The Impact of Output Volatility on CO2 Emissions in Turkey: Testing EKC Hypothesis with Fourier Stationarity Test

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Research Article

Keywords: Environmental Kuznets Curve, CO2 emissions, Output Volatility

Posted Date: April 13th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-356337/v1

Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on August 12th, 2021. See the published version at https://doi.org/10.1007/s11356-021-15448-3.

Ethics approval and consent to participate

Not applicable

Consent for publication

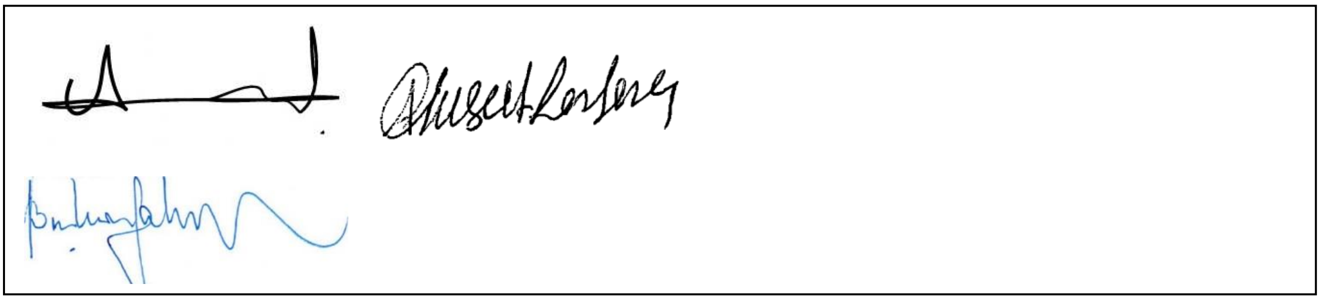
Not applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the [World Bank Open Data] repository, [https://data.worldbank.org/]

Competing interests

The authors declare that they have no competing interests



Funding

The authors declare that they have no funding

Authors' contributions

AE and BS analyzed and interpreted the literature and theory section. AE and MCG performed the empirical models. All authors have contribution on conclusion and introduction sections and read and approved the final manuscript.

Acknowledgements

Authors' information (optional)

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Abstract: This study uses the environmental Kuznets curve (EKC) approach to determine the dynamic short- and long-term impacts of the volatility of economic growth (VOL) on carbon dioxide (CO_2) emissions in Turkey from 1980 to 2016. The results of the Autoregressive Distributed Lag (ARDL) approach indicate that there is a long-run relationship between CO_2, per capita real GDP, and VOL. The coefficients obtained from the ARDL estimation indicate that economic growth increases CO_2 emissions, but VOL decreases CO_2 emissions in the long run. However, the coefficients obtained from the ARDL error correction model show that VOL increases CO_2 emissions in the short run. We also find that the EKC is valid in Turkey.

Keywords: Environmental Kuznets Curve, CO_2 emissions, Output Volatility

1. Introduction

Since developed countries started to identify a strong relationship between economic growth and environmental deterioration in the late 1960s, the relationship between economic growth and energy consumption has become an attractive research area (Beckerman, 1992). With this heightened intellectual attention, the United Nations Conference on the Human Environment, along with the signing of the Stockholm Declaration, was held in 1972. This was the first effective declaration to introduce the international shared responsibility for environmental problems. This Declaration identified the 26 common principles, such as poverty alleviation for protecting the environment, suggested by the environmental Kuznets Curve (EKC) hypothesis. In the same year, the Club of Rome published a report titled “Limits to Growth,” and based on its early computer simulations, it suggested that economic growth would not continue indefinitely because of resource depletion (Meadows et al., 1972). The report increased public concern on growth and environmental issues in the 1970s oil crisis years. Thus, the scarcity of natural resources became a topic of interest and debate by many researchers. In 1987, the Brunnthal report brought the concept of sustainable development to the agenda.

The United Nations Environment and Development Conference held in Rio in 1992 was an important step towards sustainable development. After the Rio Conference, environmental issues became an important international agenda. The Kyoto Protocol held in 1997 was a significant turning point in reducing greenhouse gas (GHG) emissions through a strong public awareness of global warming (Bildirici and Gokmenoglu, 2017). These efforts gained further momentum with the introduction of the Millennium Development Goals (MDGs), which was an outcome of a series of meetings held by the UN and finalized in 2005 to tackle eight main goals; one of the MDGs is to “ensure environmental sustainability”. After a decade of introducing the MDGs, the global community has set a new and broader set of goals. The new goals, which was adopted in 2015 by all United Nations member states and comprising of 17 goals and 169 targets that pursue a highly ambitious agenda in which the environmental goals are divided into six explicitly defined goals, are labeled as the Sustainable Development Goals (SDGs) (see UN, 2020). After the SDGs, the UNs Conference of the Parties (COP) gained more importance and most significantly, the 21st COP help in Paris (COP21-Paris Agreement) in 2015 marked a major milestone on climate change, especially carbon emission. The 21st COP steered the international community towards a strict climate agreement to keep global warming at 1.5°C - 2°C and reduce GHG emissions by 2025-2030. Although it was widely supported, many countries did not ratify the Paris Agreement mainly because of concerns over growth and economic welfare, depending on their relative economic development level.

Because people are more interested in jobs and income than clean air and water, many countries polluted the environment during the first industrialization stage (Dasgupta et al., 2002). In the later stage of industrialization, as income rises, people tend to value the environment more, so regulatory institutions become more effective and pollution level declines (Dinda, 2004). Many developed countries implement environmentally friendly economic growth policies in the later stage. EKC, which is based on the study of Kuznets (1955) that proposed a relationship between economic growth and income inequality, explains the inverted U-shaped relationship between income and environmental degradation. High-income level increases environmental degradation to its peak, and then it starts to decline after a threshold level of income has been reached. The EKC hypothesis was first estimated and tested by Grossman and Krueger (1991) and then many studies introduced other factors, such as scale, technological and composition effects, international trade, market mechanism, and regulation to the hypothesis (for the literature see Dinda, 2004).

Numerous studies have tested the EKC hypothesis in Turkey. The findings of most of the studies support the EKC hypothesis (see Lise, 2006; Yavuz, 2014; Shahbaz et al., 2013; Tutulmaz, 2015; Bölük and Mert, 2015), whereas some of them do not support the EKC hypothesis (see Lise and Montfort, 2007; Akbostancı et al., 2009; Ozturk and Acaravci, 2010; Katircioğlu and Katircioğlu,2018a). Aside economic growth, a large part of the literature focuses on the relationship between carbon emission and other factors, such as agriculture (Dogan, 2016), foreign direct investment (Balibey, 2015; Seker et al., 2015; Gökmenoğlu and Taspinar, 2016), tourism (Vita et al., 2015), trade openness (Halicioglu, 2009; Ertugrul et al., 2016; Ozatac, 2017; Pata 2019), export product diversification (Gozgor and Can, 2016), fiscal policy (Katircioglu and Katircioglu, 2018b), financial development (Ozturk and Acaravci, 2013; Katircioğlu and Taspinar, 2017), urbanization and industrialization (Pata, 2018a, 2018b, 2018c), income inequality (Uzar and Eyuboglu, 2019), shadow economy (Köksal et al. 2020), hydropower energy (Pata and Aydin, 2020), renewable energy (Sharif et al. 2020), as well as information and communications technologies (Barış-Tüzemen et al. 2020).

As seen from the literature, the relationship of CO_2 emissions with economic growth and other factors is well-examined. However, there is a gap in the literature about the relationship between output volatility and carbon emissions. In recent years, the literature has discussed the effect of business cycle and financial crisis on carbon emission and the broad effect on the environment but mainly in the US, China, or developed economies. This study focuses on the effect of output volatility on carbon emission in Turkey, which is a novel study in the literature. Turkey, as an upper-middle income country that is yet to ratify the Paris Agreement, is an ideal economy for investigating the EKC hypothesis. Therefore, the findings of the model and inference will also be useful to similar economies.

The paper is organized as follows. Section 2 reviews the theory and literature and constructs the theoretical foundations of the model. Section 3 presents the econometric model and data. Section 4 discusses the empirical results and the main findings. Finally, the last section concludes.

2. Output Volatility and CO_2 Emissions: Theory and Literature

The theoretical approaches to output volatility and environmental pollution do not have clear distinctions since the research area is relatively new, highly multidisciplinary, and mostly related to long-term growth but not business cycles. Geels (2013) distinguished four main theoretical views on the impact of output volatility on environmental problems. The first three views, (1) a comprehensive transformation of the capitalist system, (2) a green Industrial Revolution, which is linked to the sixth

Kondratieff cycles, and (3) green growth, show a positive impact of output volatility on environmental pollution. The fourth view shows a negative impact since a financial/economic crisis weakens public, political, and business attention on environmental problems.

According to the first view, the relationship between economic growth, business cycles, and environmental pollution have deeper cultural and structural roots that emphasize high growth that brings modern societies into a "triple crisis." Addison et al. (2011) defined the triple crisis as when global finance, climate change, and food crises coincide; in a broader sense, it is a financial, socio-economic, and environmental crisis. They described the first crisis a reduction in capital flows and falling remittances. The second crisis, climate change is when there is exceeding growth in the previous estimates of GHG emissions, and the concomitant rise in temperatures and sea level (see Sokolov et al., 2009). Lastly, malnutrition and hunger are the third crisis. The pursuit of higher growth rates, which only addresses growth in the real GDP, creates its internal conceptual crisis and eventually raises concerns about the type, nature, or definition of economic growth. The SDGs incorporated a broader perception of growth and development through 17 goals and 169 targets. These goals were solidified by the Sendai Framework for Disaster Risk Reduction, Addis Ababa Action Agenda on Financing for Development, and the Paris Agreement on Climate Change (see UN, 2020). The 2008 global financial crisis was a profound shock not only to developed economies but also to least developed and developing countries; this made developing economies to abruptly contract international trade and capital flows and limit official development assistance. The economic crisis had a major impact and negative externalities on sustainable development, such as employment, social stability, health, education, and environment.

The 2008 global crisis was a financial crisis, but the COVID-19 pandemic is an out-of-the-box crisis, which is a sudden powerful health crisis. Its impact on the global economy was simultaneous and immense, reducing both aggregate supply and demand. In addition to a sharp decrease in economic growth expectations, compared with the 2008 global financial crisis, the COVID-19 pandemic has had deeper negative effects on economies, especially on trade volume and the service sector (IMF, 2020). Moreover, the COVID-19 pandemic has had a strong impact on social life, working life, education, pollution, and health because of the social distancing, lockdown, travel and transportation as well as economic measures adopted (see Barkas et al., 2020; ILO, 2020). The COVID-19 pandemic, as a multidimensional crisis, is an urgent call for all countries to follow more sustainable and inclusive development that is consistent with the SDGs. Understanding the triple crisis from the perspective of the COVID-19 pandemic is an opportunity to reassess the transition to a sustainable society, which requires fundamental solutions, such as a low, slow, or even de-growth economy, redistribution of work and time, redistribution of income and wealth, universal basic income, accessibility of health and social services, green growth, and beyond-GDP measures (Van Parijs, 2004; Victor, 2008; Jackson, 2009; Gough, 2010; Jackson and Victor, 2011).

The second view links the Kondratieff long cycles and environmental pollution. Kondratieff (1922, 1925, 1935) was the first economist to propose long cycles in economic life based on a statistical inquiry. Schumpeter (1939) named the long cycles as "Kondratieff waves" and explained these 40 to 60 years waves with his notion of "creative destruction." He stated that technological innovations, such as railroads, steel, and electricity, leads to the Kondratieff waves of economic development. Freeman and Perez (1988) stressed that due to a major economic crisis, changes in techno-economic paradigm bring a new optimal match between new technology and the social management system of an economy, as in the regime of regulation. Berry (1991) stated that the acceleration and deceleration phases of Kuznets growth cycles in Kondratieff waves result in technology, energy, and resource transitions to a sustainable economy. Some researchers have argued that we are in the sixth

Kondratieff wave, which is mostly characterized by cybernetic revolution (Grinin et al., 2016), nano-revolution (Wonglimpiyarat, 2005), smart cities (Batty, 2016), and green revolution, such as renewable energy, resource efficiency, green nanotechnology, and green chemistry (Moody and Nogrady, 2010; Gore, 2010). Severe economic crisis, such as the 2008 global crisis and COVID-19 pandemic may have a positive effect on the environment by triggering green revolution with more efficient use of technology, energy, and resource.

The third view explains the positive relationship between green growth and the environment. Green growth, which is as a result of sustainable development (see Jacobs, 2012), claims that protecting the environment can yield better economic growth. Therefore, economic growth should be environmentally sustainable, biodiverse, climate resilient, and have low carbon emissions. Initially, advocates of green growth highlighted the cost side of "ungreen" growth. Compared to the substantial effect on long-term growth, the cost of providing green growth is minimal (see Stern 2007, Kuik et al., 2009). By contrast, some researchers claim that only economic growth can provide advance technology to adapt to or prevent global warming and environmental pollution (see Nordhaus 2007). It is hard to defend these ideas since they are about long-term growth in areas with low growth and high unemployment rates after the 2008 global crisis. Some researchers have also put forward an idea that is based on different economic theoretical frameworks but with the same conclusion (see Bowen and Fankhauser, 2011; Jacobs, 2012). Protecting the environment does not only lead to long-term sustainable growth but also has a positive effect on output in the short run.

Green growth has three main theoretical explanations: (i) Green Keynesianism, which is an environmental stimulus in recession, uses the traditional Keynesian fiscal expansion to get rid of recession but changes the composition of fiscal expansion from classical expenditure to green stimulus programmes, such as energy and environmental programs (Pollin et al., 2008; Bowen et al., 2009; Houser et al., 2009). Tax policies and regulations are also an important tool to reach the optimal green fiscal multiplier (Zenghelis, 2012). (ii) The growth theory, which is about correcting market failures, proposes that aside other traditional factors, such as labour and physical, technology, and human capital, the natural environment should also be considered as a factor of production. The standard growth theory has both market failure and sub-optimal growth, that is, misallocation of resources between the different factors of production, without considering the natural environment as a factor of production (Nordhaus 1974, Smulders 1999, Brock and Taylor 2005). (iii) The last is a comparative advantage and technological revolution (innovation and industrial policy). The first countries to adopt new and high environmental standards can gain comparative advantage, boost their production for both domestic and export markets and create new jobs in environmental industries. Spreading innovations also have positive effects on other countries' economic growth rate in the long run (Porter and Linde, 1995; Lanoie et al. 2008; Lorek and Spangenberg, 2014).

The fourth view emphasizes the uncertainty channel. Economic crisis and macroeconomic instability, such as an increase in output volatility, weakens the attention of economic agents on negative externalities of environmental problems (see Geels, 2013). Moreover, economic volatility erodes investor confidence and discourages green investment. A credit crunch has many negative effects on the environment since it reduces investment in energy sectors and low-carbon projects, makes investors switch from conventional technologies to low-carbon and renewable energy technologies, weakens the global carbon markets, and cuts funds to environmental institutions (see Huang, 2011).

As a leading study on business cycle and CO_2 emissions, Doda (2014) investigated business cycles in a cross-country panel using the Hodrick–Prescott (HP) filter to identify cyclical components of CO_2 emissions and output. The following four facts emerged from his statistical analysis. (i) Emissions are procyclical. (ii) Procyclicality of emissions is positively correlated with GDP per capita. (iii) Emissions are cyclically more volatile than GDP. (iv) Cyclical volatility of emissions is negatively correlated with GDP per capita.

Menyah and Wolde-Rufael (2010) found a positive short and long-run relationship between emeissions and economic growth in South Africa from 1965 to 2006, using the bound test approach to cointegration. Using a dynamic stochastic general equilibrium model with persistent productivity shocks with a monthly data on pollution externality in the U.S. economy from 1981 to 2003, Heutel (2012) showed that optimal policy makes carbon emissions procyclical, that is, it increases during expansions and decreases during recessions. He also found that compared with an unregulated case, optimal policy mitigates the procyclicality of emissions.

Shahiduzzaman and Layton (2015) examined the asymmetry of changes in CO_2 emissions during recession and expansion periods in the U.S. economy with 1949 yearly data and 1973 monthly data. The study suggested that emissions and emissions intensity reduce faster in recession and emissions per capita continued to decline in the post-global financial crisis expansion period. Sheldon (2017) investigated the asymmetric effects of business cycle on CO_2 emissions in the U.S. economy as quarterly frequency from 1950 to 2011 using asymmetric time series model. The empirical results suggest that the elasticity of emissions is not constant with the GDP; emissions fall more sharply when GDP declines, but when they rise, GDP partly increases due to a decrease in industrial energy intensity.

Khan et al. (2019) investigated the response of emissions to supply and demand shocks to GDP using structural vector autoregression SVAR models and quarterly US data from 1973 to 2016. They found that anticipated investment technology shocks, unanticipated technology shocks, and government spending and monetary policy shocks accounted for 25, 10, and 1% of the changes in emissions, respectively. Using Markov-switching approach and monthly data from 1973 to 2015, Klarl (2020) showed that emissions are significantly more elastic during recessions than in normal times and the elasticity of emissions is above one in recession times and below one in normal times in the U.S. Gozgor et al. (2019) found a significant dependence structure between business cycles and CO_2 emissions using the time-varying copula and the Markov switching models in the U.S. economy from January 1973 to January 2017. Although there was a high dependence regime during the recession episodes up to 1982, the low dependence structure regime became prominent after 1983.

Jalles and Ge (2020) studied the emissions and economic development of 46 commodity-exporting countries from 1990 to 2014 using time series and panel data techniques. The empirical results suggest that the Environmental Okun's Law that suggests a cyclical relationship between emissions and output is strong in some countries, which is as expected, but negative in others, which supports the successful transition to a low-carbon path. Jalles (2020) evaluated the effect of different types of financial crises on emissions using panel data of 55 developing countries from 1980 to 2012. The empirical results show that financial crises reduce CO_2 emissions. Azami and Angazbani (2020) examined CO_2 response to business cycles of six large CO_2-emitting countries, China, India, Japan, Iran, Saudi Arabia, and South Korea, using Markov-switching autoregressive models. They found that the elasticity of the emission to GDP significantly depends on regimes. For example, the elasticity of CO_2 emissions during expansions is significantly larger than during recessions in Japan and South Korea, but in Iran and Saudi Arabia, CO_2 emissions' response to GDP during recessions is significantly larger than during expansions. The empirical results imply that the optimal response of pollution abatement costs varies in the countries.

3. Econometric Model and Data

The effect of output volatility on CO_2 emissions in Turkey can be tested with the EKC hypothesis by estimating an inverse U-shaped quadratic equation as follows:

$$lnCO_{2_t} = \alpha_0 + \alpha_1 lnY_t + \alpha_2 lnY_t^2 + \alpha_3 lnVOL_t + \varepsilon_t \quad (1)$$

where $lnCO_{2_t}$ is the log of the per capita CO_2 emissions (metric tons); lnY_t is the log of the per capita real GDP (2010 constant $); lnY_t^2 is the square of the log of per capita real GDP; $lnVOL_t$ denotes the log of output volatility and measured as the five years moving average of the standard deviation of the per capita growth rate. When the coefficients of α_1 and α_2 in Equation (1) are positive and negative, respectively, the EKC hypothesis is valid in Turkey. Furthermore, the model tests the effect of output volatility on CO_2 with the coefficient of α_3. The annual data from 1980 to 2016 used in this study are from the World Bank's Development Indicators online database.

3.1. Unit Root Test

In this study, the stationarity of the variables was tested using Fourier Augmented Dickey-Fuller (ADF) test developed by Christopoulos and Leon-Ledesma (2010).

The standard unit root tests were biased towards non-rejection of the unit root in the presence of a structural break in the time series. The importance of structural breaks in unit root tests was first emphazised by Perron (1989), who suggested that the structural break date is exogenously determined and known ex-ante. However, Zivot and Andrews (1992) proposed that the structural break date should be endogenous when testing for unit root. Lumsdaine and Papell (1997) allowed for two endogenous breaks under the alternative hypothesis. Lee and Strazicich (2003) showed that spurious rejection problems may arise when breaks are absent in the null hypothesis. There may be a tendency for endogenous break tests to suggest evidence of stationary with breaks. Schmidt and Phillips (1992) used the Lagrange multipliers (LM) test, which allows single and double breaks, to eliminate this problem. Another approach to test unit roots with breaks is the Fourier Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test developed by Becker et al. (2006). According to the Fourier KPSS test, it is not necessary to determine the number and date of structural breaks when using Fourier functions. The Fourier KPSS test is estimated as follows:

$$y_t = \alpha_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 cos\left(\frac{2\pi kt}{T}\right) + e_t \quad (1),$$

where π, k, t, and T denote pi, frequency, trend, and the number of observations, respectively. Equation (1) is used to estimate the frequency from 1 to 5 with the ordinary least squares OLS to reach the minimum sum of squared residuals (SSRs) to determine the optimal frequency. The statistical significance of the trigonometric coefficients, γ_1 and γ_2, are determined by the F test. If γ_1 and γ_2 are statistically insignificant, the standard KPSS test is conducted; otherwise, Fourier KPSS test is used (Becker et al. 2006: 391). The group significance of the trigonometric coefficients tested using the F test is as follows:

$$F_\tau(k) = \frac{(SSR_0 - SSR_1(k))/2}{(SSR_1(k)/(T-q)} \quad (2),$$

where τ denotes the model with the trend; SSR_1 is the sum of the squared residuals of the unrestricted equation, that is, Equation (1) is estimated using the least square method for k optimal frequency; SSR_0 is the SSRs of the restricted equation, that is, Equation (1) without trigonometric coefficients, implying that γ_1 and γ_2 are zero; T denotes the number of observations, and q is the number of variables. If the

F statistics is bigger than the critical values of the Becker et al. (2006) table, the null hypothesis is rejected, implying that the trigonometric values are statistically significant, and the Fourier KPSS test is valid. Christopoulos and Leon-Ledesma (2010) proposed a Fourier ADF test that uses the same procedure as the Fourier KPSS test. In the Fourier ADF test, the residuals obtained from Equation (1) is used to test the stationary in the standard ADF test.

3.2. ARDL bounds testing approach

ARDL bounds testing approach is a cointegration method developed by Pesaran et al. (2001) to test the presence of a long-term relationship between variables. In contrast with the cointegration methods proposed by Engle and Granger (1987) and Johansen and Juselius (1990), the ARDL bounds test has been used when the series integration of different orders is less than I(2). However, the ARDL bounds test produces efficient results in small samples. The approach has both short- and long-run dynamics and is shown as unrestricted error correction model as follows:

$$\Delta \ln CO_{2_t} = \beta_0 + \sum_{i=1}^{k} \beta_i \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{l} \delta_i \Delta \ln Y_{t-i} + \sum_{i=0}^{m} \alpha_i \Delta (lnY_{t-i})^2$$
$$+ \sum_{i=0}^{n} \gamma_i \Delta lnVOL_{t-i} + \vartheta_1 lnCO_{2_{t-1}} + \mu_1 lnY_{t-1} + \sigma_1 (lnY_{t-1})^2 + \tau_1 lnVOL_{t-1} + u_t \ (3),$$

where β_0 is the constant term; β, δ, α, γ, ϑ, μ, σ, and τ are the coefficient of the variables; *k, l, m*, and *n* are the optimal lag lengths, Δ is the first difference, and *u* is the white noise error term. We perform the bound test for Equation (3) after determining the optimal lag length using Akaike Information Criteria (AIC), Schwartz Information Criteria (SIC), and the Hannan-Quinn information criterion (HQ). The null hypothesis is $\vartheta=\mu=\sigma=\tau=0$ and shows that there is no cointegration relationship between the variables, whereas the alternative hypothesis is $\vartheta \neq \mu \neq \sigma \neq \tau \neq 0$ and indicates that there is cointegration between the variables. If the F test statistics is greater than the upper bound critical values of Pesaran et al. (2001) and Narayan (2005), the null hypothesis is rejected, and there is cointegration relationship. If the null hypothesis is rejected, "there is no long-term cointegration relationship," so we can estimate the long-term "levels model" presented in Equation (4) and a separate the "restricted" ECM to measure the short-term dynamic effects in Equation (5). The ARDL model presents the long-term coefficients as follows:

$$\ln CO_{2_t} = \beta_0 + \sum_{i=1}^{k} \beta_i \, lnCO_{2_{t-i}} + \sum_{i=0}^{l} \delta_i \ln Y_{t-i} + \sum_{i=0}^{m} \alpha_i (lnY_{t-i})^2 + \sum_{i=0}^{n} \gamma_i lnVOL_{t-i} + u_t \ (4),$$

where β_0 is the constant term; β, δ, $\alpha, and\ \gamma$ denote the long-term coefficient; *k, l, m,* and *n* denote the optimal lag length; Δ is the first difference, and *u* represents the white noise error terms. After estimating ARDL (k, l, m, n) model and obtaining the long-term coefficient, we can perform the restricted Error Correction Model (ECM) model to determine the short-term coefficients.

$$\Delta \ln CO_{2_t} = \beta_0 + \sum_{i=1}^{k} \beta_i \Delta \, lnCO_{2_{t-i}} + \sum_{i=0}^{l} \delta_i \Delta \ln Y_{t-i} + \sum_{i=0}^{m} \alpha_i \Delta (lnY_{t-i})^2$$
$$+ \sum_{i=0}^{n} \gamma_i \Delta lnVOL_{t-i} + \mu ECT_{t-1} + u_t \ (5),$$

where ECT is the error correction term and represents the error term of the long-term coefficient calculated with Equation (4); μ is the coefficient of the ECT, which shows how quick the variables attain a long-run equilibrium. The expected value of this coefficient is between 0 and -1, and it is also expected to be significant.

4. Empirical Findings

4.1. The Findings of the ADF and Fourier ADF unit root test

The ADF (Dickey and Fuller, 1981) and Fourier ADF (Christopoulos and Leon-Ledesma, 2010) unit root tests are used to determine the stationary level of $lnCO_2$, lnY, $(lnY)^2$, and lnVOL. As mentioned in Section 3.1, the Fourier ADF test is a two-step test. In the first step, Equation (1) is used to estimate the optimal frequency by providing the minimum SSR. In the second step, the ADF test is conducted on the residuals of Equation (1) with the optimal frequency, and if the nonlinear trend coefficients, γ_1 and γ_2, are insignificant in Equation (1), the standard ADF test is valid. The results of the unit root test are presented in the fourth and sixth column of Table 1.

Table 1: ADF and Fourier ADF Unit Root Tests

Series	MinSSR	k	Fourier ADF	F(k)	ADF
lnCO2	1.448994	1	-1.521493 (0)	16.73240^{***}	-1.528279 (0)
lnY	1.570234	1	-0.899191 (0)	18.55217^{***}	0.153236 (0)
lnY^2	512.8292	1	-0.848540 (0)	18.52755^{***}	0.301650 (0)
lnVOL	5.476290	1	-4.668836^{***} (4)	7.123125^{***}	-2.469318 (0)
ΔlnCO2	0.067743	4	-7.475168^{***} (0)	1.454173	-6.723793^{***} (0)
Δ lnY	0.050027	4	-7.720571^{***} (0)	3.305205	-6.319437^{***} (0)
Δ lnY^2	16.32920	4	-7.601668^{***} (0)	3.381914	-6.226760^{***} (0)
Δln VOL	4.659194	5	-6.925054^{***} (0)	2.415460	-5.833537^{***} (0)

Notes: ***, ** and * respectively represent 1%, 5% and 10% signifigance level. The values in the parentheses refer to the optimum lag lengths over maximum nine lag lenght.

The second, third, fourth, fifth, and last columns of Table 1 present the minimum SSR, optimal frequency, Fourier ADF test statistics, F statistics, and ADF test statistics, respectively. Table 1 indicates that all variables are stationary at the first difference except VOL, which is stationary at level, as expected.

4.2. The findings of the ARDL bounds test

$lnCO_2$, lnY, and $(lnY)^2$ are stationary at the first difference level but lnVOL is stationary at level. Then, we perform the ARDL model to determine the cointegration relationship. The findings of the ARDL bounds test are presented in Table 2:

Table 2: ARDL Bound Test

Model	k	F statistic	Critical values	Critical Values Pesaran et al. (2001)		Critical Values Narayan (2005)	
				Lower Bound I(0)	Upper Bound I(1)	Lower Bound I(0)	Upper Bound I(1))
			10%	2.37	3.20	2.618	3.532
CO_2=f(Y, Y^2, VOL)	3	6.792906	5%	2.79	3.67	3.164	4.194
			1%	3.65	4.66	4.428	5.816

Since the F-stat (6.79) is higher than the critical values (Pesaran et al., 2001 and Narayan, 2005), the null hypothesis, there is no cointegration relationship, is rejected at 1% significance level. After identifying the cointegration relationship between the variables, we use the ARDL model to measure the short- and long-run relationships. Based on the AIC, SIC, and HQ criteria, the best model for Equation (3) is the ARDL (2,1,1,4) model. The results of the model are shown in Table 3.

Table 3: The ARDL(2,1,1,4) Model

Variable	Coefficient	Std. Error	t-Statistic
$lnCO2_{t-1}$	0.025558	0.202648	0.126121
$lnCO2_{t-2}$	0.175204	0.11349	1.543779
lnY	21.02447***	6.835897	3.075597
lnY_{t-1}	-10.7552	6.362199	-1.69048
lnY^2	-1.12871***	0.379455	-2.97456
lnY^2_{t-1}	0.604116	0.356264	1.695699
lnVOL	-0.01745	0.017074	-1.02207
$lnVOL_{t-1}$	-0.01778	0.017253	-1.03056
$lnVOL_{t-2}$	0.012717	0.017636	0.721065
$lnVOL_{t-3}$	0.015753	0.016782	0.938682
$lnVOL_{t-4}$	-0.05866***	0.016765	-3.49879
Constant	-49.1906***	12.3687	-3.97702

Breusch-Godfrey Serial Correlation LM Test Statistic: 0.972496 (0.3358)
Breusch-Pagan-Godfrey Heteroskedasticity Test Statistic: 1.136464 (0.3836)
White Heteroskedasticity Test Statistic: 1.132195 (0.3864)
ARCH Heteroskedasticity Test Statistic: 0.008480 (0.9272)
Jarque-Bera Normality Test Statistic: 0.023815 (0.988163)

Notes: : *** represent 1% signifigance level. The values in the parentheses refer to the probability of the statistics.

The long-term coefficients of the ARDL (2,1,1,4) model are presented in Table 4. The coefficient of *Y* is positive and significant at 1% level, and the coefficient of Y^2 is negative and significant at 1% level, implying that the EKC hypothesis is valid in Turkey and consistent with the findings of the studies of Lise (2006), Shahbaz et al. (2013), Yavuz (2014), Tutulmaz (2015), and Bölük and Mert (2015). The long-term coefficient of output volatility is -0.08 and significant at the 5% level, which indicates that an increase in output volatility decreases CO_2 emissions in the long run. This negative relationship between output volatility and CO_2 emissions supports the first three theoretical views mentioned in the previous section.

Table 4: Long Run Coefficients of ARDL(2,1,1,4)

Variable	Coefficient	Std. Error	t-Statistic
lnY_t	12.84884***	2.05925	6.239574
lnY^2_t	-0.65637***	0.113175	-5.79961
$lnVOL_t$	-0.08185**	0.033132	-2.47049
Constant	-61.5469***	9.43248	-6.52499

Notes: : *** and ** respectively represent %1 and %5 signifigance level.

The first view is about the transformation of the capitalist system; the second view focuses on the sixth Kondratieff wave, and the third view is related to green growth. Following the literature on Turkey that used various factors, such as financial development (Ozturk and Acaravci, 2013; Katircioğlu ve Taspinar, 2017), urbanization and industrialization (Pata, 2018a, 2018b, 2018c), income inequality (Uzar and Eyuboglu, 2019), shadow economy (Köksal et al. 2020), hydropower energy (Pata and Aydin, 2020), renewable energy (Sharif et al. 2020), and information and communications technologies (Barış-Tüzemen et al. 2020), we add output volatility as another factor and find evidence in favor of the EKC hypothesis. After determining the long-run relationship between output volatility and CO_2, we run the restricted ECM to measure the short-run relationship using the ARDL (2,1,1,4) model.

Table 5: The Results of the ARDL (2,1,1,4) Error Correction Model

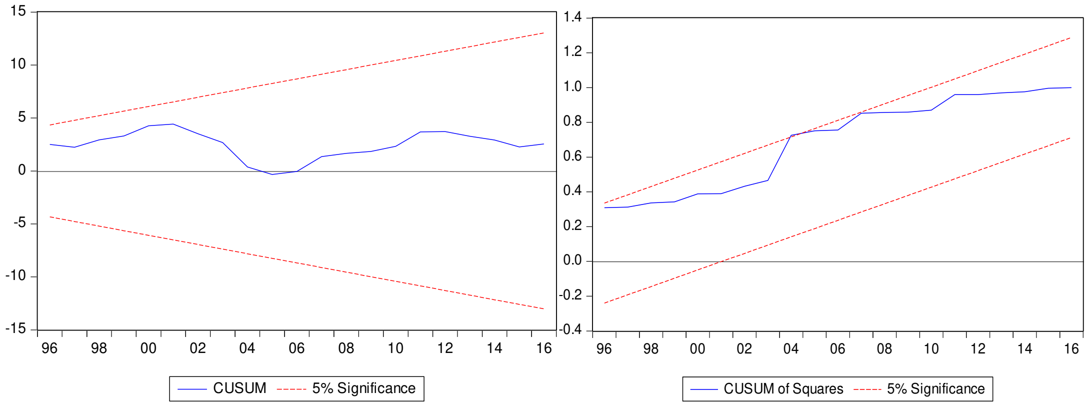
Variable	Coefficient	Std. Error	t-Statistic
$\Delta lnCO2_{t-1}$	-0.1752^{**}	0.083656	-2.09433
ΔlnY_t	21.02447^{***}	3.540578	5.938145
ΔlnY^2_t	-1.12871^{***}	0.196593	-5.74136
$\Delta lnVOL_t$	-0.01745	0.010684	-1.63343
$\Delta lnVOL_{t-1}$	0.030189^{**}	0.013229	2.281945
$\Delta lnVOL_{t-2}$	0.042906^{***}	0.012872	3.333281
$\Delta lnVOL_{t-3}$	0.058659^{***}	0.01412	4.154253
ECT_{t-1}	-0.79924^{***}	0.125691	-6.35877

Notes: *** and ** respectively represent %1 and %5 signifigance level.

The results of the short-run estimation are shown in Table 5. The coefficient of the error correction term is negative and significant, which is as expected. The EC term measures the speed of adjustment towards the long-run equilibrium. The EC term is -0.80 and indicates that annually, the system corrects its previous period disequilibrium at a speed of 79.92% to reach a steady state. The full convergence to the equilibrium level takes about 1.33 years. The error correction model also proves the short-run effect of output volatility on carbon emission. In contrast with the negative sign in the long-run model, the total effect of the ΔlnVOL coefficients up to three lags is positive. This finding is important for a country like Turkey, which is a small open economy with high output volatility mostly caused by financial crises. In theory, the short-run positive relationship between carbon emission and output volatility is also well explained as a fourth view as the uncertainty channel. As explained in the theory and literature section, a credit crunch has a strong negative effect on investment in energy sectors and low-carbon projects. However, economic volatility weakens the public's attention on environmental issues, erodes investor confidence, and discourages green investment.

Finally, diagnostic tests are conducted to ensure the model stability. The diagnostic test statistics do not suggest the presence of any serial correlation and heteroskedasticity. The estimated model also passes the diagnostic tests of functional form specification and normality. Moreover, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests developed by Brown et al. (1975) are used to determine the stability of the coefficients of the ARDL error correction model. The results of the tests are presented in Figure.

Figure 1: CUSUM and CUSUMSQ Tests Results



As shown in Figure 1, the results of the CUSUM and CUSUMSQ tests do not exceed the critical values at the 5% significance level, implying that all the estimated coefficients of the ARDL error correction model are stable.

5. Conclusion

There is an increasing interest in the relationship between economic growth and SDGs. The SDGs are based on the MDGs, which prioritize the fight against extreme poverty. Therefore, although climate and other environmental concerns are rising, the focus of policymakers is still on increasing income and economic growth even in the early years of Turkey. Since the fight against poverty has had some success and climate issues have gained some sense of urgency, the relationship between economic activity and climate/environmental concerns has become more prominent in nonprofessional discourse as well. This study fills a gap in the literature by using data on Turkey to identify the relationship between output volatility while considering long-term cycles of the economy and CO_2 emission.

Since Turkey is classified by the World Bank as an upper-middle-income economy and as a developing economy by the UN, its profile is fitting to analyze. Since the 1980s, Turkey has enjoyed a robust growth rate despite experiencing several economic and financial crises stemming from both external and domestic imbalances. During this period, Turkey's main exports shifted from the textiles to the automotive, household appliances, and consumer electronics industries, indicating a transformation in technology and factor intensity, whereas the share of services sector constantly increased in GDP in comparison to both agriculture and the industrial value added. Moreover, Turkey is the only G20 country that is yet to ratify the Paris Agreement. Additionally, Turkey as a candidate country is not part of the European Green Deal.

The ARDL estimation method provides a suitable tool to test the the dynamic short- and long-term impacts of the output volatility on CO_2 emissions while considering EKC hypothesis. The empirical results also show that the EKC hypothesis is valid in Turkey. One important finding of the model comes from the estimated long-term coefficient of output volatility. This indicates that in the long run, an increase in output volatility decreases CO_2 emissions, supporting the theoretical views of transformation of a market economy, the shifts in production technology and boost from green growth. In the current global economic and political phase, these three theoretical approaches coincide. Changes in technology or technological innovations tend to support greener growth, along with heightened environmental awareness that affects the markets. However, in Turkey, these results also suggest that bolder actions towards accepting stricter green deals, such as the Paris Agreement and European Green Deal, would positively affect Turkish GDP growth.

The estimated error correction term indicates that convergence to equilibrium/long-run level takes about 1.33 years, which is as expected and compatible with a developing or emerging market economy. One significant finding is that there is a short-term positive relationship between carbon emission and output volatility. This uncertainty channel limits any given economy's investment demand and particularly, the desire to invest in technology transformation for greener growth. Since Turkish output volatility is mostly due to financial crises, the adverse effect on long-term investment is even more staggering. Moreover, this also weakens the public attention and political prioritization of climate problems, thereby hindering the positive long-term relationship. Thus, for an economy like Turkey, policy changes towards ratifying international green growth standards would help long-term growth, whereas achieving macroeconomic stability will also bolster this long-term positive relationship. This two-fold findings of this study will encourage policymakers to see some of the issues from a broader perspective, based on factual, empirical studies, such as this.

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Figures

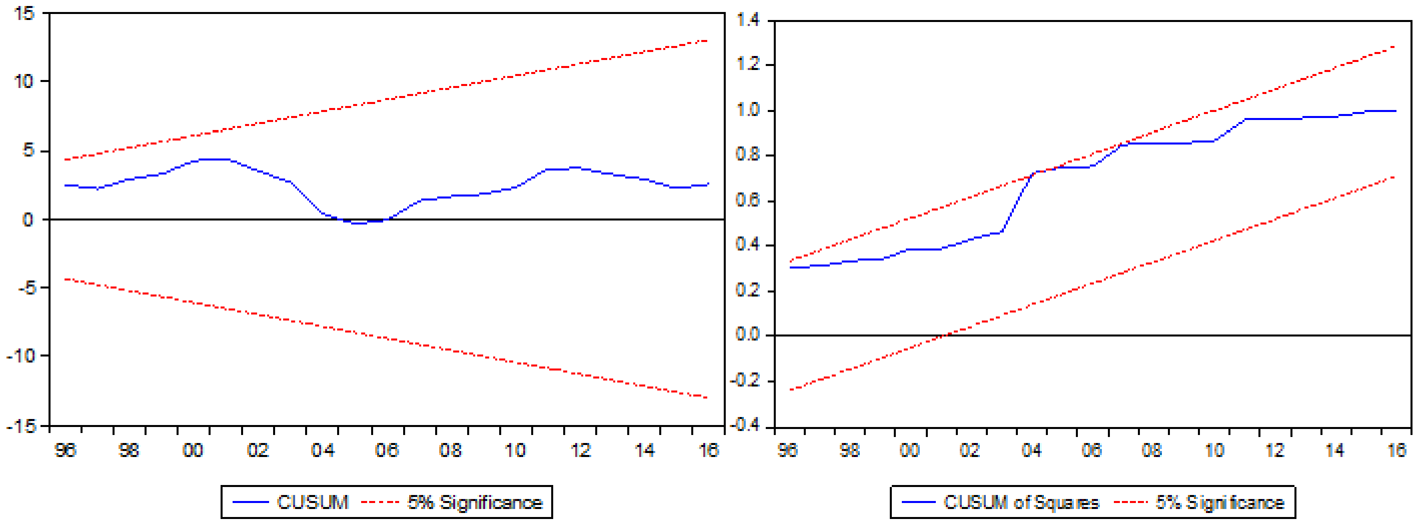

Figure 1

CUSUM and CUSUMSQ Tests Results