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#### THE INTERPLAY OF TECHNOLOGICAL INNOVATION, EXCHANGE RATE, INCOME INEQUALITY, NATURAL RESOURCES ON CO<sub>2</sub> EMISSIONS IN PAKISTAN

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	Abstract
<p><b>Syed Hilal Mubarik</b> Lecturer, Department of economics, Hazara University, Mansehra <a href="mailto:hilaleconomics@hu.edu.pk">hilaleconomics@hu.edu.pk</a></p> <p><b>Dr. Raza Muhammad Khan</b> Department of economics, Hazara University, Mansehra <a href="mailto:razaeconomics@hu.edu.pk">razaeconomics@hu.edu.pk</a></p> <p><b>Dr. Amjad Ur Rehman</b> Department of Management Sciences, Hazara University Mansehra <a href="mailto:amjadk@hu.edu.pk">amjadk@hu.edu.pk</a></p>	<p>This study investigates the dynamic relationship between technological innovation, income inequality, exchange rate, natural resources and inflation on carbon emissions (CO<sub>2</sub>) in Pakistan over the period 1995 to 2019, using annual time series data. The analysis begins with stationarity testing through the Augmented Dickey-Fuller (ADF) test, confirming that variables are integrated of order one, I(1). Subsequently, the Johansen Cointegration Test is employed to examine the long-run relationship among the variables. The results confirm the existence of three cointegrating equation, indicating a stable long-run equilibrium relationship between CO<sub>2</sub> emissions and the independent variables. Empirical findings reveal that technological innovation, exchange rate and inflation have positive and significant influence on CO<sub>2</sub> emissions in the long run. While, income inequality has a negative and statistically significant relationship with CO<sub>2</sub> emissions in the long run. In the short run, Technological innovation has positive but insignificant, exchange rate and inflation have significant positive effect, natural resources has negative insignificant effect on CO<sub>2</sub> emission. Therefore, policymakers in Pakistan should consider energy-efficient innovations, manage inflation, and implement inclusive growth strategies to balance environmental and social goals.</p>
<p><b>Keywords:</b></p>	<p>Technological innovation, Income inequality, Natural resources, CO<sub>2</sub> emissions</p>

### Introduction

CO<sub>2</sub> emission is one of the most pressing global issues in recent years because it is disrupting human livelihoods and economies in every state (Usman *et al*, 2022). According to the report of (IPCC, 2022) warned that global temperature is projected to reach 1.5°C between 2030 and 2050 and will continue to rise if no action is taken to control greenhouse gas emissions. As noted by (Shahzad *et al*, 2017) carbon dioxide gas is released globally around 58% annually out of total greenhouse gases emissions. Economic activities that are supported by the burning of fossil fuels produce CO<sub>2</sub> as one of the basic factors of climate change. From an environmental perspective, unsustainable development is driven by deforestation, burning of fossil fuel, and rapid urbanization (Usman and Lorente, 2022; Yang *et al*, 2020). Though, the priority of sustainable development economies demand for more energy have forced to expand the burning of fossil fuels, that leading the challenge to world of enhance greenhouse gases emissions (Qadir *et al*, 2021). The main sources of CO<sub>2</sub> emission is the burning of fossil fuels such as coal, oil, natural gas etc, (Chang and Li, 2019). Researchers, (Jahangir *et al*, 2021; Dagar *et al*, 2021; Qiang *et al*, 2021; Ahmad *et al*, 2022) posited that climate change and global warming posted various diseases, hunger, water scarcity and flood. A prior study of World Health Organization (2019) stated approximately 7 million early deaths caused by air pollution in 2018.

As a consequence of increasing importance of environmental issue, a large of researchers were studied the effect of technological innovation on CO<sub>2</sub> emissions. For example, the studies of (Adebayo *et al*, 2021; Udemba *et al*, 2021; Zhao *et al*, 2021; Kihombo *et al*, 2021; Haq *et al*, 2022) described that technological innovation is reducing environmental degradation. In contrast, several researchers found positive relationship between technological innovations and CO<sub>2</sub> emissions (Li *et al*, 2022; Adebayo and Kirikkaleli, 2021; Chen and Lee, 2020).

As for inequality, the Gini coefficient of Pakistan is 0.45, which is higher than rest of the developing world, indicating extreme inequality in the region (). Meanwhile, income inequality generates a diverse effect on different social classes of society (Grottera *et al*, 2017). The impoverished people of society get affected the most from an unequal distribution of wealth since they are an extremely vulnerable sector of society. Besides, income inequality increases emissions by creating obstacles in the way of environmental policy. Moreover, it may lead to less environmental protection and ultimately responsible for higher emissions. It is further argued that income inequality increases emissions through ownership and voting channels (Grunewald *et al*, 2017).

Exchange rate variations effecting trade volumes and configuration, persuading pollution levels (Antweiler *et al*, 2001). Depreciation may lead to export-led industrialization, enhancing energy use and emissions. Exchange rate effect CO<sub>2</sub> emissions by changing a country's trade pattern. When currency of a nation is strong, its exports internationally turn into less competitive, lead to a decrease in export activities and potentially lowering carbon emissions. On the other hand a weaker currency can increase exports, boost exports, enhance industrial activities and thus increase emissions (Zhang and Zhang, 2018). Despite this empirical research investigated the effect of exchange rate on CO<sub>2</sub> emissions remains limited, in case of Pakistan.

Inflation can significantly affect CO<sub>2</sub> emissions as inflation reducing the purchasing power, consumption and investment. Higher level of inflation harms the overall economic performance through influencing aggregate demand (Ahmad *et al*, 2020). Due to high costs inflation causes the excess use of fossil fuels, which results in the growth of carbon emissions (Xu *et al*, 2023).

The relationship between natural resources and CO<sub>2</sub> emissions is a critical aspect of understanding the complex dynamics of climate change. Natural resources, including fossil fuels, minerals, land and water are essential for human well-being and economic development. However, their extraction, processing, transportation and consumption have significant environmental consequences, particularly in terms of greenhouse gas emissions (Gutti and Aji, 2012; Khan *et al*, 2021). While in contrast, natural resources contributed to improve the ecological quality with the help of recycling waste and emissions from human activities (Kongbuamai *et al*, 2020). Wherever, agriculture land, grazing land forests reduce the amount of Carbon dioxide emitted by human activities, but other types of natural resources such as coal, gas and oil are deteriorating environment (Danish and Khan, 2020; Ahmad, 2021).

Past research does not highlight the issue of environment pollution due to inflation, income inequality and exchange rate influence CO<sub>2</sub> emissions in Pakistan. There is also a lack of research employing dynamic time series methodology (e.g. VECM) to determine both short run and long run equilibrium effects in this regard. To fill this gap, this study aims to examine the impact of technological innovation, exchange rate, natural resources, inflation and income inequality CO<sub>2</sub> emissions in Pakistan during the period of 1990 to 2023.

The remaining study is structured as follows: literature review is presented in section 2, data and methodology in section 3, empirical results in section 4, conclusion and policy recommendation is presented in section 5.

## 2. Literature Review

### 2.1. Technological innovation-CO<sub>2</sub> emissions nexus

At present, technological innovation has been included a new indicator in the framework of growth and environment, as it is acknowledged worldwide as an important element in the reduction of CO<sub>2</sub>. For instance, Li *et al*, (2022) investigated the effect of technological innovation on CO<sub>2</sub> emissions in MINT countries applied panel data from 2000 to 2020 and concluded that technological innovation increase environmental degradation. Similarly, Kumail *et al*, explored the relationship between technological innovation on environmental degradation in Pakistan during the period of 1990-2017. They concluded that technological innovation increase environmental quality, as it would lead to reduce CO<sub>2</sub> emissions. Yii and Geetha (2017) assessed the causal nexus between TI and CO<sub>2</sub> emissions in Malaysia. The result showed that technological innovation granger cause CO<sub>2</sub> emissions in unidirectional way. Using data for the period 1970 to 2017, Khan *et al*, (2020) conducted a study on the association between technological innovation and CO<sub>2</sub> emissions in China and found that TI decreases CO<sub>2</sub> emissions. Similarly, Udemba *et al*, (2021) examined the determinants of consumption based carbon emission in Chile during the period of 1990 to 2018. Using nonlinear ARDL technique, they suggest that shift in TI increase (decrease) carbon emissions. Chen and Lee, (2020) scrutinized the relationship between technological innovation and CO<sub>2</sub> emissions in a panel of 96 countries for the time period of 1996 to 2018 and found that technological innovation help to improve the quality of environment and thus lead to decrease CO<sub>2</sub> emissions. Moreover, kihombo *et al*, (2021) estimated the impact of technological innovation on CO<sub>2</sub> emissions in West Asia and Middle East countries from 1990-2017. Their study discovered that technological innovation mitigates CO<sub>2</sub> emissions. Adebayo *et al*, (2021) investigated the causality between technological innovation and CO<sub>2</sub> emissions in Portugal using dataset from 1980 to 2019. Their findings revealed that TI increases environmental degradation in Portugal and also cause effect of TI on CO<sub>2</sub>. Another study of Adebayo *et al*, (2021) conducted in case of South Korea use ARDL model to assess the influence of technological innovation on CO<sub>2</sub> emissions over the period 1980-2018, finding that technological innovation improves the environmental quality by lowering CO<sub>2</sub> emissions. In addition, technological innovation can cause CO<sub>2</sub> emissions in South Korea. In contrast, other researchers argued that technological innovation degrade environment (Kumar and Managi, 2009; Su and Moaniba, 2017; Dauda *et al*, 2021; Shahbaz *et al*, 2020). For example, Adebayo and Kirikkaleli, (2021) study the influencing factors of CO<sub>2</sub> emissions in Japan, discovering that technological innovation increases CO<sub>2</sub> emissions. However, the research studies of (Ali *et al*, 2016; Shaari *et al*, 2016; Garrone and Grilli, 2010) have found insignificant relationship between technological innovation and CO<sub>2</sub> emissions.

### 2.2. Income Inequality-CO<sub>2</sub> emissions nexus

Around the mid-1990s, economists developed theoretical arguments to explain the relationship between income inequality and environmental degradation (Grunewald *et al*, 2017). This has continuously been subject to further debate (Baloch *et al*, 2018). Boyce (1994) considered the inequality in power and wealth to be causing more environmental degradation. This was associated with the ability of the rich to degrade and pollute the environment in pursuit of profit without any regard for sustainability. Baloch *et al*, (2020) applied Driscoll-Kraay model on data 2010 to 2016 in Sub-Sahara Africa, they concluded that poverty and income inequality increases carbon emissions. Used ARDL model on BRICS economies, Mahalik *et al*, (2018) reported that income inequality exacerbated carbon emissions in Brazil, China and India but reducing them in South Africa. In the same way, Zhao *et al*, (2021) applied NARDL model and established that positive shocks in income inequality enhanced emissions in China, Russia and Brazil, while negative shocks decreased CO<sub>2</sub> emissions. Conducted a study on OECD nations, Hailemariam *et al*, (2020) found that higher income inequality raises emissions. In terms of marginal propensity of emissions Gini index diminishes the carbon emissions in the sample countries. Similar to this findings, Guo *et al*, (2020)

examined the nexus between income inequality and CO<sub>2</sub> emissions in high income countries and lower income countries. Their findings indicated that income inequality has negative association on CO<sub>2</sub> emissions in high income countries, while a positive effect in lower income countries. Padhan *et al.* (2019) investigated the relationship between wealth inequality, energy consumption, economic growth and CO<sub>2</sub> emissions in eleven nations over the period of 1971 to 2013. The findings revealed that energy consumption, economic growth and income inequality raises CO<sub>2</sub> emissions. Tested EKC hypothesis framework in Turkey, Demir *et al.* (2019) examined the effect on CO<sub>2</sub> emissions of income inequality. Analyzed time series data by ARDL technique, they found negative affect of income inequality on environment. Suggesting that income inequality decreases environmental degradation in the sample countries. Chen *et al.* (2020) argued that equal distribution of income improves environmental quality in developed nations, while inequality has a negligible effect on carbon emissions levels. Khan *et al.* (2022) explored the nexus between income inequality, poverty, energy consumption, economic growth and CO<sub>2</sub> emissions in BRI nations during the period of 1996-2018. The results of GMM model indicate that income inequality, poverty, energy consumption and economic growth enhancing CO<sub>2</sub> emissions and bring environmental degradation.

### 2.3. Exchange Rate- CO<sub>2</sub> emissions nexus

According to the report of (WTO, 2022) almost 20% to 30% of total carbon dioxide emissions are caused by international trade. When exchange rate of a country appreciate or depreciates, it can influence significantly its trade volume. When the value of currency declines the price of raw materials increase which increase the cost of production then industrialists reduces their product production, then as a result energy demand also decrease as well as this will decline CO<sub>2</sub> emissions (Dimitris, 2006). On the other hand, the devaluation of currency allows foreigners buyer to buy host country products at low rates making the more competitive in international market. It will rise trade due to raise in production process but CO<sub>2</sub> level spurs resultantly (Zhang and Zhang 2018). In this situation, currency devaluation has positive impact on economic growth, which further stimulates carbon dioxide emissions. Shah *et al.* (2022) used (NARDL) technique and found that exchange rate is a major factor of energy consumption and CO<sub>2</sub> emissions in Pakistan. They argued that depreciation of currency leads environmental costs on account of high reliance on energy, thus increasing CO<sub>2</sub> emissions. Another study conducted by (Smaili and Gam, 2023) showed that the effect of exchange rate on CO<sub>2</sub> emissions varies with development status. Appreciated exchange rates can decrease environmental degradation due to increasing of fossil fuels prices, which can forcing firms to shift to renewable energy resources. This conversion from non-renewable energy consumption to cleaner energy, as illustrated by Shah *et al.* (2022) is essential in decrease CO<sub>2</sub> emissions driven by energy consumption. Adjei-Mantey *et al.* (2023) assessed the relation of international tourism, renewable energy and exchange rate on CO<sub>2</sub> emissions of 7 most visited African countries. Using FMOLS and Quantile techniques, they found that Variations in the exchange rate effect CO<sub>2</sub> emissions firstly by exports and imports. An appreciation of exchange rate makes local economy inexpensive for tourists to spend and visit and carries to low carbon emissions.

### 2.4. Inflation- CO<sub>2</sub> emissions nexus

Inflation can have both negative and positive impacts on countries. Ronaghi *et al.* (2020) found that inflation significantly reduces carbon emissions. This occurs because rising inflation increases the prices of goods and services, leading to decreased consumer demand, reduced production, and consequently, lower CO<sub>2</sub> emissions. Supporting this, Shpak *et al.* (2022), analyzing US and Asia-Pacific data from 1970–2020, concluded that CO<sub>2</sub> emissions decrease as inflation rises, while unemployment has a positive but insignificant effect. Studies on BRICS countries (1997–2020) also reveal a significant negative relationship between inflation and carbon emissions. Ahmad *et al.* (2021) noted that high inflation volatility reduces CO<sub>2</sub> emissions, indicating a positive effect on environmental quality. They argue that inflation creates economic instability, discourages new industrial investment, lowers the use of industrial goods, and ultimately decreases emissions. Similarly, Bilal *et al.* (2022) identified a negative correlation between inflation and CO<sub>2</sub> emissions in Germany. Khan (2019) countered that overall economic stability boosts consumption and production, increasing emissions. However, high inflation typically fosters economic uncertainty (Gozgor *et al.*, 2019), which aligns with the finding that higher inflation correlates negatively with CO<sub>2</sub> emissions. Research on Pakistan (1975–2018) using a NARDL model showed that negative inflation shocks are positively associated with CO<sub>2</sub> emissions. In contrast, Jamal *et al.* (2024), examining Pakistan from 1981–2020 with an ARDL model, found a positive and significant long- and short-run relationship between inflation, unemployment, financial development, and CO<sub>2</sub> emissions.

### 2.5. Natural Resources- CO<sub>2</sub> emissions nexus

The link between natural resource (NR) and carbon emissions has been extensively studied in both developed and emerging economies (Chien *et al.* 2021a; Chien *et al.* 2021b; Li *et al.* 2021a, b, c, d, e, f). In this regard, one of the recent contributions is Bekun *et al.* (2019), they observed the trends of sustainable environment though seeing the connection between resource rent, carbon emission, and other independent variables in 16 EU economies time spanning 1996 to 2014. Their finding show a positive long-run association between NR and carbon emissions. Ullah *et al.* (2021a) examined the nonlinear relationship between NR and ecological footprint for 15 nations. The result illustrates a positive significantly nonlinear nexus between NR and ecological footprint in both high and low-income economies. Conversely, Tufail *et al.* (2021) empirically investigated the impact of natural resources and fiscal decentralization in relation of carbon emission for the OECD nations for the time period of 1990 to 2018. Therefore, the study outcomes show that natural resource rent increases the environmental quality by decreasing carbon emissions. Joshua and Bekun (2020a) lead an empirical study to analyzed the role of energy consumption and the NR in identifying carbon emissions in South Africa. The study conclusions show that there occurs a long-run link between pollutant emissions and total NR in South Africa. Research on G7 countries by Wang *et al.* (2020) indicated that NR contributes to higher carbon emissions, while Anh Tu *et al.* (2021) reported a positive link in China (1995–2017). Another research conducted by Anh Tu *et al.* (2021) for China. The empirical results indicate that national NR is positively related with carbon emission in China. Testing the EKC hypothesis, Huang *et al.* (2021) done researched on the role of energy consumption and NR in determined the carbon emission of China from 1995 to 2019. Their findings confirmed that NR has significantly impacts environmental quality in China. Other studies further explored the link between NRR and environmental issues like carbon emission (Canh *et al.* 2020; Chien *et al.* 2021c; Joshua and Bekun 2020b; Li *et al.* 2021a, b, c, d, e, f; Ulucak and Ozcan 2020). A literary workout was done by Bekun *et al.* (2019) to investigated the long term causal interaction between natural resource rent, CO<sub>2</sub> emission, and environmental degradation for 16 EU countries. The results intricate that if proper management or conservation methods are not used, the natural resource rent increases the CO<sub>2</sub> emission into the air. Empirical research was made by Ullah *et al.* (2021), to identify the interrelationship between renewable energy consumption, natural resource rent, CO<sub>2</sub> emission, and environment quality in the context of the world's top 15 renewable energy consumption economies to attain sustainable development. They concluded that natural resource rent causes an increase in the amount of CO<sub>2</sub> into the air and leads to environmental degradation. Recently Razzaq *et al.* (2021) also explored the resources depletion effect attributed to infrastructure development in highly resource consuming economies and argued that innovation can help to reduce these negative effects.

## 3- RESEARCH METHODOLOGY

### 3.1. Data

This study investigates the impact of Technological innovation (lnTI), income inequality (lnGini), exchange rate (lnExch), inflation (lnInf) and Natural resources (lnNR) on CO<sub>2</sub> emissions (CO<sub>2</sub>) in Pakistan, using annual time series data from 1990 to 2021. In this analysis, CO<sub>2</sub> emissions serve as the dependent variable, while lnTI, lnGini, lnExch, and lnInf are treated as independent variables. This study used dataset from 1990 to 2021 is used for extended analysis. The Gini coefficient, measuring income inequality, is sourced from the Standardized World Income Inequality Database (SWIID) version 9.9. Data for Technological innovation (lnTI), exchange rate (lnExch), inflation (lnInf) and Natural resources (lnNR) and CO<sub>2</sub> emissions (CO<sub>2</sub>) are retrieved from the World Bank Development Indicators. All the variables are transformed into natural logarithms to allow the coefficients to be interpreted as elasticities with respect to CO<sub>2</sub> emissions.

### 3.2 Unit Root

Most economic variables are non-stationary in their level form but become stationary after taking the first difference, as established by Nelson and Plosser (1982). Regressing non-stationary variables can result in spurious or misleading relationships (Granger and Newbold, 1974). Asteriou and Hall (2007) further noted that many macroeconomic time series exhibit trending behavior, indicating that non-stationarity is a common feature.

To avoid spurious regression, it is essential to determine the order of integration of each variable. This study conducts a univariate time series analysis using the Augmented Dickey-Fuller (ADF) test to assess the stationarity of each variable. The ADF test is applied at both the level and first difference, with specifications including intercept only. The null hypothesis of the ADF test states that the series is non-stationary. If the null is rejected, the series is considered stationary. If all variables are found to be non-stationary at level but stationary after the first difference, this implies they are integrated of the same order (usually I(1)). In such cases, the existence of a cointegration relationship is likely, indicating a long-run equilibrium among the variables (Granger, 1986).

### 3.3 Johansen Cointegration Test

We have used the Johansen Cointegration Test because it is suitable for models involving three or more variables. In contrast, the Engle and Granger (1987) approach is typically used for models with only two variables. Johansen (1988) introduced the Vector Autoregressive (VAR) framework to analyze long-run relationships among variables, which was later extended by Johansen and Juselius (1990). Their methodology applies maximum likelihood estimation to determine the number of cointegrating vectors in a system of non-stationary time series.

The Johansen cointegration model can be represented as a VAR of order P.

$$Y_t = \varphi + \beta_1 Y_{t-1} + \dots + \beta_p Y_{t-p} + \varepsilon_t = 1, \dots, T \dots \dots (1)$$

Here  $Y_t$  is a  $(p \times 1)$  vector of I (1) time series variables,  $\beta$ 's represents the coefficient matrices,  $\varphi$  is a vector of constants, and  $\varepsilon$  is a white noise error term. To test for cointegration, the VAR is reformulated into a vector error correction model (VECM):

$$\Delta Y_t = \varphi + \omega_1 \Delta Y_{t-1} + \dots + \omega_k \Delta Y_{t-k} + \psi Y_{t-k} + \varepsilon_t \dots \dots (2)$$

In this specification, the rank of the matrix  $\psi$  indicates the number of integrating vectors, i.e., how many linear combinations of the non-stationary series is stationary. The Johansen method provides two test statistics, Trace statistic and Maximum Eigenvalue statistic to determine the number of cointegrating vectors. If the data has no deterministic trend and that all variables are integrated of the same order, typically I(1), which supports the existence of a long-run relationship among them in this case we are using Johansen co-integration model.

### 3.4. Granger Causality Test

To enhance the robustness of our analysis, we also apply the Granger Causality Test. This test helps determine the direction of causality between variables. Specifically, it examines whether past values of one variable can statistically predict another. If the lags of variable X significantly explain changes in variable Y, then X is said to Granger-cause Y. As noted by Brooks (2008), Granger causality identifies whether the current value of one variable is influenced by the historical values of another. This test provides insight into short-run dynamics and causal linkages within the model.

## 4. EMPIRICAL RESULTS

### 4.1. Descriptive Statistics

Table 1 gives the descriptive statistics for all the variables. The average CO2 emission in metric tons per capita is 4.8736 with a standard deviation of 0.3589. The highest recorded CO2 emission in metric tons is 5.466 and the lower recorded value was 4.1839. The annual average of technological innovation (lnTI) was 6.85% with a standard deviation of 0.3030. This ratio has the highest value of 7.4604% with a lowest record of 6.2614 %. Natural resources averaged 0.4971% with a standard deviation of 0.3424. The average value of Gini is 34.42 with a standard deviation of 0.156. The minimum and maximum values for this variable are 34.1 and 34.7 respectively. The mean value of inflation is 4.68 having maximum and minimum 5.38 and 2.89. The annual mean value of exchange rate is 4.68 with standard deviation of 0.087. Maximum value of 4.84 and minimum value of 4.57.

**Table 1. Descriptive Statistics**

	LNCO2	LNTI	LNNR	LNGINI	LNINF	LNEXCH
Mean	4.873600	6.854986	0.497119	34.42258	4.686241	4.686241
Median	4.897030	6.839476	0.408262	34.40000	4.021389	4.673929
Maximum	5.466978	7.460490	1.061660	34.70000	5.389432	4.841332
Minimum	4.183916	6.261492	0.035284	34.10000	2.890167	4.577455
Std. Dev.	0.358919	0.303086	0.342454	0.156439	0.754812	0.087352
Skewness	0.211449	0.115473	0.104454	-0.115875	0.037987	0.269004
Kurtosis	2.062042	2.510897	1.489514	2.509051	1.736483	1.527193
Jarque-Bera	1.367370	0.377886	3.003396	0.380704	2.069569	3.175710
Probability	0.504754	0.827834	0.222752	0.826668	0.355303	0.204364
Sum	151.0816	212.5046	15.41068	1067.100	129.3277	145.2735
Sum Sq. Dev.	3.8646678	2.755834	3.518249	0.734194	17.09221	0.228910
Observations	31	31	31	31	31	31

Source: Author's Self efforts



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### 4.2. Results of Correlation matrix

Table 2 shows the summary of correlation matrix. The problem of multicollinearity arises when coefficient value exceeds 0.8. Thus from the estimation all variables having correlation coefficient are lower than 0.8, illustrating multicollinearity not existed in our variables.

**Table 2. Correlation matrix**

	CO2	LNTI	LNEXCH	LNGINI	LNINF	LNNR
CO2	1.000000					
LNTI	0.3818633	1.000000				
LNEXCH	0.5646200	-0.6736246	1.000000			
LNGINI	0.6947279	-0.0938649	0.3134325	1.000000		
LNINF	0.164820	0.2553029	-0.5057046	-0.6640991	1.000000	
LNNR	-0.0734272	0.5366008	-0.6126888	-0.0166880	0.02799750	1.000000

Source: Author's own efforts

### 4.3. ADF test results

Table 3 illustrates the results of the Augmented Dickey-Fuller (ADF) test, which was conducted to determine the stationarity of the time series data (Dickey and Fuller, 1979). According to the findings, all the variables are non-stationary at level but becomes stationary after first differencing.

**Table 3. Unit root tests**

**Table 3. Unit root tests**

Variables	ADF test statistic		Decision
	Level	1 <sup>st</sup> difference	
lnCO2	-1.208301	-4.815499***	I(1)
lnTI	-1.363283	-4.328461**	I(1)
lnEXCH	-2.323554	-4.145712**	I(1)
lnGini	-0.871560	-6.304021***	I(1)
lninf	1.854499	-2.773147*	I(1)
lnNR	-2.170513	-4.129843**	I(1)

Source: Author's own efforts

### 4.4. Optimal Lag Length

Before using the Johansen cointegration test, the first step is to determine the optimal lag length for the model. This is done using the Vector Autoregressive (VAR) approach, with lag selection based on multiple information criteria such as the Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), Sequential Modified Likelihood Ratio (LR) Test, Final Prediction Error (FPE), and Hannan-Quinn Criterion (HQ). As is shown in Table 4, the lag order is set as 1 by all criterions. Considering these results, the study selects lag 1 as the basis for further analysis, given it is supported by the minimum values in key information criteria.

**Table 4 Optimal Lag Length**

Lag	LogL	LR	FPE	AIC	SC	HQ
0	38.47567	NA	0.005840	-2.308667	-2.072926	-2.234836
1	50.60630	19.24169*	0.002717*	-3.076297*	-2.793408*	-2.987700*
2	50.62426	0.027246	0.002918	-3.008570	-2.678533	-2.905206

\* shows lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Source: Author's own efforts

#### 4.5. Results of Johansen Cointegration tests

The application of the Johansen cointegration method to the time series data aims to determine whether a long-run equilibrium exists and, if so, how many cointegrating equations are present. The outcomes of the Trace statistic and Max-Eigenvalue statistic, as shown by Table 5, indicate the presence of three cointegrated vectors, all statistically significant at the 5% level. Both test statistics confirm the existence of long-run relationships among the variables. According to the Johansen cointegration test, CO<sub>2</sub> emissions, income inequality, exchange rate, technological innovation, inflation rate and natural resources move together in the long run, suggesting that these variables are cointegrated. In conclusion, the cointegration test confirms a long-run equilibrium relationship among the studied variables, justifying the move to estimate the Vector Error Correction Model (VECM) for short-run and long-run dynamics.

**Table 5: Johansen Cointegration tests**

#### Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value 0.05	P-value**
None *	0.753468	101.2148	95.75366	0.0199
At most 1	0.617510	63.40772	69.81889	0.0059
At most 2	0.520959	37.45929	47.85613	0.0062
At most 3	0.325119	17.58814	29.79707	0.5966
At most 4	0.174572	6.971215	15.49471	0.5810
At most 5	0.064187	1.791180	3.841465	0.1808

  

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen	Critical Value 0.05	P-value**
None *	0.753468	37.80712	40.07757	0.0882
At most 1	0.617510	25.94843	33.87687	0.0039
At most 2	0.520959	19.87115	27.58434	0.0031
At most 3	0.325119	10.61693	21.13162	0.6853
At most 4	0.174572	5.180035	14.26460	0.7189
At most 5	0.064187	1.791180	3.841465	0.1808

Trace test reveals the existence of 6 co-integrating equations at the 5% level

\*shows rejection of the hypothesis at 0.05 level

\*\* Established on Mackinnon-Haug-Michelis (1999) p-values

#### 4.6. Long Run Results

Table 6 revealed VECM long run results. The coefficient of (lnTI) is positive and statistically significant. A one % increase in technological innovation led to raise CO<sub>2</sub> emissions by 0.15 %. supports the previous findings of (Li *et al*, 2022; Adebayo *et al*, 2021). This implies that technological innovation has degraded the environment in Pakistan under the studied period. This suggests that technological innovation initially reducing emissions, but increasing them again over time. This may bring short-term environmental benefits; it can also drive long-term increases in emissions due to increased demand for energy inputs and greater use of natural resources. In Pakistan, technology adoption is often not clean or green. Technological innovation may lead to increased industrial production, energy use and urbanization, all of which are carbon-intensive due to reliance on fossil fuels. The results also suggest that Pakistan's development is still carbon-intensive and technological, macroeconomic reforms need to be greener and more inclusive.

Income inequality has a significant negative effect on CO<sub>2</sub> emission. The findings indicate that increasing income inequality decreases CO<sub>2</sub> emission leading to environmental restoration. The coefficient value shows that if income inequality in Pakistan rises by 1% leads to decrease in CO<sub>2</sub> emissions by 0.24%. This implies that high inequality suppresses consumption for the majority. Poorer households consume less energy and goods, reducing carbon emissions. Economic activities may be concentrated in a few sectors, limiting overall emissions. The outcome of this study is the same with previous studies like (Demir *et al*, (2019).

Depreciation of the currency increases CO<sub>2</sub> emission. The reason is that when Pakistani rupee depreciates, exports become cheaper, boosting export-led industries, which are often pollution-intensive (like textiles, cement). Increased production leads to higher emissions align with the studies of (Zhang and Zhang 2018; Shah *et al*, 2022).

The parameter of CPI has a Positive and significant impact on CO2 emission. This outcome implies that, in the long run, if the inflation (CPI) rises by 1%, the CO2 emission increases by 0.405%. This result indicates that inflation in Pakistan may lead to cost-push production where energy and raw material costs rise, but producers continue operations with less efficient technology, increasing emissions. Also, higher prices may shift demand to cheaper, dirtier energy sources. Our findings are consistent with (Jamal et al. (2024)). The coefficient of natural resources is insignificant which may be the reason that Pakistan's natural resource use is limited and inefficient, and the data may not capture its true environmental impact. Lack of resource governance and under-utilization may explain the weak relationship.

**Table 6: Long Run Results**

Dependent Variable:  $\ln CO_2$

Variable	Coef	S.error	t-value	Prob
C	10.70848	3.435428	3.117074	0.0045
$\ln TI$	0.157466	0.049433	4.113446	0.0004
$\ln Gini$	-0.247962	0.092493	-2.680878	0.0128
$\ln Exch$	0.389749	0.219211	1.777960	0.0944
$\ln Inf$	0.405050	0.022389	18.09150	0.0000
$\ln NR$	0.058306	0.044285	-1.316615	0.1999

Source: Author's own efforts

#### 4.7. Short Run Results

Table 7 presents the result of the short run of ECM. The coefficient of ECT shows the speed of adjustment toward equilibrium and negative sign, and statistically significant implies a convergence from short run to long run. The speed is 0.0.544 means that 54.49 % of this disequilibrium is corrected in the short run. Technological innovation has positive but insignificant impact on CO2 emission. The results further states that the natural resources is adverse, but insignificantly associated to CO2 emission. While in the short run Exchange rate and Inflation hold a positive as well as significant interconnection with CO2 emission. The value of R-squared indicates that 0.57 % variations explained by explanatory variables. The value of F-statistic is highly significant that showing overall significant of the model.

**Table 7. Short Run Results**

Dependent Variable: Gini

Variable	Coef	S.error	t-value	Prob
Cointg(-1)				
$D(\ln TI)$	0.033272	0.048423	0.687105	0.5019
$D(\ln TI(-1))$	0.070078	0.04797	1.46079	0.1524
$D(\ln GINI)$	-0.250278	0.101596	-2.463474	0.0255
$D(\ln GINI(-1))$	0.097063	0.115893	0.837520	0.4146
$D(\ln Exch)$	0.389749	0.219211	1.777960	0.0944
$D(\ln Exch(-1))$	0.140279	0.290698	0.482558	0.6359
$D(\ln Inf)$	-0.415963	0.445486	-0.933728	0.3616
$D(\ln Inf(-1))$	-0.544915	0.437591	3.245261	0.0024
$D(\ln NR)$	-0.981832	3.663994	-2.451377	0.0241
$D(\ln NR(-1))$	-0.926634	4.025290	-1.223920	0.2359
R-squared	0.572071			
F-statistic	580.2343			
Prob(F-statistic)	0.0000			

Source: Author's own efforts

#### 5. CONCLUSION AND POLICY RECOMMENDATIONS

This study examines the impact of technological innovation, income inequality, exchange rate, inflation and natural resources on CO2 emission from 1990 to 2021. After determining the variables, the entire variables are integrated at the first difference. The consequence of Johansen's Co-integration demonstrates the presence of long-term association of explanatory variables with CO2

emissions. The outcomes indicate that technological innovation, exchange rate and inflation have positive and significant influence on CO<sub>2</sub> emissions in the long run. While, income inequality has a negative and statistically significant relationship with CO<sub>2</sub> emissions in the long run.

### POLICY RECOMMENDATIONS

Based on these findings, several policy recommendations are proposed:

- Redirect technological advancement toward green and energy-efficient innovations through R&D subsidies and clean tech incentives.
- Manage inflation to avoid excessive consumption and inefficient energy use.
- Implement inclusive growth strategies to balance environmental and social goals.
- Develop exchange rate policies that align export growth with environmental sustainability by encouraging low-carbon production.
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### REFERENCES

- Adebayo TS, Kirikkaleli D (2021) Impact of renewable energy consumption, globalization, and technological innovation on environmental degradation in Japan: application of wavelet tools. *Environ Dev Sustain.* <https://doi.org/10.1007/s10668-021-01322-2>
- Adebayo,S,T., Oladipupo,D,S., Adeshola,I. & Rjoub,H.(2021). Wavelet analysis of impact of renewable energy consumption and technological innovation on CO<sub>2</sub> emissions: evidence from Portugal. *Environmental Science and Pollution Research* <https://doi.org/10.1007/s11356-021-17708-8>
- Adebayo, T.S.; Coelho, M.F.; Onbas ,og˘lu, D.Ç.; Rjoub, H.; Mata, M.N.; Carvalho, P.V.; Rita, J.X.; Adeshola, I. Modeling the Dynamic Linkage between Renewable Energy Consumption, Globalization, and Environmental Degradation in South Korea: Does Technological Innovation Matter? *Energies* 2021, 14, 4265. <https://doi.org/10.3390/en14144265>
- Adebayo, S.T., Oladipupo,D.S., Adeshola,I., & Rjoub,H.(2021). Wavelet analysis of impact of renewable energy consumption and technological innovation on CO<sub>2</sub> emissions: evidence from Portugal. *Environmental Science and Pollution Research* <https://doi.org/10.1007/s11356-021-17708-8>
- Adebayo T. S. (2023). Trade-off between environmental sustainability and economic growth through coal consumption and natural resources exploitation in China: New policy insights from wavelet local multiple correlation. *Geological Journal*, 58(4), 1384–1400.
- Adjei-Mantey, K., Adusah-Oku, F., & Kwakwa, P, A. (2023). International Tourism, exchange rate, and renewable energy: Do the boost or burden efforts towards a low carbon economy in selected African countries? *Cogent Economics & Finance*, 11(2), 2245258
- Ahmad, F., Draz, M. U., Chang, W. Y., Yang, S. C., and Su, L. (2021). More than the resource curse: exploring the nexus of natural resource abundance and environmental quality in northwestern China. *Resour. Policy* 70, 101902. doi:10.1016/j.resourpol.2020.101902
- Ahmad, W., Ullah, S., Ozturk, I., & Majeed, M.T. (2021). Does inflation instability affect environmental pollution? Fresh evidence from Asian economies, *Energy Environ.* 32 (7)
- Ali, W.; Abdullah, A.; Azam, M. The dynamic linkage between technological innovation and carbon dioxide emissions in Malaysia: An autoregressive distributed lagged bound approach. *Int. J. Energy Econ. Policy* 2016, 6, 389–400.
- Baloch MA, Khan SU-D, Ulucak ZŞ, Ahmad A (2020) Analyzing the relationship between poverty, income inequality, and CO<sub>2</sub> emission in Sub-Saharan African countries. *Sci Total Environ* 740:139867
- Bekun, F.V., Alola, A.A., Sarkodie, S.A. (2019). Toward a sustainable environment: nexus between CO<sub>2</sub> emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Sci Total Environ* 657:1023–1029. <https://doi.org/10.1016/j.scitotenv.2019.1023-1029>
- Bilal, I., Khan, D., Tan, W., Azam, S., & Hassan, S., T. (2022). Alternate energy sources and environmental quality: The impact of inflation dynamics. *Gondwana Research*. 106(June):51–63.
- Chen J, Xian Q, Zhou J, Li D (2020) Impact of income inequality on CO<sub>2</sub> emissions in G20 countries. *J Environ Manage* 271:110987
- Chien, F., Kamran, H,W., Nawaz, M, A., Thach, N, N., Long, P, D., & Baloch, Z, A. (2021a) Assessing the prioritization of barriers toward green innovation: small and medium enterprises nexus. *Environ Dev Sustain*:1–31.<https://doi.org/10.1007/s10668-021-01513-x>
- Chien F, Zhang Y, Sadiq M, Hsu CC (2021b) Financing for energy efficiency solutions to mitigate opportunity cost of coal consumption: an empirical analysis of Chinese industries. *Environ Sci Pollut Res.* <https://doi.org/10.1007/s11356-021-15701-9>
- Danish, R., Khan, S.Ud D., and Khan, S. U. D. (2020). Determinants of the ecological footprint: role of renewable energy, natural resources, and urbanization. *Sustain. Cities Soc.* 54, 101996. doi:10.1016/j.scs.2019.101996
- Dauda, L.; Long, X.; Mensah, C.N.; Salman, M.; Boamah, K.B.; Ampon-Wireko, S.; Dogbe, C.S.K. Innovation, trade openness and CO<sub>2</sub> emissions in selected countries in Africa. *J. Clean. Prod.* 2021, 281, 125143.
- Demir C, Cergibozan R, Gök A (2019) Income inequality and CO<sub>2</sub> emissions: empirical evidence from Turkey. *Energy Environ* 30(3):444–461
- Dickey, D.A., & Fuller, W.A. (1979). Distribution of the estimators for autoregressive time series with a unit root, *J. Am. Stat. Assoc.* 74 (366a) (1979) 427–431.
- Eyraud L., Clements B., & Wane A. (2013). Green investment: Trends and determinants. *Energy Policy*, 60, 852–865.
- Garrone, P.; Grilli, L. Is there a relationship between public expenditures in energy R&D and carbon emissions per GDP? An empirical investigation. *Energy Policy* 2010, 38, 5600–5613.
- Gozgor, G., Demir, E., Belas, J., & Yesilyurt S. (2019). Does economic uncertainty affect domestic credits? An empirical investigation. *Journal of International Financial Markets, Institutions and Money.* <https://doi.org/10.1016/j.intfin.2019.101147>.
- Guo Y, You W, Lee CC (2022) CO<sub>2</sub> emissions, income inequality, and country risk: some international evidence. *Environ Sci Pollut Res* 29:12756–12776. <https://doi.org/10.1007/s11356-020-09501-w>
- Gutti, B., and Aji, M. M. (2012). Environmental impact of natural resources exploitation in.
- Hailemariam A, Dzhumashev R, Shahbaz M (2020) Carbon emissions, income inequality and economic development. *Empir Econ* 59(3):1139–1159
- Haq Iu, Mehmed B, Naradda Gamage SK, Allayarov P, Khan D, Khattak ZZ (2022) Nexus between export variety and carbon emissions in Pakistan: The role of FDI and technological development. *PLoS ONE* 17(1): e0263066. <https://doi.org/10.1371/journal.pone.0263066>
- Hieu, M., V. (2022). Influence of Green Investment, Environmental Tax and Sustainable Environment: Evidence from ASEAN Countries. *International Journal of Energy Economics and Policy*, 12(3), 227-235.
- Hohne, N., Khosla, S., Fekete, H., & Gilbert, A. (2012). Mapping of green finance delivered by IDFC members in 2011. Cologne: Ecofys. [http://www.idfc.org/Downloads/Publications/01\\_green\\_finance\\_mappings/IDFC\\_Green\\_Finance\\_Mapping\\_Report\\_2012\\_14-06-12.pdf](http://www.idfc.org/Downloads/Publications/01_green_finance_mappings/IDFC_Green_Finance_Mapping_Report_2012_14-06-12.pdf)
- Hordofa,T,T., Vu,M,H., Maneengam,A.,Mughal,N.,Cong,T,P. & Liying,S. (2022). Does eco-innovation and green investment limit the CO<sub>2</sub> emissions in China? *ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA* 2023, VOL. 36, NO. 1, 634–649 <https://doi.org/10.1080/1331677X.2022.2116067>

- Jamal, F., Ullah, U., Khan, U. U., Israr, M., Ullah, H. I., & Israr, K. (2024). Empowering Sustainable Development of Pakistan: The Relationship between Inflation and CO2 Emissions Using ARDL Model. *International Journal of Multidisciplinary Comprehensive Research*
- Joshua, U., & Bekun, F. V. (2020b). The path to achieving environmental sustainability in South Africa: the role of coal consumption, economic expansion, pollutant emission, and total natural resources rent. *Environ Sci Pollut Res* 27(9):9435–9443
- Khan, H., Weili, L., Khan, I., & Zhang, J. (2022b). Exploring the nexus between energy consumption, income inequality and poverty, economic growth, and carbon dioxide emission: evidence from two step system generalized method of moments. *Environmental Science and Pollution Research* <https://doi.org/10.1007/s11356-022-24695-x>
- Khan Z, Ali M, Kirikkaleli D, Wahab S, Jiao Z (2020) The impact of technological innovation and public-private partnership investment on sustainable environment in China: consumption-based carbon emissions analysis. *Sustain Dev* 28(5):1317–1330. <https://doi.org/10.1002/sd.2086>
- Khan, M.A., Riaz, H., Ahmed, M., and Saeed, A. (2022). Does Green Finance Really Deliver what Is Expected? an Empirical Perspective. *Borsa Istanbul Rev.* 22, 586–593. doi:10.1016/j.bir.2021.07.006
- Khan, I., Hou, F., and Hoang, P. (2021). The impact of natural resources, energy consumption, and population growth on environmental quality: fresh evidence from the United States of America. *Sci. Total Environ.* 754, 142222. doi:10.1016/j.scitotenv.2020.142222
- Khan M. (2019). Does macroeconomic instability cause environmental pollution? The case of Pakistan economy. *Environmental Science and Pollution Research*; 26(14):14649–59.
- Kihombo S, Ahmed Z, Chen S, Adebayo TS, Kirikkaleli D (2021) Linking financial development, economic growth, and ecological footprint: what is the role of technological innovation? *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-021-14993-1>
- Kongbuamai, N., Bui, Q., Yousaf, H. M. A. U., and Liu, Y. (2020). The impact of tourism and natural resources on the ecological footprint: a case study of ASEAN countries. *Environ. Sci. Pollut. Res.* 27 (16), 19251–19264. doi:10.1007/s11356-02008582-x
- Kumail, T., Ali, W., Sadiq, F., Wu, D., and Aburumman, A. (2020). Dynamic Linkages between Tourism, Technology and CO2 Emissions in Pakistan. *Anatolia* 31 (3), 436–448. doi:10.1080/13032917.2020.1742169
- Li S, Yu Y, Jahanger A, Usman M and Ning Y (2022) The Impact of Green Investment, Technological Innovation, and Globalization on CO2 Emissions: Evidence From MINT Countries. *Front. Environ. Sci.* 10:868704. doi: 10.3389/fenvs.2022.868704
- Li, Z. Z., Li, R. Y. M., Malik, M. Y., Murshed, M., Khan, Z., & Umar, M. (2021d). Determinants of carbon emission in China: How good is green investment? *Sustainable Production and Consumption*, 27, 392–401. <https://doi.org/10.1016/j.spc.2020.11.008>
- Li, W., Chien, F., Kamran, H.W., Aldeehani, T.M., Sadiq, M., Nguyen, V.C., & Taghizadeh-Hesary, F. (2021a). The nexus between COVID-19 fear and stock market volatility. *Econ Res Istraživanja*. <https://doi.org/10.1080/1331677X>.
- Li, J., Huang, X., Chuai, X., Yang, H. (2021b). The impact of land urbanization on carbon dioxide emissions in the Yangtze River Delta, China: a multiscale perspective. *Cities* 116:103275. <https://doi.org/10.1016/j.cities.2021.103275>.
- Li, W., Chien, F., Hsu, C.C., Zhang, Y., Nawaz, M.A., Iqbal, S., & Mohsin, M. (2021c). Nexus between energy poverty and energy efficiency: estimating the long-run dynamics. *Resour Policy* 72:1–9. <https://doi.org/10.1016/j.resourpol.2021.101672>.
- Li, X., Li, Z., Jia, T., Yan, P., Wang, D., ..., & Liu G (2021e). The sense of community revisited in Hankow, China: combining the impacts of perceptual factors and built environment attributes. *Cities* 111:103108. <https://doi.org/10.1016/j.cities.2021.103108>.
- Li, J., Zhao, Y., Zhang, A., Song, B., & Hill, R. L. (2021f). Effect of grazing exclusion on nitrous oxide emissions during freeze-thaw cycles in a typical steppe of Inner Mongolia. *Agric Ecosyst Environ* 307. <https://doi.org/10.1016/j.agee.2021.107400>.
- Luo, R., Ullah, S., & Ali, K. (2021). Pathway towards Sustainability in Selected Asian Countries: Influence of Green Investment, Technology Innovations, and Economic Growth on CO2 Emission. *Sustainability* 2021, 13, 12873. <https://doi.org/10.3390/su132212873>
- Mahalik MK, Mallick H, Padhan H, Sahoo B (2018) Is skewed income distribution good for environmental quality? A comparative analysis among selected BRICS countries. *Environ Sci Pollut Res* 25(23):23170–23194
- Musarat, M.A.; Alaloul, W.S.; Liew, M.S.; Maqsoom, A.; Qureshi, A.H. Investigating the impact of inflation on building materials prices in construction industry. *J. Build. Eng.* 2020, 32, 101485.
- Nouira, I., Hammami, R., Frein, Y., and Temponi, C. (2016). Design of Forward Supply Chains: Impact of a Carbon Emissions-Sensitive Demand. *Int. J. Prod. Econ.* 173, 80–98. doi:10.1016/j.ijpe.2015.11.002
- Padhan H, Haouas I, Sahoo B, Heshmati A (2019) What matters for environmental quality in the Next Eleven Countries: economic growth or income inequality? *Environ Sci Pollut Res* 26(22):23129–23148
- Razzaq A, Sharif A, Najmi A, Tseng ML, Lim MK (2021) Dynamic and causality interrelationships from municipal solid waste recycling to economic growth, carbon emissions and energy efficiency using a novel bootstrapping autoregressive distributed lag. *Resour Conserv Recycl* 166:105372
- Ronaghi M, Reed M, Saghalian S. The impact of economic factors and governance on greenhouse gas emission. *Environmental Economics and Policy Studies*. 2020;22:153–72.
- Shahbaz, M.; Raghutla, C.; Song, M.; Zameer, H.; Jiao, Z. Public-private partnerships investment in energy as new determinant of CO2 emissions: The role of technological innovations in China. *Energy Econ.* 2020, 86, 104664.
- Shah, M, H., Ullah, I., Salem, S., Ashfaq, S., Rehman, A., Zeeshan, M., & Fareed, Z. (2022). Exchange rate dynamics, energy consumption, and sustainable environment in Pakistan: New evidence from nonlinear ARDL cointegration. *Frontiers in Environmental Science*, 9, 814666
- Shaari, M.S.; Abdullah, D.N.C.; Alias, N.S.; Adnan, N.S.M. Positive and negative effects of research and development. *Int. J. Energy Econ. Policy* 2016, 6, 767–770.
- Smaili, S.M., & Gam, I. (2023). Dynamic effect of exchange rate depreciation on carbon emission in the Mediterranean basin: Fresh insights from linear and non-linear ARDL approaches. *Environmental Science and Pollution Research*, 30(21), 1–18.
- Shpak N, Ohinok S, Kulyniak I, Sroka W, Fedun Y, Ginevičius R, Cygler J. CO2 emissions and macroeconomic indicators: Analysis of the most polluted regions in the world. *Energies*. 2022;15:2928. <https://doi.org/10.3390/en15082928>.
- Su, H.-N.; Moaniba, I.M. Does innovation respond to climate change? Empirical evidence from patents and greenhouse gas emissions. *Technol. Forecast. Soc. Chang.* 2017, 122, 49–62.
- Udemba EN, Adebayo TS, Ahmed Z, Kirikkaleli D (2021) Determinants of consumption-based carbon emissions in Chile: an application of non-linear ARDL. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-021-13830-9>
- Ullah, A., Ahmed, M., Raza, S.A., & Ali, S. (2021b). A threshold approach to sustainable development: nonlinear relationship between renewable energy consumption, natural resource rent, and ecological footprint. *J Environ Manage* 295:113–129. <https://doi.org/10.1016/j.jenvman.2021.113129>.
- Ulucak, R., & Ozcan, B. (2020). Relationship between energy consumption and environmental sustainability in OECD countries: the role of natural resources rents. *Resour Policy* 69:101803
- Xu Y, Li X, Yuan, P., & Zhang, Y. (2023). Trade-off between environment and economy: The relationship between carbon and inflation. *Frontiers in Environmental Science*. 11:334.



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- Yii, J.K., & Geetha, C.(2017). The nexus between technology innovation and CO2 emissions in Malaysia: Evidence from granger causality test. [www.sciencedirect.com](http://www.sciencedirect.com) Energy Procedia 105 ( 2017 ) 3118 - 3124.
- Zhang YJ, Peng YL, Ma CQ, Shen B (2017). Can environmental innovation facilitate carbon emissions reduction? Evidence from China. Energy Pol 100:18-28.
- Zhao J, Shahbaz M, Dong X, Dong K (2021). How does financial risk affect global CO2 emissions? The role of technological innovation. Technol Forecast Soc Chang 168:120751. <https://doi.org/10.1016/j.techfore.2021.120751>
- Zhao W, Hafeez M, Maqbool A, Ullah S, Sohail S (2021) Analysis of income inequality and environmental pollution in BRICS using fresh asymmetric approach. Environ Sci Pollut Res 28(37):51199- 51209. [https:// doi. org/ 10. 1007/ s11356- 021- 14209-6](https://doi.org/10.1007/s11356-021-14209-6)
- Zhang, Y., & Zhang, S. (2018). The impacts of GDP, trade structure, exchange rate and FDI inflows onChina's carbon emissions. Energy policy, 120, 347-353.