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The Effect of the Transmission Impact of the U.S Interest Rate on Turkey's CO2 Emissions: Evidence from Bootstrap ARDL

Ahmed Samour[1] * | Aliya Zhakanova Isiksal[2] | Turgut Tursoy[3]

[1]*Dhofar University, Department of Accounting, Salalah, Sultanate of Oman*
[2]*Near East University, Faculty of Economics and Administrative Sciences, Mersin, Turkey*
[3]*Near East University, Faculty of Economics and Administrative Sciences, Mersin, Turkey*

*Correspondence to: Ahmed Samour, Dhofar University, Department of Accounting, Salalah, Sultanate of Oman
E-mail: asamour@du.edu.om

Abstract: The U.S. economy is the largest in the world; any change in the US economic policies exert a significant impact on global markets. The main purpose of this study is to investigate the spillover effect of the U.S interest rate on Turkey's CO2 emission. The empirical results and the subsequent study discussion will be the first contribution of its kind to the environmental literature field. The study employs the newly developed bootstrap autoregressive distributed lag (ARDL) testing approach as proposed by McNown et al. (2018). The main findings of this study show that there is a negative and significant relationship between the U.S interest rate and Turkey's CO2 emission. The results also provide significant evidence of the spillover effects of the U.S interest rate on CO2 emission in Turkey through the domestic interest rate, economic growth, and energy consumption channels. It is suggested that policymakers should design strategies such as sustained economic growth for responding to any external shocks, in particular, the U.S interest rate.

Keywords: bootstrap ARDL, CO2 emissions, energy, The U.S interest rate, Turkey

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INTRODUCTION

Turkey is the 17th largest economy in the world, with its growing economy and increasing population, Turkey is dependent on imported energy sources, and nearly 88% of essential energy consumption is based on fossil fuels, the majority of which are imported. However, it is expected that the economic growth process will be increased in Turkey in the next years, and therefore, the demand and consumption of nonrenewable energy will continue to increase. Non-renewable energy resources such as fossil fuels: coal, petroleum, and natural gas cannot renew themselves and spontaneously get removed after a certain amount of time. Furthermore, using these types of energy sources harms the environment and the ozone layer by increasing the amount of CO2 emissions (Wolde-Rufael & Weldemeskel, 2020). In contrast, renewable energy resources are green energy and therefore they have no negative effects on the environment. Moreover, renewable energy resources are types of energy that are clean, highly productive, without fuel expenses. However, with the increasing nonrenewable energy demand in the country, the levels of CO2 emissions are also increasing. Turkey is among the 20 countries that emitted the most carbon emissions in 2018 and ranks 15th in total CO2 emissions and 16th in per-capita CO2

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emissions. According to World Development Indicators (WDI), Turkey is one of the most energy-intensive and greatest rates of increase in GHG countries among emerging economics over the period 1990-2014. Although, Turkey's 2023 vision aims to decrease the level of CO_2 emissions. Therefore, several plans have been created to overcome environmental degradation in Turkey. For example, the 11th Development Plan targeted emission control in buildings that emit GHGs in the energy, industry, transportation, waste, agriculture, and forestry sectors. In 2015, a report was presented within the scope of the United Nations Framework Convention on Climate Change (UNFCCC), in which it was stated that by 2030 GHG emissions originating from businesses should decrease by 21% through the measures taken.

This study fills the gap in the literature by testing the spillover impact of the U.S interest rate on CO_2 emission through four channels namely domestic interest rate, income, trade, energy consumption. To our knowledge, no research in the literature tested the impact of the U.S interest rate on CO_2 emission for Turkey. The international effects of the U.S interest rates have been a significant topic in the literature. According to many empirical studies, the U.S interest rate has a significant impact on emerging financial markets (Ehrmann & Fratzscher, 2009, Wongswan, 2009, Özatay et al., 2009, Basu et al., 2014, Samour et al., 2019, Yaman et al., 2020). Thus, the changes in financial markets will affect goods and aggregate output which in turn affect many economic factors such as trade, FDI, and economic growth, thus, may lead to affect consumption of energy. Besides, the U.S interest rate can affect emerging markets, through its spillover impact on domestic monetary policy. Thus, any change in the interest rate affects local credit supply conditions. Also, the spillover effect of the U.S interest rate affects the cost of raising funds internationally and the flow of international capital (Greenwood & Hanson, 2013). However, Turkey still has considerable potential for CO_2 emission reduction, if the energy consumption structure is dominated by fossil fuels. In this line, this study aims to provide a new discussion by examining the effect of the transmission impact of the U.S interest rate on Turkey's CO_2 emissions using the Bootstrap ARDL. The study can make a significant impact in terms of the policies intended to diminish CO_2 emissions in Turkey. Furthermore, to the best of our knowledge, no study has examined the effect of the tested variables on CO_2 emissions in Turkey using bootstrap ARDL. The bootstrap ARDL approach, which is an improved version of the ARDL approach, has increased the power of the t-test and F-test, using the F independent test with the F-test and t dependent tests is important, and will yield robust results. In addition, the study used the Granger causality test under error correction to investigate the directions of the relationships between variables. Figure 1 shows the linkage among the tested variables of the current study.

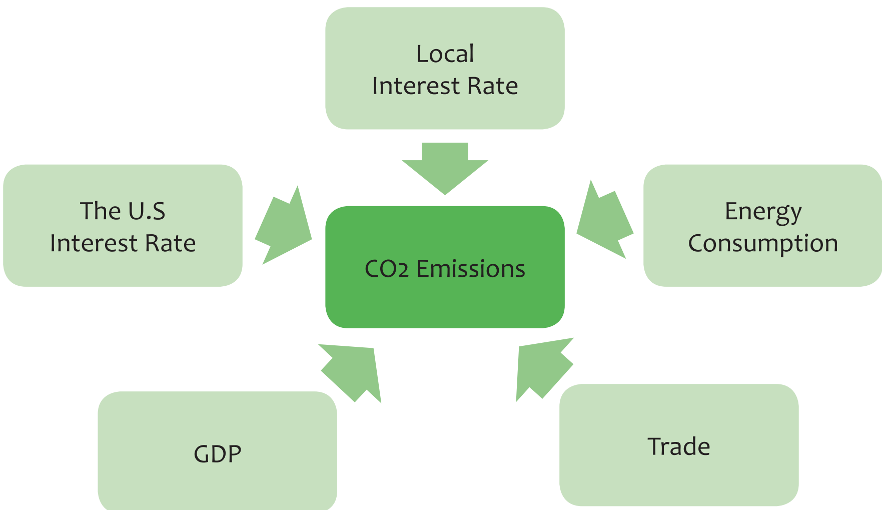

Figure 1 Shows the linkage among the tested variables

The linkage between CO_2 emission and economic growth has gained an increase in literature, and it is anticipated to contribute to the development of CO_2 emission lowering strategies. The environmental Kuznets curve hypothesis explains the relationship between economic growth and environmental pollution, this hypothesis postulates that pollution increases in the early stages of economic growth, after that, it decreases (Grossman & Krueger, 1991). Following the pioneering work of Grossman & Krueger (1991). Many empirical studies have investigated the relationship between income and CO_2 emission (Apergis et al., 2010; Pata, 2018; Katircioglu & Katircioglu, 2018, Khattak et al., 2020). In Validation of the environmental Kuznets curve hypothesis. Apergis et al. (2010) showed there is a causal relationship between energy consumption, economic growth, and CO_2 emissions. Khattak et al. (2020) used the CCEMG technique and found that the environmental Kuznets curve hypothesis is valid in BRICS economies from 1980 to 2016. In Turkey, Yavuz (2014) showed that the environmental Kuznets curve hypothesis is valid in Turkey. By using the ARDL model: Pata (2018), and Katircioglu & Katircioglu (2018) confirmed that the environmental Kuznets curve hypothesis holds in Turkey over different periods.

In the relation between energy consumption and CO_2 emission, Soytas et al. (2007) found that there is a significant impact between energy consumption and CO_2 emission in the USA. Pao & Tsai (2011) suggested that there is a bidirectional causal relationship between energy consumption and CO_2 emissions in Brazil, Russia, India. Abbasi et al. (2020) implied that nonrenewable energy consumption has a positive influence on CO_2 emissions in 8 Asian countries during the period from 1982-2017. Using the ARDL model, Jayanthakumaran et al. (2012) found that a positive linkage between non-renewable energy consumption and CO_2 emission in China and India. Habib (2015) showed that there is a positive association between energy consumption and CO_2 emission in Tunisia from 1980 to 2011. Bölük & Mert (2015) have suggested a positive linkage between non-renewable consumption and Turkey's CO_2 for the period 1961-2014. Balaguer & Cantavella (2016) found a positive linkage between energy consumption and CO_2 emission in Spain. In relation between trade and CO_2 emission, Kim et al. (2013) showed that international trade has a positive impact on CO_2 emission in selected developing and developed countries over the period 1960–2013. Omri et al. (2014) indicated that international trade has a positive influence on CO_2 emission in 12 selected countries. In Turkey, Samour et al. (2019) used the ARDL approach and showed that international trade affects positively Turkey's CO_2 emission in Turkey from 1980 to 2014.

On other hand, the international transmission effects of the U.S interest rate policy have been an important topic in literature. Given the significance of the U.S economic policies on international capital flows, it is likely that any change in the U.S. interest rate can affect the global markets. Given the importance of the U.S. interest rate policy, it is unsurprising that the influence of the U.S. interest rate on global economics is examined frequently. Many studies find significant evidence of spillovers of the U.S. monetary policy on emerging markets. In this regard, Andritzky et al. (2007) suggested that discovered the U.S. interest rate matters more to countries with less transparent policies and lower credit ratings. Minihane & Rogers (2007) suggested that the impact of U.S. interest rates on the global market depends on countries' capital controls. Ehrmann & Fratzscher (2009) show that there is a strong effect on the U.S interest rate on global markets. Wongswan (2009) tested the impact of the U.S. interest rate channel on 15 selected countries. The results suggest that financial linkages play a significant role in determining the response of global economics to any change in the U.S. interest rate channel. Özatay et al. (2009) confirmed that there is a powerful impact on the U.S interest rate on 18 emerging markets. Rogers et al. (2014) showed that a lower U.S. interest rate stimulates financial conditions abroad and, in many cases. Also, the lower U.S. interest rate weakens the dollar. Basu et al. (2014) suggested that any change in the U.S monetary policy had a sharp impact on capital flows in India. The results found that the size and the sign of spillover effects of the U.S interest rate on emerging equity and exchange markets vary across regimes, and there is no common pattern of spillovers.

Recently studies from Turkey, Yaman et al. (2020) found the U.S interest rate policy has a significant impact on the Turkish banks in Turkey. Samour et al. (2019) tested the impact of the U.S interest rate on the Turkish stock market by using the ARDL model; the authors have shown that there is a significant influence of spillover of the U.S interest rate on the equity market in Turkey through the domestic interest rate channel. The study suggested the policymakers in Turkey should pay more attention to the role of domestic policies in attenuating spillovers of the U.S interest rate on Turkey's economy when these occur. Although many empirical types of research focus on the influence of the U.S interest rate on global markets and economics, the spillover of the U.S interest rate on the global environment is ignored. However, the main purpose of this study is to explore the spillover effect of the U.S interest rate on Turkey's CO2 emission. The empirical findings and discussions will be the first contribution to environmental studies literature. In this regard, if there is a significant effect of the U.S interest rate on the global market and many macroeconomic variables such as FDI, economic growth, trade, exchange rate, and local interest rate policy, it may affect energy consumption and energy prices, which in turn lead may affect environmental pollution.

METHODS

Much empirical research (Grossman & Krueger, 1995) have applied the following expressed model to test the relation between economic growth, and CO2 emission:

$$InCO_{2\,t} = \alpha_o + \beta_1\, InGDP_t + \beta_2 InGDP^2_t + \varepsilon_{it} \quad (1)$$

Where α is intercept and β_1, β_2 are coefficients of explanatory variables, and ε_{it} is the error term. $InCO_{2\,t}$ is the carbon dioxide emissions, *InGDP* and $nGDP_2$ are *GDP* and square of *GDP*. To our knowledge, no study in the existing literature tested the impact of the U.S interest rate on CO_2 emission for Turkey. Thus, the U. S interest rate as an external factor will be added to the model of environmental Kuznets curve hypothesis to test how the U.S interest rate effect on environmental population in emerging economies like Turkey. The empirical model of this study is presented as follows:

$$InCO_{2\,t} = \alpha_o + \beta_1\, InGDP_t + \beta_2 InGDP^2_t + \beta_3 InNEC_t + \beta_4 InT^I_t + \beta_5 InIN_t + \beta_6 InUSI_t + \varepsilon_{it} \quad (2)$$

Where *In* is the logarithm of the variable, $CO_{2\,t}$ is the dependent variable, *GDP*, GDP_2, *NEC*, *TI*, *IN*, and *USI* are explanatory variables. Abbreviations, units of measurement, and the source of these variables are presented in Table 1. The data is the annual time series data covering the period from 1985 and 2014, and the data obtained from the World Bank and Organization for Economic Cooperation and Development. Figure 2 shows a plot of the variables.

The current study entails an autoregressive distributed lag model to find out the association between the U.S interest rate, local interest rate, energy consumption, trade, economic growth, and Turkey's CO2 emission. In the first step, the study tested the stationarity of the time-series data. These tests aim to test the degree of integration of each variable. However, the traditional unit root tests, which do not include the dates of structural breaks, can yield misleading outcomes. To overcome this issue, the study uses Zivot–Andrews unit root test includes one date of structural break. Also, the Clemente, Montanes, & Reyes (1998) unit root test includes two dates of his test that allows us to test the degree of integration of each variable. The null hypothesis of Clemente, Montanes, & Reyes, and Zivot & Andrews tests implies that the data of this study is stationary. whereas, the alternative hypothesis implies that the data of this study is stationary.

Table 1 The description of the variables and sources of the data

Variable Name	Abbreviation	Unit of Measurement	Source
CO2-emissions	$CO2_E$	metric tons of emission per-capita	WB
GDP	GDP_t	(2010 = 100) in USD	WB
Square/GDP	GDP^2_t	the square of GDP	WB
Energy-consumption	NEC_t	kt of oil equivalent	WB
Interest rate	LIN_t	Landing interest rate	OECD
The U.S interest rate	USI_t	Short term interest rate	OECD
International trade	T^I_t	the sum of imports and exports measured. as a % of GDP	WB

Note: WB is the World Bank, OECD is the Organization for Economic Cooperation and Development

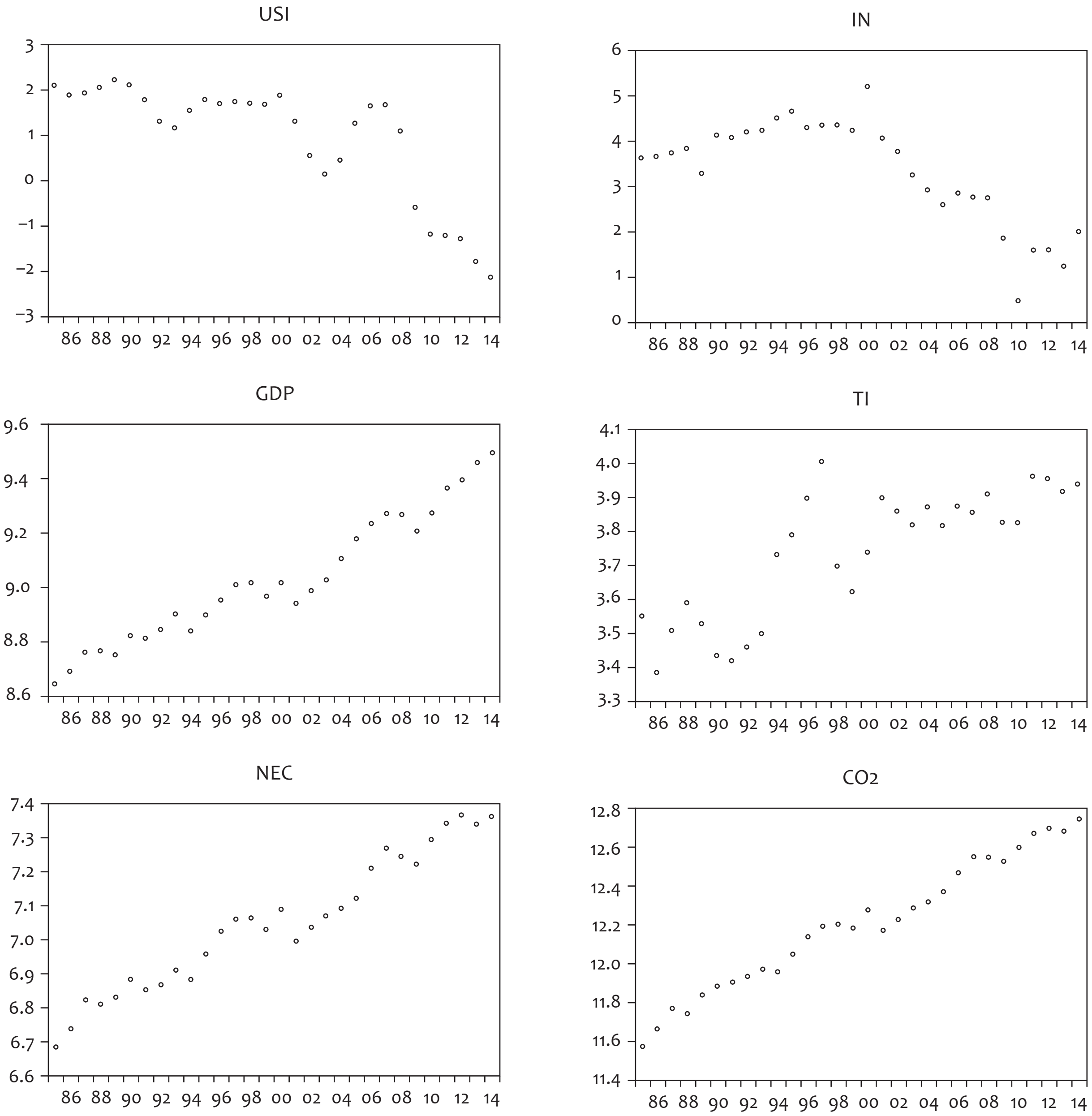

Figure 2 Plot of the variables

For analysis of long- and short-run correlations, the study uses the recent ARDL bounds testing approach to the cointegration which was suggested by McNown et al. (2018). In the fact the traditional cointegration tests, such as Engle & Granger (1987) and Johansen (1988), the time-series data must have a unique order of integration, thus, the ARDL testing model is more suitable for the time series data which have a various order of integration. In an ARDL testing approach, the integration order was distributed among the variables at I(0) or I(1) or mutually co-integrated. One of the main advantages of this approach is more suitable for small data. Furthermore, the coefficients can be estimated simultaneously in the short and long run. The lag lengths are specified by using the Akaike-information criterion or Schwarz-information criterion.

The ARDL approach was proposed and developed by Pesaran & Shin (1998) and Pesaran et al. (2001) to test the long-term association between time series. Recently, this approach was upgraded by McNown et al. (2018). Based on the ARDL testing approach, equation (3) is formulated in the following equation:

$$\Delta LnCO2_t = \alpha_0 + \sum_{i=1}^{k} \delta_1 \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \delta_2 \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \delta_3 \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \delta_4 \Delta lnNEC_{t-1} + \sum_{i=1}^{k} \delta_5 \Delta lnT^l_{t-1} + \sum_{i=1}^{k} \delta_6 \Delta lnIN_{t-1} + \sum_{i=1}^{k} \delta_7 \Delta lnUSI_{t-1} + \sum_{i=1}^{k} \delta_8 D08_{t-1} + \sigma_1 lnCO_{2\,t-1} + \sigma_2 lnGDP_{t-1} + \sigma_3 lnGDP^2_{t-1} + \sigma_4 lnNEC_{t-1} + \sigma_5 lnT^l_{t-1} + \sigma_6 lnIN_{t-1} + \sigma_7 USI_{t-1} + \varepsilon_t \quad (3)$$

where Δ is the operator of the first difference, α_0 represents the constant term, ε_t is the error term, δ_1, δ_2, δ_3, δ_4, δ_5, δ_6, δ_7 are short-run estimated coefficients, σ_1, σ_2, σ_3, σ_4, σ_5, σ_6, σ_7 are long-run coefficients, *n* represents the maximum number of lags. D08 is the dummy variable of the 2008 financial crisis. In ARDL bounds tests, the $F_{Pesaran}$ the test is aimed to determine a (single) long-term association in Equation (3). The null hypothesis of the ARDL bounds test is $H_0 : \sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = \sigma_5 = \sigma_6 = \sigma_7 = 0$. In contrast, the alternative hypothesis is $H_1 : \sigma_1 \neq \sigma_2 \neq \sigma_3 \neq \sigma_4 \neq \sigma_5 \neq \sigma_6 \neq \sigma_7 \neq 0$.

Recently, this approach upgraded by McNown et al. (2018), the recent version includes additional t-test $t_{dependent}$ or F-test $F_{independent}$ on the coefficients of lagged independent variables. The H_0 of $t_{dependent}$ test is: $\sigma_1 = 0$. The H_1 of $t_{dependent}$ test is: $\sigma_1 \neq 0$. While The H_0 of $F_{independent}$ test is: $H_0 : \sigma_2 = \sigma_3 = \sigma_4 = \sigma_5 = \sigma_6 = \sigma_7 = 0$. The H_1 of $F_{independent}$ test is: $H_1 : \sigma_2 \neq \sigma_3 \neq \sigma_4 \neq \sigma_5 \neq \sigma_6 \neq \sigma_7 \neq 0$.

The critical values in the bootstrap ARDL approach are created based on the set integration features of each time-series employing the procedures of ARDL bootstrap, which in turn lead to eliminating the instability result of the ARDL bounds test (McNown et al., 2018). However, McNown et al. (2018) upgraded the bootstrap ARDL test by employing a table of critical values gained by bootstrap simulation. These steps of the bootstrap test will lead to getting better results than the traditional ARDL bounds test. In particular, the Pesaran et al. (2001) critical values allow for (1) examined variable to be endogenous, while the critical values generated with a bootstrap technique allow for the endogeneity of explanatory examined variables. Also, this approach is more suitable for data that includes more than (1) explanatory variable (Goh et al. 2017).

However, the bootstrap ARDL approach, which is an improved version of the ARDL approach, has increased the power of the t-test and F-test. The traditional ARDL bounds testing approach derives critical values only for F-tests and t dependent tests, and it disregards F independent tests. However, using the F independent test with the F-test and t dependent tests is important, and will yield robust results.

In the determination of the level of the cointegration relationship, the values of $F_{Pesaran}$, $t_{dependent}$, $F_{independent}$ should be statistically significant and exceed the critical values in the bootstrap ARDL technique to have an integration relationship between the examined variables (McNown et al., 2018).

The error correction model (ECM) to estimate the coefficient in short-run relation is presented in Eq. (4):

$$\Delta LnCO2_t = \alpha_o + \sum_{i=1}^{n} \delta_1 \Delta lnCO2_{t-1} + \sum_{i=1}^{n} \delta_2 \Delta lnGDP_{t-1} + \sum_{i=1}^{n} \delta_3 \Delta lnGDP^2_{t-1} + \sum_{i=1}^{n} \delta_4 \Delta lnNEC_{t-1} + \sum_{i=1}^{n} \delta_5 \Delta lnT^I_{t-1} + \sum_{i=1}^{n} \delta_6 \Delta lnIN_{t-1} + \sum_{i=1}^{n} \delta_7 \Delta USI_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (4)$$

where Δ stands the operator of the first difference, α_o represents the constant term, the white-noise error term, $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7$ are short-run estimated coefficients. In (4) equation, ωECT_{t-1} is the (one) period lagged *ECT*. However, it estimated is to be a negative (-) and statistically significant, ωECT_{t-1} implies the speed of adjustment of the long-term levels of equilibrium level.

The study uses several diagnostic tests to confirm the model of this study is formulated correctly. In this regard, the study uses the Breusch-Godfrey Serial Correlation test to test if there is a serial correlation. the Ramsey RESET and ARCH tests are used to check the stability of the model. The Jarque-Bera normality test to test the normality of the model. Also, the study used the cumulative sum CUSUMtest and the CUSUM of square tests to test the stability of the model Maji et al. (2020).

Furthermore, Granger causality is used to analyze the direction of causality among the time series In this, (*ECT*) determines the short-term deviations of the study variables from the long-term equilibrium level. The *ECM* equation is formulated in equations 5 to 11:

$$\Delta LnCO2_t = \alpha_o + \sum_{i=1}^{k} \gamma_1 \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnNEC_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnT^I_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnIN_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnUSI_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (5)$$

$$\Delta lnGDP_t = \alpha_o + \sum_{i=1}^{k} \gamma_1 \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnNEC_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnT^I_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnIN_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnUSI_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (6)$$

$$\Delta lnGDP^2_t = \alpha_o + \sum_{i=1}^{k} \gamma_1 \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnNEC_{t-1} + \sum_{i=1}^{n} \gamma_o \Delta lnT^I_{t-1} + \sum_{i=1}^{n} \gamma_o \Delta lnIN_{t-1} + \sum_{i=1}^{n} \gamma_o \Delta lnUSI_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (7)$$

$$\Delta lnNEC_t = \alpha_o + \sum_{i=1}^{k} \gamma_1 \Delta lnNEC_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnT^I_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnIN_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnUSI_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (8)$$

$$\Delta lnT^I_t = \alpha_o + \sum_{i=1}^{k} \gamma_1 \Delta lnT^I_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \gamma_1 \Delta lnNEC_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnIN_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnUSI_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (9)$$

$$\Delta lnIN_t = \alpha_o + \sum_{i=1}^{k} \gamma_1 \Delta lnIN_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \gamma_1 \Delta lnNEC_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnT^I_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnUSI_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (10)$$

$$\Delta lnUSI_t = \alpha_o + \sum_{i=1}^{k} \gamma_1 \Delta lnUSI_{-1} + \sum_{i=1}^{k} \gamma_o \Delta lnCO2_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnGDP^2_{t-1} + \sum_{i=1}^{k} \gamma_1 \Delta lnNEC_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnT^I_{t-1} + \sum_{i=1}^{k} \gamma_o \Delta lnIN_{t-1} + \omega ECT_{t-1} + \varepsilon_t \quad (11)$$

Where *ln*CO2, *lnGDP*, $lnGDP^2$, *lnNEC*, lnT^I, *lnIN*, *USI* are the research variables, ε_t stand the error-terms, and ωECT_{t-1} is the lagged error correction term. The direction of association in the short-term is determined by Wald test's $F\text{–}_{statistics}$ testing approach to find the significance of the related estimated coefficient by utilizing the first operator of the first difference. To examine the direction of association in the long term, the test of the related estimated coefficient of the lagged (ECT) is applied.

RESULTS AND DISCUSSION

In the first step, the study tested the stationarity of the time series data using Z–A and CMR tests. The outcomes of Zivot–Andrews, and Clemente, Montanes, & Reyes unit root tests with one and two dates of structural breaks are presented in Table 2. The results show that CO2, GDP_t, $GDP^2{}_t$, NEC_t, LIN_t, USI_t, and $T^I{}_t$ are not stationary at level, thus, the null hypothesis (*H*0) of Zivot–Andrews, and Clemente, Montanes, & Reyes tests is rejected. In contrast, the results show that CO2, GDP_t, $GDP^2{}_t$, NEC_t, LIN_t, USI_t, and $T^I{}_t$, are stationary at first differed, thus the time series of this research are stationary and integrated at I(1).

The bootstrap ARDL test results are showed in Table 3, the results show that there is a cointegration relationship between CO2, GDP_t, $YGDP^2{}_t$, NEC_t, IN_t, USI_t, and $T^I{}_t$ for $F_{Pesaran}$, $t_{dependent}$, $F_{independent}$ tests at a 5% level. The results provide strong evidence that there cointegration relationship between the examined variables.

Table 2 The results of Zivot–Andrews and Clemente, Montanes, & Reyes

	The Zivot–Andrews			Clemente, Montanes, & Reyes			
	t-stat	CV	1D-SB	t-stat	CV	2D-SB	2D-SB
lnCo2	-2.321	-4.42	2005	-3.931	-5.49	2001	2008
lnGDP	-2.931	-4.42	1999	-4.310	-5.49	2003	2009
$lnNEC_t$	-3.345	-4.42	2004	-3.878	-5.49	2001	2004
lnT_I	-3.659	-4.42	1984	-4.141	-5.49	2000	2008
lnIN	-1.207	-4.42	2001	-4.210	-5.49	2000	2011
lnUSI	-4.112	-4.42	2008	-3.251	-5.49	2008	2009
Δ*lnCO2*	-5.065**	-4.42	2002	-6.878**	-5.49	1985	2008
Δ*lnGDP*	-7.624**	-4.42	2000	-5.411**	-5.49	2001	2010
$\Delta lnNEC_t$	-5.207**	-4.42	1997	-5901**	-5.49	2001	2008
ΔlnT^I	-6.516**	-4.42	1988	-8.412**	-5.49	2000	2006
Δ*lnIN*	-5.931**	-4.42	1994	-5.910**	-5.49	2001	2009
Δ*lnUSI*	-5.490**	-4.42	2008	-6.320**	-5.49	1995	2008

** statistical sign at a 5% level. D-SB is a date of a structural-break

Table 3 The results of the Bootstrap ARDL approach

ARDL)1,0,0,0,1,0,1)	SB-date	$F_{Pesaran}$	$t_{dependent}$	$F_{independent}$
$CO2_E = f(Y_t, Y^2{}_t, NEC_t, T^I{}_t, LIN_t, USI_t)$	2008	6.873***	-3.94***	6.628***
Bootstrap-based table CV	1%	3.99	-3.88	7.06
	5%	3.28	-3.08	4.85
	10%	2.94	-2.85	3.96

***,**,,* statistical sign at 1%,5%,10% level respectively

The results from Table 4 show that the ARDL equation passed all diagnostic tests for autocorrelation, nonmorality, and heteroscedasticity. Also, the results of CUSUM and CUSUM^{sq} figures (figure 3 and figure 4) showed that the estimated coefficients of the ARDL model are stable. The findings indicate that the speed of adjustment ECT_{t-1} is a negative sign (-) and statistically significant at (1%) level. This result confirms that there is a long-term linkage between the variables from the short-run to the long-run equilibrium which is amended back around 70.6% every year. After providing and confirming the cointegration relationship between the variables, the study estimates an ARDL model.

The result of short and long-run coefficients from the ARDL model is shown in Table 4 and Table 5. The results show that GDP_t has a positive and statistically significant effect on CO2 emission. In contrast, GDP^2_t has a negative and statistically significant effect on CO2 emission. The positive impact of GDP_t and the negative impact of GDP^2_t are providing significant evidence that the environmental Kuznets curve hypothesis in Turkey holds. Thus, an increase in the GDP in Turkey led to increasing CO2 emissions first and, after a certain period, decreased these CO2 emissions. This finding supports the studies of Pata (2018), which suggested that the environmental Kuznets curve hypothesis is valid in Turkey.

In the relationship between non-renewable energy consumption (*NEC*) and CO2 emissions, the findings show that non-renewable energy consumption has a positive and statistically significant influence on Turkey's CO2 emission. In the long run, a 1% increase in per capita non-renewable energy consumption led to an increase in CO2 emissions by 1.17%. In the short run, a 1% increase in per capita non-renewable energy consumption led to an increase in CO2 emissions by 1.05%. This finding confirmed the paper of Bölük & Mert (2015) which suggested that non-renewable energy consumption has a positive impact on emission in Turkey. Furthermore, the results showed that international trade has a positive and significant impact on CO2 emission in the short run. Also, the empirical results from the long-run show that trade affects positively CO2 emissions. In the long run, a 1% increase in trade led to an increase in CO2 emissions by 0.009%. In the short run, a 1% increase in trade led to an increase in CO2 emission by 0.003%. This finding confirmed the paper of Samour et al. (2019) which suggested that trade has a positive impact on emission in Turkey. The findings of this study may provide helpful implications for policymakers in shaping their trade to CO2 emissions, and they should design new environmental regulations to reduce environmental degradation, especially for international trade and economic growth channels. According to the findings of this research, policymakers in Turkey should be aware of the impacts of energy consumption, trade openness, and economic growth on the CO2 emissions level when they are trying to achieve higher levels of economic development.

On the other hand, the results imply that domestic interest rates are negatively and statistically significant on Turkey's CO2 emission. In the short-run relation, a 1% decrease in the local interest rate in Turkey led to an increase in CO2 emission by 0.0127 %. The coefficient in the long-run relation, a 1% increase in local interest rates led to an increase in CO2 emission by 0.05%. However, these results suggested that policymakers should pay more attention to environmental pollution by supporting the investment and projects in renewable resources with low-interest rates. It is suggested that the policymakers should use this channel to reduce environmental degradation by introducing monetary policy reforms, and also encourage energy investment and the production of electricity using renewable sources. Besides, the results showed that the U.S interest rates interest rate is negatively and statistically significant on Turkey's CO2 emission in both short and long- run. The coefficient in short-run relation shows that a 1% increase in the U.S interest rate led to a decrease in CO2 emission by 0.019%. In the long-run relation, a 1% increase in local interest rate led to a decrease in CO2 emission by 0.014%.

Table 4 The result of Long-run coefficients

Regressor	Coeff.	t-ratio	Standard errors	Diagnostics tests	
lnGDP	6.129***	3.705	2.212	JB	0.155(.925)
*lnGDP*²	-0.313**	-3.592	0.087	LM test	1.874(0.150)
*lnNEC*ₜ	1.169***	8.337	0.14	ARCH	2.237(0.145)
*lnT*ᴵ	0.009	1.761	0.097	Ramsey	0.832(0.413)
lnIN	-0.051*	-2.994	0.017	Heteroscedasticity	0.652(0.725)
lnUSI	-0.0142*	-2.849	0.005		
D2008	-0.030**	-2.418	0.012		

** statistical sign at 5% level

Table 5 The result of short-run coefficients

Regressor	Coeff.	t-ratio	Standard errors
Δ*lnGDP*	4.705***	1.654	2.126
Δ*lnGDP*²	-0.362**	-2.208	0.029
Δ*lnNEC*ₜ	1.056***	6.600	0.637
Δ*lnT*ᴵ	0.003**	4.222	0.002
Δ*lnIN*	-.0127**	-3.162	0.004
Δ*lnUSI*	-0.0193*	-2.895	0.006
ECT(−1)	-0.706*	-6.649	0.106

***,**,,* statistical sign at 1%,5%,10% level respectively

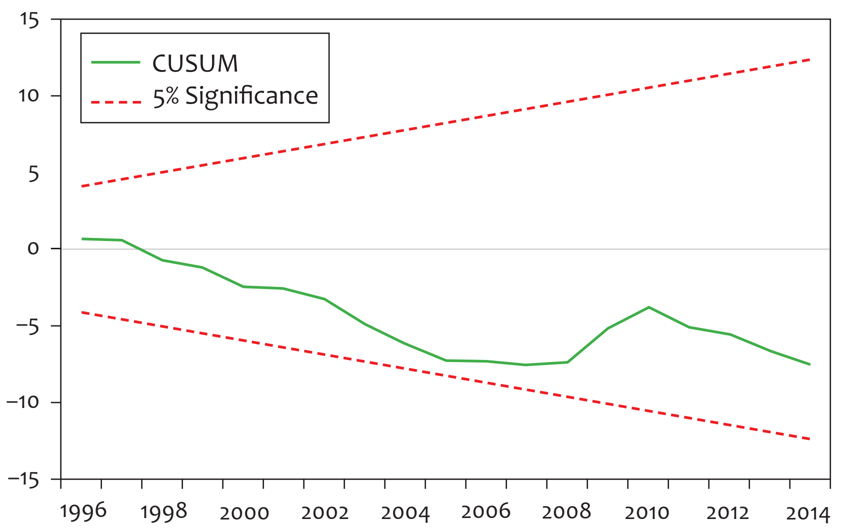

Figure 3 Testing of the stability using CUSUM test

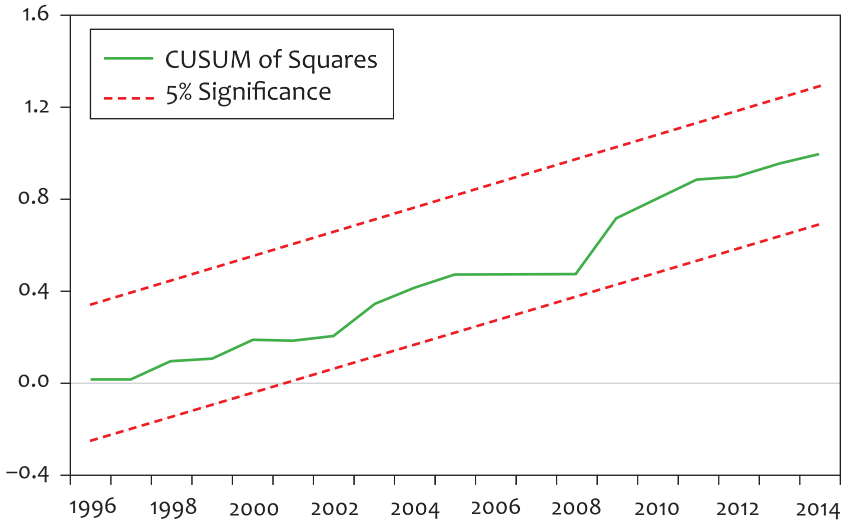

Figure 4 Testing of the stability using CUSUM-squares test

The results of Granger causality are shown in Table 6. The null hypothesis this test there is no causal linkage between the examined variables. The result shows that *t*-statistics on the lagged-value of the ECT provides evidence that there is a unidirectional causal relation from GDP_t, GDP^2_t, NEC_t, IN_t, USI_t to CO2 in the long run. The empirical outcomes from the short-run indicate that there is a unidirectional causal linkage from the U.S interest rate, interest rate, economic growth, trade, and nonrenewable energy consumption to CO2 (GDP_t, IN_t, USI_t and T^I_t, $NEC \rightarrow$ CO2). Also, the empirical outcomes from the short-run indicate that there is a unidirectional causal linkage from the U.S interest rate, interest rate, economic growth, trade to nonrenewable energy consumption (GDP_t, IN_t, USI_t, and $T^I_t \rightarrow NEC_t$). This empirical result Granger causality test provides evidence that economic growth, trade, and the local and U.S interest rate affect nonrenewable energy consumption in Turkey, which may lead to an increase in Turkey's CO2 emissions. Also, there is the unidirectional causal linkage from interest rate to nonrenewable energy consumption, economic growth ($IN \rightarrow GDP_t$, NEC_t). These results provide evidence that there is a significant spillover of local interest rates on CO2 emissions through energy consumption and economic growth.

Also, it is highly important to show that the U.S interest rate causes local interest rates, energy consumption, and economic growth. In this regard, the U.S interest rate may affect the increase in environmental pollution in emerging countries like Turkey through energy consumption, economic growth, and local interest rate channels. This result shows that the US interest rate channel has proved itself capable of affecting Turkey's carbon emissions through the interest rate channel and economic growth. It is suggested that this might be driven by high external debt and limited foreign exchange reserves, while the USD remains the primary reserve currency. The country's low international reserves do not grant a buffer against possible external influence, with capital outflow and changes in investor sentiment to the other emerging markets. All these factors increase the spillover effect of the U.S interest rate on Turkey's carbon emission, as the dollar is the prior reserve currency and the majority of the external debt is composed of this currency.

However, the study suggests that the spillover impact of the U.S interest rate on Turkey's CO2 emissions can be significant in two ways. First, any change in the U.S interest rate may affect the domestic monetary policy. For instance, an increase in the U.S interest rate leads to an appreciation of the U.S currency. In contrast, it may lead to the depreciation of the Turkish currency. In response to the depreciation of the local currency, the first line of defense for central banks is to increase short-term interest rates (Inoue & Rossi, 2019). Thus, an increase in local interest rate will lead to an increase in the costs of investment finance, thus causing a decrease in investments in new projects, also, any change in the interest rate affect the consumption of automobiles, electric machines, which in turn leads to affect in energy consumption and subsequently leads to affect CO2 emission. Second, any change in the U.S interest rate can affect cash flow and foreign investment in Turkey. Also, it may affect trade, FDI, and economic growth, which in turn affect energy consumption, and subsequently affect carbon emissions.

Another important factor that must be investigated is whether the global financial crisis has had any effect on the environmental population. In the last years, the majority of economics suffered from financial crises. According to (Cömert & Çolak, 2016) the 2008 crisis harmed Turkey's economy. Turkey faced an excessive current account deficit and large amounts of external debt, and lower economic growth. Thus the change in the economic factors may lead to a change in energy consumption, which in turn affects CO2 emission. In this way, the study aims to test the effect of the 2008 financial crisis on the environmental population in Turkey. In this sense, the results show that the 2008 economic crisis harms carbon emissions in both the short run and the long run. However, in 2008 both energy consumption and economic growth in Turkey decreased. Hence, the empirical results suggest that the 2008 global crisis caused a reduction in CO2 emissions due to a decrease in energy consumption and economic growth in both the short and long run. However, this result confirms the significant impact of external shocks on environmental pollution.

Table 6 The results of the Granger causality test

	$\Delta lnCO2_E$	$\Delta lnGDP$	$\Delta lnGDP^2$	$\Delta lnNEC_t$	ΔlnT^I_t	$\Delta lnIN$	$\Delta lnUSI$	ECT_{t-1}
$\Delta lnCO2_E$	-	5.27*	4.272	6.97**	6.27*	7.31*	6.014*	-0.27**
$\Delta lnGDP$	0.27	-	0.149	1.67	1.67	5.95*	12.91**	-0.24
$\Delta lnGDP^2$	2.36*	2.97*	-	4.27	4.27	0.73	6.92**	0.52
$\Delta lnNEC_t$	0.93	6.55**	0.27	-	6.32**	6.43**	5.05*	-0.27**
ΔlnT^I_t	1.23	2.39	0.92	3.92	-	6.31	5.25	
$\Delta lnIN$	2.19	0.81	0.83	3.94	3.94	-	2.32	0.49
$\Delta lnUSI$	0.28	2.36	2.05	0.08	0.08	2.89	-	-0.59

***,**,,* statistical sign at 1%,5%,10% level respectively

The empirical results and discussion of this study will be the first contribution to the environmental literature field. The study employs the newly developed bootstrap ARDL testing approach as proposed by (McNown et al., 2018) with smooth structural changes over the period 1985-2014. The bootstrap ARDL approach, which is an improved version of the ARDL approach, has increased the power of the t-test and F-test. The traditional ARDL bounds testing approach derives critical values only for F-tests and t dependent tests, and it disregards F independent tests. However, using the F independent test with the F-test, and t dependent tests is important, and will yield robust results. Furthermore, the Granger causality testing approach is utilized to examine the causal relationships among the variables. The empirical findings of this study show that there is strong evidence that the environmental Kuznets curve hypothesis is valid in Turkey, which is consistent with the results of (Samour et al., 2019) who indicated that the environmental Kuznets curve hypothesis is valid in Turkey. However, the findings of this study may provide helpful implications for policymakers in shaping their trade to CO_2 emissions, and they should design new environmental regulations to reduce environmental degradation, especially for international trade and economic growth channels. On the other hand, the findings from the ARDL testing model showed that there is a negative and significant effect of the U.S interest rate on CO_2 emission in both the short and long- run. Also, it is highly important to show that the U.S interest rate causes local interest rates, energy consumption, and economic growth. In this regard, the U.S interest rate may affect the increase in environmental pollution in emerging countries like Turkey through energy consumption, economic growth, and local interest rate channels. Finally, the results show that the 2008 financial crisis reduced the levels of carbon emissions in both the short run and long run, in the 2008 global crisis, both non-renewable energy consumption and economic growth in Turkey decreased. Hence, our empirical results suggest that the 2008 global crisis caused a reduction in carbon emissions due to a decrease in energy consumption and economic growth in both the short and long run. However, this result confirms the significant impact of external shocks on environmental pollution.

CONCLUSION

The U.S. economy is the largest in the world, any change in the US economic policies exert a significant impact on global markets. In this regard, the spillover impact of the U.S interest rate poses a significant challenge to policymakers in emerging countries. Although many empirical types of research focus on the influence of the U.S interest rate on global markets and economics, the spillover of the U.S interest rate on the global environment is ignored. The main purpose of this study is to investigate the spillover impact of the U.S interest rate on Turkey's CO_2 emission. The empirical outcomes of this research may provide a helpful conclusion and recommendation for policymakers for several reasons. Turkey as an emerging country has faced an increase in rates of energy consumption and economic growth rates in the period 1984-2015. On the other hand, Turkey has faced high rates of CO_2 emissions over the period from 1984-2015. However, it will be difficult to meet CO_2 emissions targets if the effects of these external shocks such as the U.S interest rate are not considered in strategies of reduction of CO_2 emissions. The U.S interest rate has essential effects on the emerging countries by either impacting trade, economic growth, trade, local interest rate. Hence if the local interest rate has a significant response to any change in the U.S interest rate, this change will affect the cost of investment and saving in an economy, thus, these changes in the interest rate may affect energy consumption and CO_2 emissions. However, this result suggested that the U.S interest rate channel has proved itself capable of affecting Turkey's carbon emissions through the interest rate channel and economic growth. It is suggested that this might be driven by high external debt and limited foreign exchange reserves, while the USD remains the primary reserve currency. The country's low international reserves do not grant a buffer against possible external influence, with capital outflow and changes in investor sentiment to the other emerging markets. All these factors increase the spillover effect of the U.S interest rate on Turkey's carbon emission, as the dollar is the prior reserve currency and the majority of the external debt is composed of this currency. In this sense, the study suggests that the policymakers should design strategies such as sustained economic growth for responding to any external shocks, in particular, the U.S interest rate. Also, and it suggested that they should design new environmental regulations and encourage investments in low CO_2 emissions levels.

ORCID

Ahmed Samour https://orcid.org/0000-0003-1477-7454
Turgut Tursoy https://orcid.org/0000-0002-6404-5748

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