/10.1016/j.jenvman.2019.109742.
Romero, J.P., Gramkow, C., 2021. Economic complexity and greenhouse gas emissions. World Dev. 139, 105317. https://doi.org/10.1016/j.worlddev.2020.105317.
Sahoo, M., Sahoo, J., 2022. Effects of renewable and nonrenewable energy consumption on CO_2 emissions in India: empirical evidence from disaggregated data analysis. J. Publ. Aff. 22 (1), e2307. https://doi.org/10.1002/pa.2307.
Saud, S., Haseeb, A., Zafar, M.W., et al., 2023. Articulating natural resource abundance, economic complexity, education and environmental sustainability in MENA countries: evidence from advanced panel estimation. Resour. Pol. 80, 103261. https://doi.org/10.1016/j.resourpol.2022.103261.
Seetanah, B., Sannassee, R.V., Fauzel, S., et al., 2019. Impact of economic and financial development on environmental degradation: evidence from small island developing states (SIDS). Emerg. Mark. Finance Trade 55 (2), 308–322.
Shahbaz, M., Hye, Q.M.A., Tiwari, A.K., et al., 2013. Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renew. Sustain. Energy Rev. 25, 109–121.
Shahzad, U., Madaleno, M., Dagar, V., et al., 2022. Exploring the role of export product quality and economic complexity for economic progress of developed economies: does institutional quality matter? Struct. Change Econ. Dynam. 62, 40–51.
Shan, S., Genç, S.Y., Kamran, H.W., et al., 2021. Role of green technology innovation and renewable energy in carbon neutrality: a sustainable investigation from Turkey. J. Environ. Manag. 294, 113004. https://doi.org/10.1016/j.jenvman.2021.113004.
Sharif, A., Baris-Tuzemen, O., Uzuner, G., et al., 2020. Revisiting the role of renewable and nonrenewable energy consumption on Turkey's ecological footprint: evidence from Quantile ARDL approach. Sustain. Cities Soc. 57, 102138. https://doi.org/10.1016/j.scs.2020.102138.
Sofuoğlu, E., Kirikkaleli, D., 2022. Towards achieving net zero emission targets and sustainable development goals, can long-term material footprint strategies be a useful tool? Environ. Sci. Pollut. Res. 30 (10), 26636–26649.
Solarin, S.A., 2019. Modelling the relationship between financing by Islamic banking system and environmental quality: evidence from bootstrap autoregressive distributive lag with Fourier terms. Qual. Quantity 53 (6), 2867–2884.
Swart, J., Brinkmann, L., 2020. Economic complexity and the environment: evidence from Brazil. In: Leal Filho, W., Tortato, U., Frankenberger, F. (Eds.), Universities and Sustainable Communities: Meeting the Goals of the Agenda 2030. Springer International Publishing, Cham, pp. 3–45.
UNDP (United Nations Development Program), 2021. Ankara event discussed the need for urgent climate action ahead of COP26 in Glasgow united nations development Programme [2023-06-17]. UNDP. https://www.undp.org/turkiye/press-releases/ankara-event-discussed-need-urgent-climate-action-ahead-cop26-glasgow.
UNFCCC (United Nations Framework Convention on Climate Change), 2015. Republic of Turkey intended nationally determined contribution [2023-06-17]. https://unfccc.int/sites/default/files/NDC/2022-06/The_INDC_of_TURKEY_v.15.19.30.pdf.
Usman, O., Elsalih, O., Koshadh, O., 2019. Environmental performance and tourism development in EU-28 Countries: the role of institutional quality. Curr. Issues Tourism 23 (17), 2103–2108.
Yaya, O.S., Ogbonna, A.E., Mudida, R., et al., 2021. Market efficiency and volatility persistence of cryptocurrency during pre-and post-crash periods of Bitcoin: evidence based on fractional integration. Int. J. Financ. Econ. 26 (1), 1318–1335.
Yilanci, V., 2019. A Residual-Based Cointegration Test with A Fourier Approximation. University Library of Munich, Munich, pp. 1–10.
Yilanci, V., Pata, U.K., 2020. Investigating the EKC hypothesis for China: the role of economic complexity on ecological footprint. Environ. Sci. Pollut. Res. 27 (26), 32683–32694.
Zhang, J., Abbasi, K.R., Hussain, K., et al., 2022. Another perspective towards energy consumption factors in Pakistan: fresh policy insights from novel methodological framework. Energy 249, 123758. https://doi.org/10.1016/j.energy.2022.123758.
Zhao, J., Sinha, A., Inuwa, N., et al., 2022. Does structural transformation in economy impact inequality in renewable energy productivity? Implications for sustainable development. Renew. Energy 189, 853–864.
Zheng, L., Abbasi, R.K., Salem, S., et al., 2022. How technological innovation and institutional quality affect sectoral energy consumption in Pakistan ? Fresh policy insights from novel econometric approach. Technol. Forecast. Soc. Change 183, 121900. https://doi.org/10.1016/j.techfore.2022.121900.
Zhou, R., Abbasi, R.K., , et al.Salem, S., 2022. Do natural resources, economic growth, human capital, and urbanization affect the ecological footprint ? A modified dynamic ARDL and KRLS approach. Resour. Pol. 78, 102782. https://doi.org/10.1016/j.resourpol.2022.102782.