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Investigating the Spillover Effects of the US Interest Rate on CO_2 Emissions. A Case of a Developing Country

Fakhr e Alam Afridi, Bushra Ayaz, Yousaf Khan
National University of Modern Language, Peshawar
Fazaila Shad
Islamia College Peshawar

Abstract

Any change in US economic policies will have a big effect on international markets due to the size of the US economy. Therefore, this study's goal is to look at how Pakistan's CO_2 emissions are impacted by the U.S. interest rate. The study uses the ARDL testing approach over the period 1985-2014. The results suggested that policymakers should pay more attention to environmental pollution by supporting investment and projects in renewable resources with low interest-rate. The findings suggest that to respond to any external shocks policymakers should keep promoting investments in low- CO_2 emission technologies. This study findings further evidence that the U.S interest rate may affect the increase in environmental pollution in emerging countries like Pakistan through energy consumption, economic growth, and local interest rate channels.

Keywords: CO_2 emissions, energy consumption, bootstrap ARDL, Pakistan

Pakistan is an emerging economy that has experienced a considerable increase in investment and foreign trade over the period 1985 to 2014. The total trade as a percentage of GDP reached 52% by 2014. Foreign direct investment (FDI) reached about 22 billion USD in 2018, compared to 128 million USD in 1980 (Rehman, Ma, Ahmad, Ozturk, & Işık, 2021). Per capita income, reached about 14,000 USD, compared to 5,000 USD in 1980 (Saleem et al., 2020). As a result of these indicators, Pakistan's energy consumption continues to increase particularly nonrenewable energy consumption. Non-renewable energy sources (Alam Rehman, Irfan Ullah, et al., 2021), such as fossil fuels and natural gas, however, cannot replenish themselves and eventually disappear on their own (Muhammad, 2019). Additionally, employing these energy sources causes' greater CO_2 emissions, which affect the ecosystem and the ozone layer (Mardani, Streimikiene, Cavallaro, Loganathan, & Khoshnoudi, 2019). On the other hand, since renewable energy sources are green energy, they don't harm the environment. Additionally, renewable energy sources are forms of energy that are efficient, clean, and cost-free of fuel (Wu, Zhu, & Zhu, 2018).

The literature on the connection between economic factors and pollution has grown in recent years, and it is anticipated that this relationship will aid in the creation of solutions for reducing pollution (Furuoka, 2015). This study by (Isiksal, Samour, & Resatoglu, 2019) experimentally examines how the U.S. interest rate affects CO_2 emissions through four different channels: domestic interest rates, income, trade, and energy use. Many research studies reported that in emerging financial markets the U.S interest rate significant impact (Isiksal et al., 2019). Thus, the changes in financial markets will affect goods and aggregate output which in turn affect many economic factors such as trade, economic growth, and FDI (Muhammad, 2019). This may lead to affect the consumption of energy. Besides, the U.S interest rate can affect emerging markets, through its spillover impact on domestic monetary policy (Isiksal et al., 2019).

This study focuses on Pakistan because it relies on foreign investments to finance its projects (Afridi, Jan, Ayaz, & Irfan, 2021). Furthermore, via international investment and trade, Pakistan's economy is highly integrated with the U.S. economy (Saleem et al., 2020). As a result, we would anticipate that the U.S.'s impact on carbon emissions in Pakistan will rely on how this rate influences economic growth, FDI, the local interest rate, as well as the use of energy. Regarding this, there are two ways in which Pakistan's CO_2 emissions may be significantly impacted by the U.S. interest rate spillover. First, on domestic monetary policy, any change in the interest rate in the United States may have an impact (Abbasi, Shahbaz, Jiao, & Tufail, 2021). For instance, the value of the US dollar increases as US interest rates rise (Isiksal et al., 2019). On the other hand, it might cause the Pakistani currency to weaken. Any change in the interest rate will also affect how much individuals spend on other products like vehicles and energy appliances (Saleem et al., 2020). It ultimately has an impact on energy use, which in turn has an impact on CO_2 emissions. Second, changes in the interest rate in the United States may have an impact on Pakistan's foreign investment and cash flow (Abdul Rehman et al., 2021). 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. The 2008 crisis harmed Pakistan's economy. Pakistan faced an excessive current account deficit and large amounts of external debt, and lower economic growth (Saleem et al., 2020). Thus the change in the economic factors may lead to a change in energy consumption, which in turn affects CO_2 emission. Therefore, the purpose of this research study is to investigate the spillover effects of the US interest rate on CO_2 emissions in Pakistan.

Literature review

Energy, Trade, Economic Growth, and CO_2 Emission

Previous research shows that CO_2 emissions are expected to play a role in the creation of CO2 emission reduction plans (Qingquan, Khattak, Ahmad, & Ping, 2020). Many studies investigated the relationship between income and CO_2 emission. In Validation of the EKC hypothesis (Bouznit & Pablo-Romero, 2016; Disli, Ng, & Askari, 2016). (Lv, 2017) for selected countries, for the period from1984-2007, found a causal relationship. (Isiksal et al., 2019) used the CCEMG technique and found that EKC-H is valid in BRICS economies from 1980 to 2016. In Pakistan, (Muhammad, 2019) for the period 1960-2007 tested the impact of, energy and income on CO_2 emission. The result showed that EKC-H is valid in Pakistan. Using the ARDL model: (Zeeshan et al., 2021) confirmed that the EKC-H is held in Pakistan over different periods.

(Wu et al., 2018) found a significant impact between energy consumption and CO_2 emission in the USA. (Akin, 2014; Amjad, Khatoon, Ather, & Akhtar, 2015; Omri, 2013) used the Grey prediction model to test the relationship and found a bidirectional causal relationship for Brazil, Russia, and India over the period 1971-2005. (Amjad et al., 2015)tested in 8 Asian countries by using panel data, the results implied that nonrenewable energy consumption has a positive influence on CO2 emissions in 8 Asian countries over the period from 1982-2017. (Q. Wang, Zeng, & Wu, 2016) tested the impact of energy consumption on CO_2 emission in China and India for the period 1971-2004 and found a positive relationship. Trade liberalization has been embraced by a significant number of industrialized and developing nations at various times, leading to industrialization and higher CO_2 emissions (Hussain, Javaid, & Drake, 2012; Lv, 2017; Q. Wang et al., 2016; Z. Wang, Asghar, Zaidi, & Wang, 2019). Additionally, green technology that might not raise CO_2 emissions is included in the trade liberalization (Raheem, Tiwari, & Balsalobre-Lorente, 2020). However, recent studies show that the transmission of renewable energy technologies has been more effective in reducing CO_2 emissions in developing nations (Isiksal et al., 2019; Mardani et al., 2019; Muhammad, 2019). However, claims that trade openness is a significant element that raises energy use through increasing CO_2 emissions.

Previous studies such as (Akbar et al., 2020) supports the idea that increasing energy consumption can boost the economies of East Asia. The case of Brazil, (Lv, 2017) confirms a bidirectional causal relationship between trade openness and energy usage. In the relation between trade and CO_2 emission, (Mardani et al., 2019) used GMM for selected developing and developed countries over the period 1960–2013 and showed a positive impact of international trade on CO_2 emission. (Akbar et al., 2020) used the data from 1990-2011. By applying SEM for panel data. In Pakistan, (Zeeshan, Han, Rehman, & Afridi, 2020) used the ARDL approach and showed that international trade affects positively on Pakistan’s CO2 emissions in Pakistan from 1980 to 2014.

The U.S Interest Rate and CO_2 Emission

The U.S interest rate policy's international transmission effects have been an important topic in literature (Langevin, Harris, & Reyna, 2019). However, due to the significance of the U.S economic policies on international capital flows it is likely that any change in the interest rate can affect the global markets (Isiksal et al., 2019). Given the significance of the American interest rate policy (Metcalf, 2020), the impact of American interest rates on international economies is still under research topic. Numerous research provides compelling evidence of U.S. monetary policy impacts on emerging markets (Khan, Teng, Khan, & Khan, 2019; Q. Wang et al., 2016). In this regard, (Wu et al., 2018) proposed that nations with less open policies and weaker credit ratings are more exposed to the U.S. interest rate. According to (Q. Wang et al., 2016), capital controls in various nations determine how the U.S. interest rate affects the global economy. They further argued that the level of countries' external debt and capital controls determines how the United States' interest rates affect the world market.

According to the findings (Furuoka, 2015), one of the important factors influencing how the U.S. interest rate is transmitted to international markets. (Halkos & Paizanos, 2016) investigated how 15 different nations the findings imply that financial linkages have a considerable impact on how the global economy reacts to any change in the United States. However, the interest rate spillover on the global environment is ignored. Therefore, the primary purpose of this study is to explore the spillover effect of the U.S interest rate on Pakistan's CO_2 emission.

Our study specifically responds to the three crucial queries. First, whether or not there is geographic autocorrelation for national carbon emissions. How does financial growth impact environmental quality while limiting spatial implications, secondly. Thirdly, the direct effects of FD on CO_2 emissions. This study analyzes how spatial interaction between FD and carbon emissions may aid researchers and environmentalists in reconsidering the effect on environmental quality through the spatial econometric lens, in contrast to prior studies that primarily focus on policy formulation stances for environmental conservation (Alam Rehman, Irfan Ullah, et al., 2021). The results of our analysis show that the carbon emissions of a certain country are negatively impacted by adjacent countries. Additionally, the immediate consequences of local FD have favorable environmental implications on nearby carbon emissions. By using less energy-intensive methods and technologies to produce low-carbon products (eco-friendly innovation), businesses can receive incentive-based loans as FD increases.

Research Methodology

Data and Model

Annual time series data covering the period 1985–2014 is used in this study. Much empirical research (Bouznit & Pablo-Romero, 2016; Isiksal et al., 2019) have applied the following expressed model to test the relation between economic growth, and CO_2 emission:

$$\ln CO_{2\,t} = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP^2{}_t + \varepsilon_{it} \quad \text{(Eq.1)}$$

here α is intercept and β1, β2 are variables coefficients, and ε_{it} is the error term. $\ln CO_{2\,t}$ are the carbon dioxide emissions, $\ln GDP$, and $\ln GDP^2$ are GDP and square of GDP. No study in the existing literature tested the U.S interest rate impact on CO_2 emission for Pakistan. Thus, the U. S interest rate as an external factor will be added to the model of EKC-H to test how the U.S interest rate effect on environmental population in emerging economies like Pakistan.

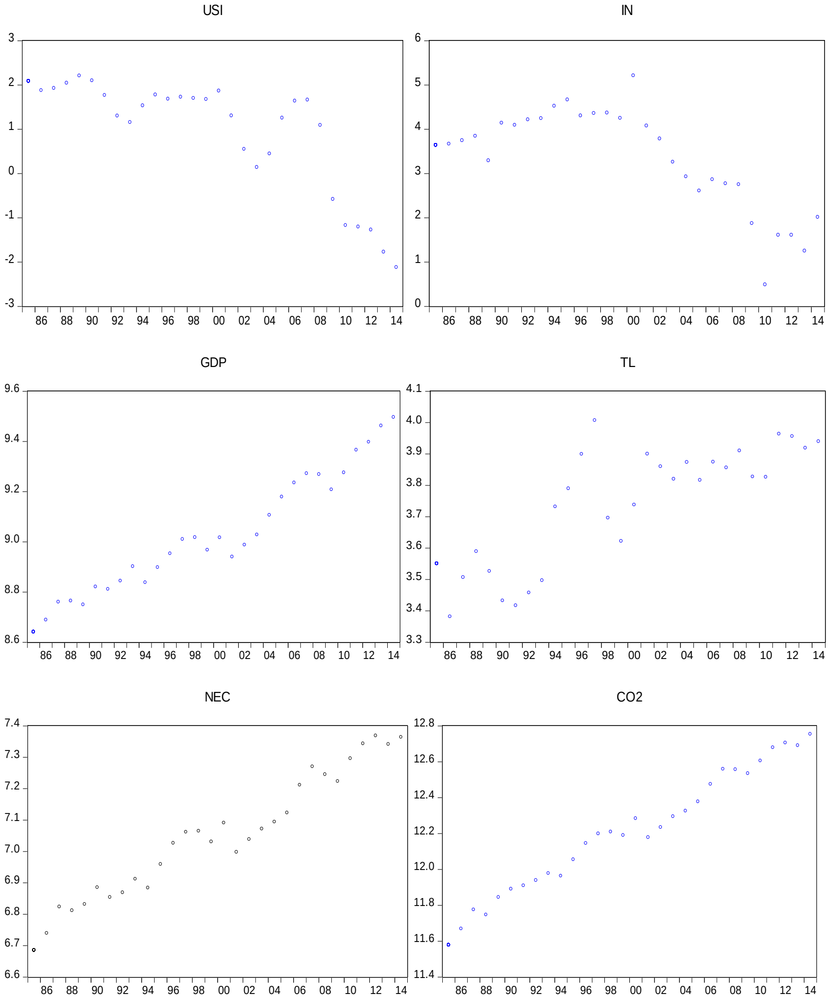
$$\ln CO_{2\,t} = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP^2{}_t + \beta_3 \ln NEC_t + \beta_4 \ln T^I{}_t + \beta_5 \ln IN_t + \beta_6 \ln USI_t + \varepsilon_{it} \quad \text{(Eq.2)}$$

where $\ln$ is the logarithm of the variable, $CO_{2\,t}$ is the dependent variable, GDP, GDP^2, NEC, T^I, IN, and USI are explanatory variables. Table 1 presented the study variable the data is the annual time series data covering the period from 1985and 2014. Figure 1 shows the plot of the variables.

Table 1.
Variable Description

Variable Name	Abbreviation	Unit of Measurement	Source
GDP	GDP_t	$(2010 = 100)$ in USD	WB
Square/GDP	$GDP^2{}_t$	the square of G.D.P.	WB
Energy-consumption	NEC_t	kt of oil equivalent	WB
CO_2	$CO2_E$	per-capita metric tons of emission	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

Figure 1.
Plot of the Variables



Unit Root Testing

An autoregressive distributed lag model is used to investigate the relationship between the U.S interest rate, local interest rate, energy consumption, economic growth, trade, and Pakistan's CO_2 emission. The study tested the stationarity of the time-series data in the first step. 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. The study uses Zivot–Andrews (Z–A) unit root test includes one date of a structural break to overcome this issue. Also, the unit root test allows us to test the degree of integration of each variable (M. H. Pesaran, 2007).

Bootstrap ARDL Bound Test to Cointegration Analysis

This study uses the recent ARDL bounds testing approach to integration to validate the existence of a co-integration relationship amid the variables. Recently used by (Nawaz, Lahiani, & Roubaud, 2019) for the analysis of correlations among variables in the short-run and long-run. (According to Hussain et al., (2012)) the ARDL testing model is more suitable for the time series data which have various orders 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. The lag lengths are specified by using the Schwarz-information criterion (Engle, Hendry, & Trumble, 1985). Based on the ARDL testing approach (H. H. Pesaran & Shin, 1998), to test the long-term association between time-series. Thus, equation (3) is formulated in the following equation:

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

where Δ is the operator of the first difference, α_0 represents the constant term, $\varepsilon_t$is the error term, $\delta_1, \delta_2, \delta_3, \delta_4, \delta, \delta_6, \delta_7$ are short-run estimated coefficients, $\sigma_1, \sigma_2, \sigma_3, \sigma_4, \sigma_5$, 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 ARDL bounds test null hypothesis is H_0: $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_3 = \sigma_4 = \sigma_5 = \sigma_6 = \sigma_7 = 0$. In contrast, the alternative hypothesis is H_1: $\sigma_1 \neq \sigma_2 \neq \sigma_3 \neq \sigma_3 \neq \sigma_4 \neq \sigma_5 \neq \sigma_6 \neq \sigma_7 \neq 0$. The recent version includes (McNown, Sam, & Goh, 2018) t-test $t_{dependent}$ or F-test $F_{independent}$. The H_0 of $t_{dependent}$ test is: σ1 =0. The H_1 of $t_{dependent}$ test is: σ_1 The H_0 of $F_{independent}$ test is:H_0: $\sigma_2 = \sigma_3 = \sigma_3 = \sigma_4 = \sigma_5 = \sigma_6 = \sigma_7 = 0$. The H_1 of $F_{independent}$ test is: H_1: $\sigma_2 \neq \sigma_3 \neq \sigma_3 \neq \sigma_4 \neq \sigma_5 \neq \sigma_6 \neq \sigma_7 \neq 0$.

Using the ARDL bootstrap methods, which eliminates the instability result of the ARDL bounds test (McNown et al., 2018). In the determination the level of the cointegration relationship, the values of $F_{Pesaran}$, $t_{dependent}$,$F_{independent}$ should be statistically significant and exceed the CV in the bootstrap ARDL technique examined variables (McNown et al. ,2018). The error correction model (ECM) to estimate the coefficient in short-run relation is presented in Eq. (4):

$\Delta LnCO_{2t} = \alpha_0 + \sum_{i=1}^{n} \delta_1 \Delta lnCo_{2\,t-i} + \sum_{i=1}^{n} \delta_2 \Delta lnGDP_{t-i} + \sum_{i=1}^{n} \delta_3 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{n} \delta_4 \Delta lnNEC_{t-i} + \sum_{i=1}^{n} \delta_5 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{n} \delta_6 \Delta lnIN_{t-i} + \sum_{i=1}^{n} \delta_7 USI_{t-i} + \omega ECT_{t-1} + \varepsilon_t$ ……(Eq.4)

where Δ stands the operator of the first difference, α_0 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, ωECT_{t-1} implies the speed of adjustment of the long-term levels of equilibrium level (Gujarati, Porter, & Gunasekar, 2012).

To confirm the model of this study is formulated correctly this study uses several diagnostic tests. The Ramsey RESET (Ogbonna & Ebimobowei, 2012) and ARCH tests (Engle et al., 1985) are used to check model stability. The Jarque-Bera normality (JB) test (Thadewald & Büning, 2007) for the normality of the model. Also, to test the stability of the model the study used the cumulative sum (CUSUM) test and the CUSUM of square tests. Furthermore, Granger causality is used in this, (ECT) from the long-term equilibrium level determines the short-term deviations of the study variables. The ECM equation is formulated in equations 5 to 11:

$\Delta lnCO_{2t} = \alpha_0 + \sum_{i=1}^{k} \Upsilon_1 \Delta lnCo_{2t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnNEC_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnIN_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta USI_{t-i} + \omega\, ECT_{t-1} + \varepsilon_t$ ……(Eq.5)

$\Delta lnGDP_t = \alpha_0 + \sum_{i=1}^{k} \Upsilon_1 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnCo_{2t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnNEC_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnIN_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta USI_{t-i} + \omega\, ECT_{t-1} + \varepsilon_t$ ……(Eq.6)

$\Delta lnGDP^2{}_t = \alpha_0 + \sum_{i=1}^{k} \Upsilon_1 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnCo_{2t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnNEC_{t-i} + \sum_{i=1}^{n} \Upsilon_0 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{n} \Upsilon_0 \Delta lnIN_{t-i} + \sum_{i=1}^{n} \Upsilon_0 \Delta USI_{t-i} + \omega\, ECT_{t-1} + \varepsilon_t$ ……(Eq.7)

$\Delta lnNEC_t = \alpha_0 + \sum_{i=1}^{k} \Upsilon_1 \Delta lnNEC_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnCo_{2t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnIN_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta USI_{t-i} + \omega\, ECT_{t-1} + \varepsilon_t$ ……(Eq.8)

$\Delta lnT^I{}_t = \alpha_0 + \sum_{i=1}^{k} \Upsilon_1 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnCo_{2t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnNEC_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnIN_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta USI_{t-i} + \omega\, ECT_{t-1} + \varepsilon_t$ ……(Eq.9)

$\Delta lnIN_t = \alpha_0 + \sum_{i=1}^{k} \Upsilon_1 \Delta lnIN_{t-i} + \sum_{i=1}^{k} \Upsilon_1 \Delta lnCo_{2t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnNEC_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta USI_{t-i} + \omega\, ECT_{t-1} + \varepsilon_{1t}$ ……(Eq.10)

$\Delta lnUSI_t = \alpha_0 + \sum_{i=1}^{k} \Upsilon_1 \Delta USI_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnCo_{2t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnGDP^2{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnNECs_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnT^I{}_{t-i} + \sum_{i=1}^{k} \Upsilon_0 \Delta lnIN_{t-i} + \omega\, ECT_{t-1} + \varepsilon_t$ ……(Eq.11)

Where $\ln CO_2$, $\ln GDP$, $\ln GDP^2$, $\ln NEN$, $\ln T^I$, $\ln IN$, USI is the research variables, ε_t stand the error terms, and $\omega\ ECT_{t-1}$is the lagged error correction term. By Wald test's the direction of association in the short-term is determined $F -_{statistics}$ testing approach to find the significance of the related estimated coefficient by utilizing the first operator of the first difference.

Data Analysis and Results

The study tested the stationarity of the time series data using Z–A and CMR tests in the first step. The outcomes of Z–A and CMR unit root tests are presented in Table 2. The results show that CO_2, 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 Z–A., and CMR isrejected. In contrast, the results show that CO_2 , 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).

Table 3 represents the bootstrap ARDL test results which show that there is a co-integration relationship between CO_2,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 Z-A and CMR

$lnCO_2$	-2.321	-4.42	2005	-3.931	-5.49	2001	2008
$lnGDP$	-2.931	-4.42	1999	-4.310	-5.49	2003	2009
$ln\ NEC_t$	-3.345	-4.42	2004	-3.878	-5.49	2001	2004
lnT^I	-3.659	-4.42	1984	-4.141	-5.49	2000	2008
$ln\ IN$	-1.207	-4.42	2001	-4.210	-5.49	2000	2011
$ln\ USI$	-4.112	-4.42	2008	-3.251	-5.49	2008	2009
$\Delta lnCO_2$	-5.065**	-4.42	2002	-6.878**	-5.49	1985	2008
$\Delta lnGDP$	-7.624**	-4.42	2000	-5.411**	-5.49	2001	2010
$\Delta ln\ NEC_t$	-5.207**	-4.42	1997	-5901**	-5.49	2001	2008
ΔlnT^I	-6.516**	-4.42	1988	-8.412**	-5.49	2000	2006
$\Delta\ ln\ IN$	-5.931**	-4.42	1994	-5.910**	-5.49	2001	2009
$\Delta ln\ USI$	-5.490**	-4.42	2008	-6.320**	-5.49	1995	2008
$lnCO_2$	-2.321	-4.42	2005	-3.931	-5.49	2001	2008

Table 3.
The Results of 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

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

ARDL equation passed all diagnostic tests for autocorrelation, nonmorality, and heteroscedasticity, according to Table 4's findings. Additionally, the predicted coefficients of the ARDL model were found to be stable according to the CUSUM results as proposed by (Brown, Durbin, & Evans, 1975). Table 4 shows the results of short-run coefficients from the ARDL model. The positive impact of GDP_t and the negative impact of ${GDP^2}_t$ are providing significant evidence that the EKC-H in Pakistan is held. Thus, an increase in the GDP in Pakistan led to an increase in CO_2 emissions first and, after a certain period, decreased these CO2 emissions. This finding supports the studies of (Khan et al., 2019), which suggested that EKC-H is valid in Pakistan. Over time, a 1% rise in per capita NEC resulted in a 1.17 % increase in CO_2 emissions. In the short term, a 1% rise in per capita NEC resulted in a 1.05 % increase in CO_2 emissions. Additionally, the findings demonstrated that short-term CO_2 (2) emission is positively and significantly impacted by global trade. The empirical findings in the short run demonstrate that trade has a favorable impact on CO_2 emissions. Furthermore, the results imply that domestic interest rates are negatively and statistically significant in Pakistan's CO_2 emission. In the short-run relation, a 1% decrease in the local interest rate in Pakistan led 0.027 % increase in CO_2 emission. While in long-run in local interest rate 1% led to 0.05% increase in CO_2

emission. The findings are similar in line with previous studies' findings such as (Abbasi et al., 2021; Abdul Rehman et al., 2021; Saleem et al., 2020; Zhang, Wang, & Wang, 2018).

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)
$ln\,NEC_t$	1.169***	8.337	0.14	ARACH 2.237(0.145)
lnT^I	0.009	1.761	0.097	Ramsey 0.832(0.413)
$ln\,IN$	-0.051*	-2.994	0.017	Heteroscedasticity BBG 0.652(0.725)
$ln\,USI$	-0.0142*	-2.849	0.005	
$D2008$	-0.030**	-2.418	0.012	

Table 5.
The Result of Short-Run Coefficients

Regressor	Coeff.	t-ratio	Standard errors
$\Delta lnGDP$	4.705***	1.654	2.126
$\Delta lnGDP^2$	-0.362**	-2.208	0.029
$\Delta ln\,NEC_t$	1.056***	6.600	0.637
ΔlnT^I	0.003**	4.222	0.002
$\Delta\,ln\,IN$	-.0127**	-3.162	0.004
$\Delta ln\,USI$	-0.0193*	-2.895	0.006
ECT(−1)	-0.706*	-6.649	0.106

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

Figure 2.
Testing of the stability using CUSUM test

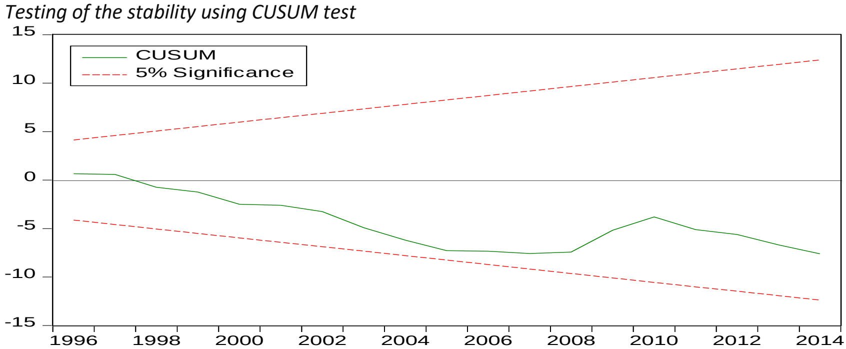
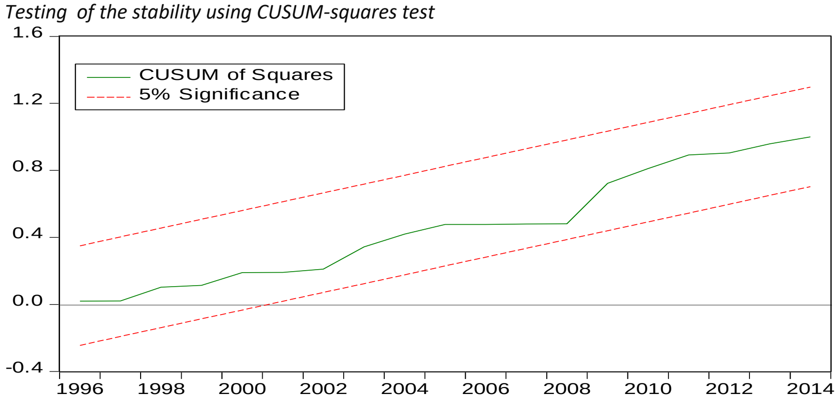


Figure 3.
Testing of the stability using CUSUM-squares test



Granger Causality Results

The results Granger causality result shows (table 6) that *t*-statistics on the lagged value of the ECT provide evidence from $\mathrm{GDP_t}$, $\mathrm{GDP^2}_\mathrm{t}$, NEC_t, IN_t, USI_t and $\mathrm{T^I}_\mathrm{t}$ to $\mathrm{CO_2}$ in the long run, shows a unidirectional causal relation. The empirical outcomes from the short-run indicate a unidirectional causal linkage between the U.S interest rate, economic growth, trade, and nonrenewable energy consumption to$\mathrm{CO_2}$ ($\mathrm{GDP_t}$, IN_t, USI_t and $\mathrm{T^I}_\mathrm{t}$, $NEC \rightarrow \mathrm{CO_2}$). The empirical result Granger causality test provides (Diks & Panchenko, 2006) evidence that economic growth, trade, and the local and U.S interest rate affect nonrenewable energy consumption in Pakistan, which results in increased CO_2 emissions. Also, there is the unidirectional causal linkage from interest rate to nonrenewable energy consumption, economic growth ($IN \rightarrow \mathrm{GDP_t}$, NEC_t). These results provide evidence and support the study of (Zhang et al., 2018) who found spillover of local interest rate on CO_2 emissions in Pakistan through energy consumption. 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-rate. The U.S interest rate may affect the increase in environmental pollution in emerging countries like Pakistan through energy consumption, economic growth, and local interest rate channels.

Table 6.

Granger causality test results

	$\Delta lnCO_{2E}$	$\Delta lnGDP$	$\Delta lnGDP^2$	$\Delta ln\, NEC_t$	$\Delta lnT^I{}_t$	$\Delta\, ln\, IN$	$\Delta ln\, USI$	ECTt – 1
$\Delta lnCO_{2E}$	-	5.272*	4.272	6.972**	6.272*	7.311*	6.014*	-0.272**
$\Delta lnGDP$	0.272	-	0.149	1.675	1.675	5.956*	12.919**	-0.242
$\Delta lnGDP^2$	2.367*	2.975*	-	4.278	4.278	0.731	6.927**	0.525
$\Delta ln\, NEC_t$	0.933	6.551**	0.276	-	6.320**	6.432**	5.057*	-0.279**
ΔlnT^I	1.2301	2.392	0.920	3.92	-	6.310	5.250	
$\Delta\, ln\, IN$	2.194	0.817	0.835	3.946	3.946	-	2.320	0.493
$\Delta ln\, USI$	0.282	2.366	2.054	0.083	0.083	2.897	-	-0.591

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

Conclusion

This study's major goal is to look at how Pakistan's CO_2 emissions are impacted by the U.S. interest rate. This study's empirical findings and analysis represent the first input into the field of environmental literature. The study makes use of the recently created bootstrap ARDL suggested by (McNown et al., 2018) with smooth structural changes during the period 1985–2014. To look at the causal connections between the variables the Granger causality testing method is used. The empirical findings of this study revealed that there is strong evidence that the EKC-H is valid in Pakistan. This support the findings of (Isiksal et al., 2019). On the other hand, 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 long and short run. In this regard, the U.S interest rate may affect the increase in the environmental pollution in emerging countries like Pakistan through energy consumption, economic growth, and local interest rate channels.

Managerial Implications

The empirical outcomes of this research may provide a helpful conclusion and recommendation for policymakers for several reasons. Pakistan has faced high rates of CO_2 emissions over the same period. 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. In emerging countries, the U.S interest rate has essential effects by impacting trade, economic growth, trade, and 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. The study suggests that policymakers should design strategies such as sustained economic growth for responding to any external shocks. Also, it suggested that they should design new environmental regulations and encourage investments in low CO_2 emissions levels.

Limitations and Future Research Direction

Like most others, this study has also some limitations. First, the data may limit the generalization of study findings to different geographical locations and periods. Hence, future studies can be conducted considering the respondents from other culturally different countries. Second, a follow-up study with a longitudinal design can confirm the causality of the association across time.

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