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Mitigating poor environmental quality with technology, renewable and entrepreneur policies: A symmetric and asymmetric approaches

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ABSTRACT

This is dual analysis of Turkish sustainable development amidst some high industrial and economic activities. Turkey is currently prioritizing the economic growth to the environmental sustainability and trying to achieve its 2023 goals and place in top 10 economies by date. This action might spark increase in emission level and decrease the environmental quality for both term. For effective and clear analysis, we apply the empirical analyses with both symmetric (dynamic ordinary least square-DOLS) and asymmetric (nonlinear autoregressive distributed lag-NARDL) approaches in short run and the long run periods for policy inferences through forecast. We apply the economic features (*entrepreneurs, FDI, technological innovation proxy by R&D, renewable energy and economic growth*) of Turkey that are important in determining both economic and environment development of the country to investigate its ability to achieve its climate goals. Turkey's data of 1985–2018 were adopted. Findings from both approaches (symmetric and asymmetric) show that carbon emission can be reduced and good environmental quality obtained through the instruments of renewable energy, technological innovation, FDI and entrepreneurial activities. A nexus is established among the instruments (renewable energy, technological innovation, entrepreneur activities and FDI) pointing towards carbon mitigation for Turkey, and this gives support to the findings from both symmetric and asymmetric approaches. Also, from symmetric analysis with dynamic ordinary least square, EKC is found for the case of Turkey which shows the ability of Turkey achieving its climate goal if right policies are implemented.

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1. Introduction

Technological innovation is one of the main factors of an economy by improving economic growth, improve efficiency and productivity, mobility and standard of living. Technological innovation has affected many economies through the industrial sector, energy sector, entrepreneurial activities, and agriculture. The use of technology innovations reduces the cost of production (Anam, 2019). Technological innovation is a vital role in achieving environmental sustainability by fighting against climate disasters through minimizing greenhouse gas (GHG) emissions and other energy-related problems. In addition, it has the enormous potential to influence sustainable environment by utilizing modern technologies. Most of the literature review supports the fact that technological innovation (TI) reduces environmental degradation [1].

Turkey strives to expand its economy majored in the energy sector and infrastructure, investment in the technology sector for growth. Economic activities such as industrial, entrepreneurial activities, agriculture and service sectors, manufacturing, and transport equipment are all contributing to environmental pollution through the excessive utilization of energy resources which in turn increases emissions. Most of the technologies used in service sectors or industrial activities utilize energy resources frequently and proceed to release emissions, which finally negatively influences the quality of the environment. Turkish economy is among the fastest growing OECD economies and this brings about increase

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in greenhouse gas pollution. Several innovative activities are taking place in the Turkish economic performance. Recently, Turkey is advancing in technological transformations, developing new technologies and the ability to create innovations. According to the Global Innovation Index (2020) Turkey is ranked 52nd in innovation inputs, indicating that the economy performs more in input than output innovation. The adoption of energy resources and technology are the most important needs globally, for economic growth, to achieve low carbon emission [2]. Most of the outcomes on the effect of renewable energy on environmental quality are positive [3], while other studies indicated a negative influence of renewable energy on the environment [4,5]. The lack of technological progress and clean energy are among the causes of negative effects of energy on the atmosphere.

Renewable energy sources such as hydro energy, solar, biomass, wind, and geothermal supply energy effectively. These sources are unlimited, and mainly domestic and clean energy sources. Turkey's energy demand has increased with increasing population and depended more on import energy. Turkey highlights the role to encourage the consumption of domestic energy and renewable energy to reduce costs and the negative effect it has on the environment [6]. Turkey has an immense hydropower source of energy which is the country's major renewable energy supply and has plans to supply energy security and a quality environment. The country is located between Europe and Asia surrounding the Mediterranean, Black Seas, and Aegean which gives the government the advantage to expand its energy generating capacity [7]. Turkey is rich in hydropower resources with a capacity of over 28.5 GW (20.5 GW from reservoir and 8 from river plants), and over 50% of hydro energy from the total renewable energy. The potion of hydropower is expected to continually expand to lessen the imports and consumption of fossil fuels (Turkey Renewable Energy Market, 2021).

Schumpeter, (2002), among the first scholars to design theories on entrepreneurship, affirmed that entrepreneurial activities are the main driver for economic growth. New entrepreneurs offer efficient resources with regards to recognizing current technology, opportunities, and the concept of marketing, to achieve economic growth. Research has shown that certain increase in entrepreneurship and innovation improves economic growth, and then later, economic growth increase entrepreneurship. Being a leading industrial economy with rapid entrepreneurial activities and population growth, Turkey has encountered environmental difficulties that have hampered its growth and development. Climate change, deforestation, and water-related difficulties are only some of the issues that can arise. Numerous studies have identified entrepreneurship as one of the key contributors to environmental pollution [8]. indicated that both formal and informal entrepreneurship contributes to reducing the quality of the environment [9]. show that entrepreneurship has massive impacts on environmental sustainability and, positive relationship of entrepreneurship with CO_2 emissions due to the regular fossil fuels use which emit a large sum of CO_2 emissions. The number of entrepreneurs in Turkey has increased over time. Nevertheless, it needs to be more competitive to be able to compete with other economies with highly efficient entrepreneurship. The determinants of an entrepreneurial structure by the GEM research model are government policies, technological support, education and training, infrastructure, trade, and entrepreneurial culture and attitude toward entrepreneurship, which have an effective impact on entrepreneurial activity in a country. Entrepreneurs need financial resources to finance their activities and innovations.

To this end, the present study seeks to investigate the possible ways of achieving climate and sustainable development goals for Turkey amidst its unpopular energy policies. Turkey is currently at a crossroad with its policy to mitigate its carbon emission and to boast domestic energy source in order to meet its energy requirements for its economic activities. Turkey is caught in between shifting from dependency on gas imports to a renewable energy and enlarging its domestic energy through coal source. This is considered as a counterproductive energy policies which looks more of boosting economic development at the expense of environmental development. Turkey is currently advancing in industrial and commercial sector through the activities of both foreign investors (through FDI) and the domestic entrepreneurs which placed the country as a commercial hub that connect both European and Asian countries. Considering the current situation of Turkey in trying to mitigate its carbon emission amidst its conscious effort to sustain its economic development, we seek to investigate the ability of the country (Turkey) to achieve its climate goal. For clear insight into this objective, we applied the important economic features (*entrepreneurs, FDI, technological innovation proxy by R&D, renewable energy measured by hydropower and economic growth*) of Turkey that are important in determining both economic and environment development of the country. Turkey currently prioritizing the economic growth to the environmental sustainability and try to achieve its 2023 goals and place in top 10 economies by date. This is dicey for Turkey's sustainable development because increase in economic performance will cause increase in emission level and decrease the environmental quality for both term. Besides, Turkey provide some flexibilities in its policies and restrictions to attract the foreign investors into the country. Therefore, it aims to increase capital inflow and reach more sources to increase the economic growth. Thus, foreign direct investment inflow gains importance in Turkey. Despite the severe effects of Covid-19, it became ninth most popular FDI destination with 160 projects in overall Europe in 2020. This cause an increase in its share in Europe to 3.1% in 2020 which was 3% in 2019. Compared to other emerging economies in Europe, Turkey was placed as the second most popular FDI destination after Poland, with a 16% share in 2020, up from the third place in 2019. (Turkey Investment office, 2021), Therefore, the significance of FDI inflow and its asymmetric effect on environmental quality was tested in our estimation. The novel part of our work is the ability to quantify the impact of entrepreneur activities on the Turkey's climate and sustainable development (economic and environment) goals. Most of the studies and econometric models shown in the energy-environment literature review have strived to extend the analysis of the technological innovation-energy-environmental degradation relationship with applicable variables. Nevertheless, none has applied entrepreneurship to their analysis. Hence, this will fill in the gap in the literature, and equally opens up new research perspective of quantifying the environmental impact of entrepreneur activities. For effective and clear analysis of this current study, we apply the empirical analyses with both symmetric (dynamic ordinary least square-DOLS) and asymmetric (nonlinear autoregressive distributed lag-NARDL) approaches. We examined both approaches in short run and the long run periods for policy inferences through forecast. Also, the causal relationship among investigated variables was investigated with the Vector Error Correction Granger Causality test. To our knowledge, this is the first study in Turkey to look at the impact of technological innovation on the environment by incorporating entrepreneurial activity. Moreover, by exploring the asymmetric short run and long run relation among the selected variables, with clear and robust policy recommendations. The study seeks to contribute to the existing literature both empirically and theoretically by examining the association of technological innovation, entrepreneurship and environmental quality.

The rest of the study is structured as: a comprehensive review of the previous studies. Data description, methodology, and empirical modeling. Empirical results and discussion, and the conclusion and policy framing.

2. Literature review

Past studies have discussed the related topic by reviewing the implications of technology, renewable policies, and FDI on environmental sustainability. The review section shows a notable trend of this topic as the results specified that there is still no consensus about the outcome of the variables conclusively. Therefore, this has made the title more compelling and stimulated significant contributions for a mutual understanding.

2.1. Carbon emission effect of technological innovation

Few researchers had analyzed the influence of technological innovation on environmental quality [10]. found that domestic innovation reduces the effect of CO_2 emissions in Turkey through intensified development level [1]. assessed the impacts of technological development and renewable policy on CO_2 emissions level in Turkey. The findings obtained from the STIRPAT model imply positive implication of technology and renewable policy on environment by diminishing CO_2. Using the augmented mean group (AMG) method [11], examined the effect of technological innovation, export diversification, renewable energy consumption, and fiscal decentralization in achieving carbon neutrality targets for Organization for Economic Cooperation and Development (OECD) economies from 1970 to 2019. The results specified that renewable energy consumption and technological innovation guarantee environmental quality. While economic growth influence emission. Using the ARDL approach from 1980 to 2017 [12], examined the role of technological innovation, renewable and nonrenewable energy on environmental degradation in Malaysia. The result confirmed the negative impact of technological innovation and renewable energy consumption on carbon emission, by improving environmental sustainability. While nonrenewable energy consumption and economic growth increase emissions. The results verified the inverted U-shape curve. Similarly, Lee and Min [13], examined the relationship between green R&D and carbon emissions in Japan. Found a negative connection between green R&D investment and carbon emissions. Implying that green technological advancement enhances environmental quality. Also, Ibrahim and Ajide [14], examined the effect of technology, trade, renewable, and nonrenewable energy on environment for G-7 economies from 1990 to 2019. The results showed that technological progress and renewable energy reduces CO_2 emissions [15]. explored the relationship of FDI, technology, renewable energy, and trade on environmental degradation in China from 1995 to 2017. The results indicated the positive effect of GDP and FDI on CO_2 emissions, while renewable energy and technology have a negative effect on carbon emission. The growth in renewable energy and technology reduces emissions and improves environmental quality. Contrarily, Ali et al. [16] assessed the linkage of technological innovation and environmental pollution in Malaysia using the ARDL approach from 1985 to 2012. The findings from the empirical test imply a negative relation of technological innovation (TI) on carbon emissions. Improvement in TI lowers environmental degradation [17]. investigate the influence of income inequality on renewable energy technological innovation (RETI) on environmental degradation in China. The findings obtained indicate that RETI tends to induce environmental degradation in high-income inequality gab. The Generalized Method of Moments (GMM) approach was employed by Ref. [18] to investigate the influence of innovation and technology investment on the environmental degradation of OECD countries. Concluded that technology investment and innovation influence carbon emissions differently, suggesting that the effect of technology investment and innovation in some of the countries reduces environmental quality.

2.2. Carbon (CO_2) emission effect of energy forms (renewable and non-renewable)

Energy consumption is a significant aspect of the economic and environmental sustainability of any economy to boost productivity. Many studies have explored the relationship between energy consumption and environmental sustainability using renewable and nonrenewable energy consumption. Some of the results confirmed a positive relationship, while others found a negative effect of energy consumption on environmental quality. Such as [19] examine the effect of renewable and nonrenewable energy consumption on ecological footprint applied the Quantile ARDL approach from 1965Q1 to 2017Q4. Concluded that renewable energy lessens ecological footprint and confirmed the EKC hypothesis in Turkey [20]. examine the influence of renewable and nonrenewable energy consumption on environmental degradation in Turkey. The findings obtained indicate that renewable energy consumption reduces carbon emissions [21]. also confirmed that renewable energy enhances environmental quality in Turkey using the ARDL approach. Alola [22], examined the role of renewable energy, non-renewable energy, and trade on environmental degradation proxy with ecological footprint for 16-EU economies from 1997 through 2014. The analyses assured that nonrenewable energy reduces environmental quality while renewable energy enhances the environment. Khan [23], investigate the role of renewable energy on environmental quality and international trade. The study confirmed that the consumption of renewable energy improves the environmental quality [24]. investigate the role of renewable and nonrenewable energy consumption and urbanization in curbing environmental degradation. According to the study, renewable energy consumption reduces carbon emissions via enhancing the environmental quality, while nonrenewable energy consumption and economic growth increase emissions [25]. examined the relationship between renewable energy and the environment of African countries from 2002 to 2017. The outcome indicated that renewable energy decreases carbon emissions [26]. confirmed that an increase in renewable energy consumption decreases carbon emissions. However, Jabli and Youssef [4], revealed that in the long run the association among renewable energy and CO_2 emission is positive, which implied that an increase in renewable energy increases CO_2 emissions [5]. found a negative relationship between renewable energy and carbon emissions. The increase in renewable energy influences environmental degradation.

2.3. Carbon (CO_2) emissions effect of economic factors

Moreover, over the past decades, several researchers had explored the relationship among economic performance and environmental quality for several countries and regions with different analyses. Some of them obtained the results as an increase in GDP deteriorates the environment such as [27] applied the autoregressive distributed lag test from 1960 to 2013 for Turkey to inspect the effect of economic growth and energy use on carbon emissions and revealed that economic growth degrades environmental quality [28]. indicated that economic growth positively impacts environmental degradation. Hence, an increase in economic growth increases CO_2 emissions. Also, Anokhin and Schulze [55] result indicates that a good environment improves the capacity of economic activities. An increase in GDP increases environmental quality [22]. examine the importance of attaining sustainability concerning decreasing the level of deterioration in the environment of the EU members using the ARDL model from the period 1997 to 2014. A rise in real GDP escalates the quality of the environment. Though, others indicated an adverse association between economic performance and the environment [29]. employing the ARDL bound test for the period of 1965–2008 for South Africa. Indicated an increase in real GDP increases emissions [30]. analyzed the link between economic performance and environmental degradation. For Azerbaijan, time series analysis has been employed using data from 1992 to 2013. The results show that GDP rises environmental deterioration level [31]. investigated the asymmetric relations of FDI and growth on environmental deterioration. Their result also confirmed the positive impact of real GDP per capita on the environment in Turkey [32]. studied the correlation of real GDP per person and CO_2 for Malaysia employing the ARDL method for the period 1980–2009. Found a Long-run association between investigated variables, and a causality running from GDP to environmental degradation [33]. examine the causal link amongst electricity use, environmental deterioration, and economic growth for the BRICS economies. Found non-existence of granger causality between economic growth and environmental degradation in India and China. However, a feedback hypothesis of GDP and environmental degradation exists for Russia, GDP causes CO_2 emissions while for Brazil from CO_2 emission to GDP.

2.4. Carbon (CO_2) emissions effect of foreign direct investment (FDI)

A Distinct number of studies have examined the connection between FDI and CO_2 emissions, showing the negative and positive impact on the environment [34]. stated that FDI contributes to CO_2 emissions. Using both time series regression and panel data regression [35], explored the relationship between FDI and environmental pollution in China. The study concluded that FDI influences pollution. Hoffmann et al., 92,005) stated that an increase in FDI influences environmental degradation [36]. stated that FDI has a positive effect on environmental degradation by increasing emissions. Also, Omri et al. [37,38] stated that FDI influences environmental degradation. Nevertheless, others found a positive effect of FDI on the environment [39]. stated that FDI has a positive impact on the environment by increasing environmental quality [40]. stated that by introducing cleaner technologies to an economy FDI influences environmental quality by mitigating pollution. Utilizing annual data from 1980 to 2018 [41], examined possible ways of reducing climate change in the UAE by analyzing the effect of FDI, energy use and GDP on ecological footprint. The outcomes shows that FDI and ecological footprint have a negative relationship and confirmed the EKC relationship.

2.5. Carbon (CO_2) emissions effect of entrepreneurship

Very few researchers had analyzed the influence of entrepreneurship on the environment [31]. analyzed the asymmetric influence of entrepreneurship on environmental quality in Turkey from 1985 to 2016. The findings confirm that entrepreneurial activities have a negative influence on environmental quality. Suggested that to reduce the negative effect on the environment, incentives should be introduced to encourage the growth of sustainable enterprises and technological innovation [42]. examined the linkage between entrepreneurship and environmental sustainability. Their study indicated that entrepreneurship reduces environmental degradation. Similarly, Shepherd and Patzett [43], also indicated that entrepreneurship reduces environmental degradation [44]. stated that in high-income economies, the effects of entrepreneurial activities on environmental pollution are low compare to low-income countries which causes more pollution [45]. investigated the impact of entrepreneurship and government spending on education on the environmental quality of developing economies found that entrepreneurship contributes to economic growth, on the contrary, impacts the environment negatively by contributing to the increase in environmental degradation. While government spending on education reduces pollution [8]. studied the roles of entrepreneurship, innovation, and institutional quality on economic performance to achieve environmental quality and sustainability for Africa. The findings indicated that both formal and informal entrepreneurship contributes to reducing the quality of the environment. However, informal entrepreneurship causes more environmental degradation compare to formal entrepreneurship [46]. indicate that CO_2 emissions are high in countries with a low level of entrepreneurship. However [9], employing the Fully Modified Least Squares model (FMOLS) from 2000 to 2012 for Nigeria. The study shows that entrepreneurship has massive impacts on environmental sustainability and, positive relationship of entrepreneurship with CO_2 emissions due to the regular fossil fuels use which emit a large sum of CO_2 emissions [47]. analyzed how entrepreneurship rises economic productivity and environmental sustainability among developing countries. Indicating that entrepreneurship contributes to productivity and social conditions. However, negatively contribute to the environmental conditions [48]. examined the influence of entrepreneurship on environmental quality. The study indicates that entrepreneurship promotes environmental pollution and concluded that sustainable entrepreneurship can reduce emissions and enhance environmental quality by providing the opportunity for innovative technologies in different sectors.

Most of the econometric models shown in the literature review have strived to extend the analysis of the technological innovation-energy-environmental degradation relationship with applicable variables. Nevertheless, none has applied entrepreneurship to their analysis. Thus we look at positive and negative shocks of explanatory variables by using NARDL to see how different shocks affect the environmental quality of turkey in short run and long run.

3. Data and methodology

Since there is no consensus and conflict for the direction and the magnitude of the effect of investigated variables on environmental deterioration in the literature, this study aims to investigate both the symmetric (Dynamic ordinary least square-DOLS) and asymmetric (non-linear autoregressive distributed lag-NARDL) association between environmental deterioration (CO_2), technological innovation (RD) and entrepreneurship (EN) for Turkey incorporating with foreign direct investment, net inflow (FDI), Hydropower energy consumption (HR) and economic performance (Y). The analyses are contained in both short run and long run periods for forecasting purpose. Environmental deterioration (CO_2) was used as dependent variable and indicated with carbon dioxide emission for our empirical analysis. It was measured in kilogram per 2010 US$ of gross domestic product (GDP). The entrepreneurial activities was measured as the total number of newly established businesses. Also, the foreign direct investment, net inflow, was measured as percentage of GDP, while economic performance is measured as constant 2010 US$. Furthermore, the asymmetric effect of renewable energy on environmental deterioration was evaluated by using hydropower energy consumption, which has the largest share in renewable energy use and measured as million tons of oil equivalent. Due to the data availability, the investigated time period was 1985–2018, on annual basis. The data for all investigated variables, except hydropower energy consumption and entrepreneurial activities, were obtained from World Bank World Development Indicators Database (WDI, 2021). The data for hydropower energy consumption was acquired from BP statistical review of world energy (2021) (https://www.bp.com/) whereas entrepreneurship data was obtained from the Union of Chambers and Commodity Exchanges of Turkey(2021).

The logarithmic form of the variables were used in empirical analysis to get the strong estimation results by decreasing the skewness and increasing the normality of the variables. The validity of the normality assumption was tested and confirmed by using Jarque-Berra test. Therefore, the following equation (Eq. (1)) was constructed in order to present the general association among investigated variables.

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln EN_t + \beta_2 \ln Y_t + \beta_3 \ln RD_t + \beta_4 FDI_t + \beta_5 \ln HR_t + \varepsilon_t \tag{1}$$

where $\ln CO_{2t}$ indicates for environmental deterioration level in period t; $\ln EN_t$ stands for entrepreneurship activities in period t; $\ln Y_t$ shows real GDP in period t; $\ln RD_t$ depicts technological innovation level in period t. Moreover, FDI_t signifies foreign direct investment inflow in period t; and $\ln HR_t$ depicts hydropower energy consumption level in period t. Here, α_0 stands for the intercept, whilst, β_1, β_2, β_3, β_4 and β_5 are the coefficients of the independent variables. The ε_t, depicts the error term for the empirical estimation.

Since entrepreneurial activities, FDI inflows and research and development activities are sensitive on economic and political changes, traditional time series analysis cannot capture the positive and negative shocks on these variables and their effect on environment. Thus, in order to observe the systematic adjustment of the variables and capture their asymmetric relationship with dependent variable, non-linear autoregressive distributed lag model (NARDL) was employed in our empirical analysis. This model, as developed by Ref. [49]; helps us to discover the responses of the environment for the negative and positive shocks of independent variables. It also gives the consistent results with low observation levels and eradicates the problems caused by endogeneity and autocorrelation. Thus, Equation (1) was extended to capture the effect of positive and negative shocks of independent variables on environment and presented below.

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln EN_t^+ + \beta_2 \ln EN_t^- + \beta_3 \ln Y_t^+ + \beta_4 \ln Y_t^- + \beta_5 lnRD_t^+ + \beta_6 lnRD_t^- + \beta_7 FDI_t^+ + \beta_8 FDI_t^- + \beta_9 lnHR_t^+ + \beta_{10} lnHR_t^- + \varepsilon_T \tag{2}$$

where, $+$ and $-$ signs on the explanatory variables depict the positive and negative shocks of them, which can be synthesised in partial sum process. The process is given below.

$$\begin{aligned}
\ln ENT_t^+ &= \sum_{i=1}^{t} \Delta \ln ENT_i^+ = \sum_{i}^{t} \\
\ln ENT_t^- &= \sum_{i=1}^{t} \Delta \ln ENT_i^- = \sum_{i}^{t} \\
\ln Y_t^+ &= \sum_{i=1}^{t} \Delta \ln Y_i^+ = \sum_{i}^{t} \\
\ln Y_t^- &= \sum_{i=1}^{t} \Delta \ln Y_i^- = \sum_{i}^{t} \\
\ln RD_t^+ &= \sum_{i=1}^{t} \Delta \mathrm{lnRD}_i^+ = \sum_{i}^{t} \\
\ln RD_t^- &= \sum_{i=1}^{t} \Delta \ln RD_i^- = \sum_{i}^{t} \\
FDI_t^+ &= \sum_{i=1}^{t} \Delta FDI_i^+ = \sum_{i}^{t} \\
FDI_t^- &= \sum_{i=1}^{t} \Delta FDI_i^- = \sum_{i}^{t} \\
\mathrm{lnHR}_t^+ &= \sum_{i=1}^{t} \Delta \ln HR_i^+ = \sum_{i}^{t} \\
\ln HR_t^- &= \sum_{i=1}^{t} \Delta \ln HR_i^- = \sum_{i}^{t}
\end{aligned} \tag{3}$$

The short run and long run dynamics can be comprehended as follows.

$$\Delta \ln CO_{2t} = \alpha_0 + \delta_1 Co_{2t-1} + \beta_1^+ \ln EN_{t-1}^+ + \beta_2^- \ln EN_{t-1}^- + \theta_3^+ \ln Y_{t-1}^+ + \theta_4^- \ln Y_{t-1}^- + \varphi_5^+ \ln RD_{t-1}^+ + \varphi_6^- \ln RD_{t-1}^- + \gamma_7^+ FDI_{t-1}^+ + \gamma_8^- FDI_{t-1}^- + \varphi_9^+ \ln HR_{t-1}^+ + \varphi_{10}^- \ln HR_{t-1}^- + \sum_{i=1}^{p-1} \delta \ln CO_{2t-i} + \sum_{i=0}^{q-1} \begin{pmatrix} \vartheta_1^+ \Delta \ln EN_{t-1}^+ + \vartheta_2^- \Delta \ln EN_{t-1}^- + \\ \vartheta_3^+ \Delta \ln Y_{t-1}^+ + \vartheta_4^- \Delta \ln Y_{t-1}^- + \vartheta_5^+ \Delta \ln RD_{t-1}^+ + \vartheta_6^- \Delta \ln RD_{t-1}^- + \\ \vartheta_7^+ \Delta FDI_{t-1}^+ + \vartheta_8^- \Delta FDI_{t-1}^- + \vartheta_9^+ \Delta \ln HR_{t-1}^+ + \vartheta_{10}^- \Delta \ln HR_{t-1}^- \end{pmatrix} + \varepsilon_t \tag{4}$$

Above equation can be developed with error correction term and shown below.

$$\Delta \ln CO_{2t} = \alpha_0 + \delta_1 Co_{2t-1} + \beta_1^+ \ln EN_{t-1}^+ + \beta_2^- \ln EN_{t-1}^- + \theta_3^+ \ln Y_{t-1}^+ + \theta_4^- \ln Y_{t-1}^- + \varphi_5^+ \ln RD_{t-1}^+ + \varphi_6^- \ln RD_{t-1}^- + \gamma_7^+ FDI_{t-1}^+ + \gamma_8^- FDI_{t-1}^- + \varphi_9^+ \ln HR_{t-1}^+ + \varphi_{10}^- \ln HR_{t-1}^- + \sum_{i=1}^{p-1} \delta \ln CO_{2t-i} + \sum_{i=0}^{q-1} \begin{matrix} (\vartheta_1^+ \Delta \ln EN_{t-1}^+ + \vartheta_2^- \Delta \ln EN_{t-1}^- + \\ \vartheta_3^+ \Delta \ln Y_{t-1}^+ + \vartheta_4^- \Delta \ln Y_{t-1}^- + \vartheta_5^+ \Delta \ln RD_{t-1}^+ + \vartheta_6^- \Delta \ln RD_{t-1}^- +) \\ \vartheta_7^+ \Delta FDI_{t-1}^+ + \vartheta_8^- \Delta FDI_{t-1}^- + \vartheta_9^+ \Delta \ln HR_{t-1}^+ + \vartheta_{10}^- \Delta \ln HR_{t-1}^- \end{matrix} + \psi \mathrm{ECT}_{t-1} + \varepsilon_t \quad (5)$$

In the above equation (Eq. (5)), the long run dynamics of explanatory variables are captured with their level form while the short term dynamics are captured with their differenced (Δ) form. On the other hand, the direction and magnitude of the effect of positive and negative shocks of explanatory variables on the deterioration level of environment can be captured by the values of $\sum_{i=0}^{q-1}(\vartheta_i^+)$ and $\sum_{i=0}^{q-1}(\vartheta_t^-)$. Together with, the presence of their long run steady state relationship can be tested by using the joint F-test and Wald test under the hypothesis of $H_0 : \beta_i{'}s = \theta_i{'}s = 0$ and $H_0 : \beta_i{'}s = \theta_i{'}s \neq 0$.

Moreover, the long run coefficients of the NARDL estimation results were confirmed by utilizing Dynamic Ordinary Least Squares (DOLS) model. The consistency and goodness of fit for the NARDL model was verified by employing the stability tests of CUSUM (cumulative sum of recursive residuals) and CUSUMsq (cumulative sum of recursive residuals squares) and the reliability of the model was checked with required tests. Lastly, the causal relationship among investigated variables were investigated with Vector Error Correction Granger Causality test.

4. Empirical results and discussion

The magnitude of asymmetric short run and long run effect of entrepreneurship and technological innovation on environmental degradation has been investigated for the second most entrepreneurial country, Turkey. This relationship was investigated incorporating with economic performance, renewable energy and foreign direct investment for the period of 1985–2018, on annual basis. To this end, firstly, the required stationarity tests have been employed to check the integration order of the variables. Both Augmented Dickey-Fuller [50] test and [51] have been utilized for this purpose. The results for these tests are given in Table 1 and indicates that all investigated variables are integrated order one. In other words, all investigated variables are stationary at their first difference form at 1% significance level.

Table 1
Stationarity test results.

Variables	*ADF*		*PP*	
	Level	Δ	Level	Δ
lnCO$_2$	−1.397	−7.316***	−1.342	−7.296***
lnEN	−1.743	−5.308***	−1.771	−5.308***
lnY	0.113	−6.067***	0.397	−6.262***
lnRD	−2.062	−6.125***	−1.940	−11.141***
FDI	−2.174	−6.398***	−2.070	−9.569***
lnHR	−2.461	−7.269***	−2.442	−8.165***

Note: (1) All variables were tested with only intercept. (2)*** depicts for the significance level at 1%.
Source: Authors computation

Subsequently, to test the presence of long run steady-state association among investigated variables, bounds test has been engaged as the pre-condition of the NARDL model. Table 2 gives the details about estimation results and confirms the cointegration relationship among investigated variables. The null hypothesis of no cointegration relationship exists among investigated variables has been rejected for these variables since the calculated F-statistics (7.8801) is greater than the upper critical bound at 1% significance level (5.06).

Afterwards, the asymmetric positive and negative effects of explanatory variables and their magnitudes have been analyzed with NARDL model and elaborated in Table 4 below.

According to Table 3 above, despite having different magnitudes of the positive and negative shocks of explanatory variables, all coefficients are statistically significant at different significance level. This shows that, entrepreneurship, technological innovation and other explanatory variables have statistically significant effect on environment and proves our theoretical assumption. In other words, all explanatory variables are proved as significant determinants of environment function. In details, the coefficient of ECT (−1) in short run estimation is negative and statistically significant at 1% significance level. This indicates that 77.9% of disequilibrium in environmental deterioration level in short run can be mended in the long run given the independent variables. However, given the estimation output, all of the coefficients of positive and negative shocks of explanatory variables are statistically significant at different significance level in both term. Remarkably, a 1% increases in entrepreneurial activities in Turkey will lead a 0.057% and 0.072% decline of carbon emissions in short run and long run, respectively. Thus, it can be said that, depending on the policies applied for start-up businesses and environmental awareness of the people leads to use environmentally friendly technologies in their activities and reduce the level of environmental degradation. On the other hand, for every 1% rise in the negative shocks on the entrepreneurship leads to 0.112% and 0.144% increase in environmental degradation in short run and the long run, respectively. Therefore, Turkey should promote entrepreneurial activities and at the same time set standards to entrepreneurs to protect and increase environmental quality. This also will lead them to have intensive care on environment and their activities will be shaped accordingly. Our finding supports the findings by Ref. [52] but contradicts the finding by Ref. [45].

Table 2
Bound test results.

		1%		5%		10%	
K	Calculated F-stat	B$_L$	B$_U$	B$_L$	B$_U$	B$_L$	B$_U$
4	7.8801	3.74	5.06	2.86	4.01	2.45	3.52

Note: B$_U$: upper critical bound B$_L$: lower critical bound.
Source: Authors computation

Table 3
Estimation output.

Var	Coeff	Std. Error	t-Stat	P-value
Short Run Coefficients				
Var	Coeff	Std. Error	t-Stat	P-value
$D(FDI^+)$	−0.677***	0.154	−4.409	0.0010
$D(FDI^-)$	−0.578***	0.162	−3.568	0.0044
$D(lnHR^+)$	−0.128**	0.081	−1.588	0.0146
$D(lnHR^-)$	−0.245***	0.076	−3.214	0.0083
$D(lnY^+)$	0.268**	0.221	1.210	0.0256
$D(lnY^-)$	1.542**	0.527	2.924	0.0137
$D(lnRD^+)$	−0.853***	0.213	−4.010	0.0021
$D(lnRD^-)$	−0.819***	0.199	−4.099	0.0018
$D(lnEN^+)$	−0.057**	0.050	−1.128	0.0283
$D(lnEN^-)$	−0.112**	0.048	−2.306	0.0416
ECT(-1)	−0.779*	0.250	−3.105	0.0100
Long Run Coefficients				
Var	Coeff	Std. Error	t-Stat	P-value
FDI^+	−0.858**	0.359	−2.384	0.0362
FDI^-	−0.816**	0.287	−2.838	0.0161
$lnHR^+$	−0.093**	0.112	−0.827	0.0426
$lnHR^-$	−0.500**	0.205	−2.437	0.0330
lnY^+	0.344**	0.312	1.102	0.0294
lnY^-	1.980***	0.624	3.172	0.0089
$lnRD^+$	−1.095**	0.479	−2.283	0.0432
$lnRD^-$	−1.051**	0.346	−3.031	0.0114
$lnEN^+$	−0.072**	0.058	−1.244	0.0239
$lnEN^-$	−0.144**	0.061	−2.351	0.0384
C	−0.316**	0.230	−1.372	0.0197

Note: ***,** and * stands for the significance levels at 1%, 5% and 10%, respectively.
Source: Authors computation

Table 4
DOLS Estimation output.

Var	Coeff	Std. Error	t-Stat	P-value
FDI	−0.029**	0.095	−0.312	0.0267
lnHR	−0.551***	0.110	−4.999	0.0007
lnY	1.424***	2.027	3.661	0.0052
lnY^2	−0.144***	0.036	−3.912	0.0036
lnRD	−0.048*	0.142	−0.338	0.0743
lnEN	−0.109***	0.029	−3.787	0.0043
C	−9.696***	2.015	−3.451	0.0073
R-squares:0.954		Adjusted R-squared		0.845

Note: ***, **,* indicate 0.01, 0.05 and 0.10 significance levels, respectively.
Source: Authors computation

Moreover, as Yousef et al. [8] also suggested, innovation and institutional quality is important for every country to have sustainable formal entrepreneurial activities and environmental quality. Accordingly, our empirical estimation proves this statement as one percent rise in technological innovation will lead to 0.853% decline in environmental degradation level in short-run while this has been accounted as 1.095% in the long run. However, 1% decline in technological innovations, will lead to decline in environmental quality by 0.819% in short run and 1.051% in the long run. Therefore, like entrepreneurial activities, Turkey should have fund for research and development activities and support technological innovation to sustain environmental quality through subsidies. Our finding supports the assertion from Yousef et al. [8,17].

Additionally, with a current condition, a one percent rise in economic performance will lead to decline in environmental quality and cause a 0.268% rise in CO_2 emissions level. This value was measured as 0.344% in the long run and statistically significant at 5% significance level. Furthermore, a one percent decline in economic performance will slow down the CO_2 emissions by 1.542% in short run and 1.98% in the long run. This shows that, in order to meet its 2023 goals of being among the top ten economies, Turkey is prioritizing economic growth over environmental sustainability. As a result, an increase in economic performance will result in an increase in emission levels and a decrease in environmental quality in both terms. Notwithstanding the severe effects of Covid-19, Turkey became ninth most popular FDI destination among all European countries with 160 projects in 2020. This caused an increase in its share in Europe to 3.1% in 2020 which was 3% in 2019. Compared to other emerging economies in Europe, Turkey was placed as the second most popular FDI destination after Poland, with a 16% share in 2020, up from the third place in 2019. (Turkey Investment office, 2021), Therefore, the significance of FDI inflow and its asymmetric effect on environmental quality was tested in our estimation. Particularly, one percent increase in positive shocks on FDI, inflow in Turkey will lead to 0.677% decline of its carbon emissions in the short run, on average, and 0.858% in the long run. Moreover, a one percent decline in FDI, inflow will cause 0.578% and 0.816% decline in environmental quality in short-run and long-run, respectively. These results prove the importance of FDI inflow for Turkish environment. The results are in line with [27,31] studies.

On the other hand, renewable energy is seen as the remedy for environmental sustainability and quality. Thus, in environmental sustainability conferences, i.e. Kyoto Protocol and Paris agreement, the importance of the environmental sustainability and the quality was highlighted and some targets are set and restrictions imposed on countries, such as keeping an increase in global heat at 1.5–2 °C by 2020. Thus, countries intensively investing on renewable energies technologies and try to rise their environmental quality. Depending on its geological advantages, Turkey has lots of renewable energy potentials, however, since decades, it has mainly invested on hydropower energy to meet with energy demand, to reduce the dependency on the energy import and the use of traditional energy sources such as oil. Thus, our estimates indicates that, a 1% rise in hydropower energy consumption in Turkey will lead to 0.128% and 0.093% decline in CO_2 emission level in short run and long run, respectively. Nonetheless, a one percent decline in the hydropower energy consumption will lead to 0.245% and 0.50%

rise in the deterioration level of environment. This means that using hydropower energy in Turkey has positive and statistically significant effect on environmental quality in both terms. In other words, reducing the use of hydropower energy in Turkey will lead to intensively use of non-renewable energy sources for energy supply and increase the CO_2 emissions which cause a decline in the quality of environment in both terms. This will also cause several problems on economic performance, since it is an energy import dependent country. Also, technological innovation through research and development (R&D) is considered among the instruments to test environmental development of Turkey. Finding from our estimations shows declining and increase of carbon emissions due to positive and negative shocks to technological innovation through research and development. Hence 1% positive and negative shocks to technological innovations will cause decline and increase in carbon emissions at 0.853% and 0.819% for short run, and 1.095% and 1.051% for long run respectively. Technological advancement has proven to be among the mitigating forces against carbon emissions through its innovative means of developing green technology. Our finding supports the findings from Refs. [23,53,54].

To confirm the results estimated with NARDL model, the DOLS estimation method has been utilized and the output are displayed in Table 4 above. The results confirm the significance of chosen explanatory variables on environmental quality in Turkey. The long run coefficients of investigated variables indicate that, except economic performance, one percent rise in explanatory variables will cause a reduction in CO_2 emissions and improve the quality of environment. In details, one percent rise in FDI inflow will cause 0.029% decline in CO_2 emissions level, on average and improve the environmental quality. Moreover, one percent rise in research and development activities and entrepreneurial activities will cause 0.048% and 0.109% improvement in environmental quality, on average, respectively. Furthermore, a one percent rise in the use of hydropower energy helps Turkey to reduce the CO_2 emissions level and increase its environmental quality by 0.551%, on average. On the other hand, most importantly, the inverted U-shaped environmental Kuznets Curve hypothesis has been affirmed for Turkey. This means that at the first phase, one percent rise in the economic performance in Turkey will degrade the environment by 1.424%, on average and after a threshold level, for every one percent increase in economic performance will cause 0.144% mitigation in CO_2 emissions level and improve environmental quality. Thus, Turkey intensively tries to increase its economic performance and prioritize the sustainable economic growth to environment at this stage. After that, given a rise in capital and welfare, with the adaption of new and environmentally friendly technologies and awareness, Turkey will aim to improve its environmental quality and sustain its environment as one of the signatory of environmental sustainability agreements.

Table 5
Diagnostic Test results.

Tests	Statistics	P-value
BG-LM test	1.632	0.223
BPG	2.183	0.0622
RESET	0.908	0.3749
ARCH	0.243	0.6156
Jarque Berra Test	1.570	0.4561

Source: Authors computation

Table 5 gives the details about the tests for the reliability of the model. According to Breusch-Godfrey LM (BG-LM) test our model is free of autocorrelation problem. Moreover, the results of Breusch-Pagan- Godfrey (BPG) and ARCH test shows the validity of homogeneous distribution of our model. Whereas, Ramsey RESET test and Jarque Berra Test demonstrate that our model is properly specified and the normality is valid for our estimation, respectively (see Table 6).

Additionally, the stability of the model was tested with CUSUM (Fig. 1) and CUSUMSQ tests (Fig. 2). The results affirms the stability of developed model for our estimation since the plots of the tests are located within the 5% critical bounds.

Lastly, Vector Error Correction Model (VECM) Granger causality analysis has been utilized to test the causal relationship among investigated variables. Particularly, the results indicates the feedback causal relationship between environmental quality and economic performance. Moreover, bidirectional causal relationships were investigated between FDI and economic performance, FDI and RD, FDI and ENT and ENT and economic performance. Also, feedback causal relationship has been found between research and development activities and economic performance. Moreover, the findings also reveal a unidirectional causal linkage running from technological innovation to entrepreneurial activities and hydropower energy consumption, whilst, another unidirectional causal relationship was running from technological innovation to entrepreneurial activities. These outcomes affirm the importance of technological innovation, entrepreneurial activities, economic performance, FDI inflow and renewable energy use on environmental quality for the short term and long term.

5. Conclusion and policy recommendation

This is a study of the possible ways of achieving climate and sustainable development goals for Turkey. Turkey is currently at a crossroad with its policy to mitigate its carbon emission and to boast domestic energy source in order to meet its energy requirements for its economic activities. Turkey is constantly increasing in industrial and commercial sector through the activities of both foreign investors (through FDI) and the domestic entrepreneurs which placed the country as a commercial hub that connect both European and Asian countries. This means a sustained

Table 6
VECM granger causality analysis.

	Causality Wald Statistic					
Variables	lnCO2	FDI	lnHR	lnY	lnRD	lnEN
lnCO2	–	5.685 (0.2239)	7.116 (0.1299)	**7.901*** (0.095)	4.687 (0.321)	0.301 (0.989)
FDI	**44.849*** (0.000)	–	13.213* (0.0103)	**13.055**** (0.011)	**6.754**** (0.028)	**6.323*** (0.067)
lnHR	**6.438**** (0.0349)	5.143 (0.2729)	–	2.246 (0.691)	3.920 (0.417)	0.158 (0.997)
lnY	**27.055***** (0.000)	**6.848**** (0.0218)	1.880 (0.7578)	–	**6.176**** (0.026)	**6.358*** (0.085)
lnRD	**49.491***** (0.000)	**6.565**** (0.016)	**13.538***** (0.009)	**12.594**** (0.013)	–	**7.908**** (0.052)
lnEN	**6.484**** (0.0166)	**6.220**** (0.0183)	**9.312*** (0.054)	**6.633*** (0.0802)	4.672 (0.323)	–

Note: **(1)** numbers into the parenthesis represents the p-values.
(2) *, **, *** symbolizes for 0.01, 0.05 and 0.10 significance level, respectively.
Source: Authors computation

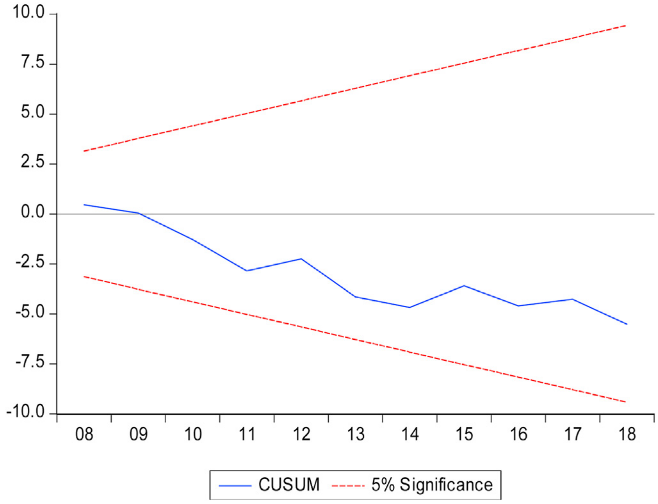

Fig. 1. Cusum test result.

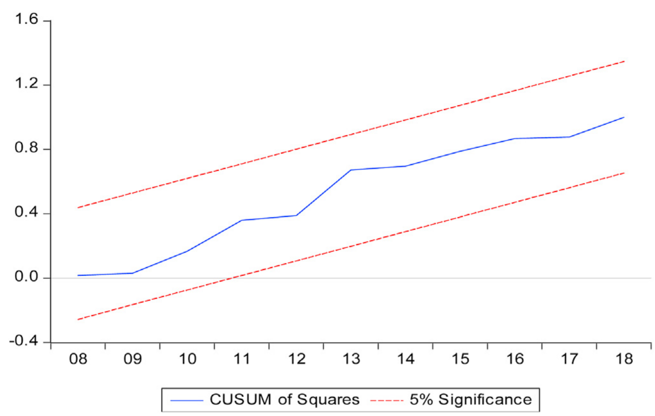

Fig. 2. CUSUMSQ test result.
Source: Authors computation **Source**: Authors computation

economic performance which demands some level of energy availability and utilization in Turkish economic development. Despite continuous economic development through domestic entrepreneurial and foreign investors, Turkey is still below its national determined contribution (NDC) in reducing carbon emission because of its energy policies. Turkey is caught in between shifting from dependency on gas imports to a renewable energy and enlarging its domestic energy through coal source. This is considered as a counterproductive energy policies which looks more of boosting economic development at the expense of environmental development. Considering the current situation of Turkey in trying to mitigate its carbon emission amidst its conscious effort to sustain its economic development, we seek to investigate the ability of the country (Turkey) to achieve its climate goal. For clear insight into this objective, we applied the important economic features (*entrepreneurs, FDI, technological innovation proxy by R&D, renewable energy measured by hydropower and economic growth*) of Turkey that are important in determining both economic and environment development of the country. We test scientifically the contribution of the mentioned instruments towards the environmental developmental and achieving its climate goal. Different scientific approaches (both symmetric-dynamic ordinary least square and asymmetric-NARDL, and VECM Granger Causality Analysis) were applied for clear and in-depth into the objective of this study. Findings from both approaches (symmetric and asymmetric) show that carbon emission can be reduced and good environment quality obtained through the instruments of renewable energy, technological innovation, FDI and entrepreneurial activities. A nexus is established among the instruments of our interest (renewable energy, technological innovation, entrepreneur activities and FDI) which shows the interactions that exist amongst the instruments in determining both economic and environmental development of Turkey. A unidirectional causal relationship is found passing from the instruments to the carbon emissions (CO_2) which points towards mitigating the emissions, and this gives support to the findings from both symmetric and asymmetric approaches. Also, from symmetric analysis with dynamic ordinary least square, EKC is found for the case of Turkey which shows the ability of Turkey achieving its climate goal if right policies are implemented.

From the findings above, it shows that Turkey has the potential to achieve its climate goals in near future irrespective of its counterproductive energy policy if the right policies are framed and implemented. Policies such as deregulation, and government subsidy targeted at expanding the renewable energy to accommodate other renewable sources like wind, solar and geothermal. The deregulation of the sector will attract individual persons and private organization to invest into the sector, while subsidies will encourage the players especially the private bodies in the sector to achieve their desired goals through technological innovation (research and development programs). Subsidies will help to solve the problem of capital need to embark on the renewable energy projects. Even though, entrepreneur activities and FDI show sign of limiting the negative impact of carbon emission, Turkish should monitor the activities of both domestic and foreign investors with moderating policies towards checkmating their excesses in carrying out their businesses. Finally, with the evidence of EKC, it shows the ability of Turkey to maintain sustainable economic development, and this should be maintained through investment into the renewable sectors.

Conclusively, our study has implication to the neighbouring countries with similar economic features like Turkey. The policy recommendation as outline in our study could be applied by the neighbouring countries to achieve good result in achieving their climate goals. The limitation of our study is the period of observation which covered 1985–2018, and non-utilization of some important variables that could give greater insight on this topic. However, this topic is still open for further research especially with other factors like institutions and trade openness, and if possible to extend the observation period beyond 2018 with updated data instruments with updated measurement units like constant 2015 US$ instead of ‘constant 2010 US$.

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Declaration of competing interest

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