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Empowering Sustainable Development of Pakistan: The Relationship between Inflation and CO_2 Emissions Using ARDL Model

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Abstract

Inflation can expect cause devastating effect wherever high inflation can dangerous for economic and social circumstances. The current study inspects the impact of inflation rate, unemployment, financial development and renewable energy consumption on CO_2 emissions, in Pakistan during the time period of 1981 to 2020 by employing ARDL model to estimate long run and short relationship among the variables. The empirical results depict a positive and significant relation was found between inflation rate, unemployment rate, financial development and CO_2 emissions in the short run and long run. While renewable energy consumption has negative impact on CO_2 emissions. Based on the results, this study suggested the policy makers to support a robust role of inflation stability in attaining objectives associated to the decline of greenhouse gasses. Financial institutions offer subsidies for low-carbon investments. The government should plan subsidies to encourage the development and use of renewable energy resources.

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Introduction

Climate change is the major challenge that modern society facing now. No wonder it is one of the serious issues today to protect the environment, since the emission of various harmful gases into the atmosphere creates a greenhouse effect which pollutes the environment. It is essential to apply environmental principles, preserve the environment, and decrease environmental loss (Shpak *et al*, 2022) [33]. For that reason, companies use technological progress as a factor of competitiveness to make equality between business, ecology and society. The greenhouse gases eradicate the ozone layer of the earth and causing global warming. It is important to adjust the industrial structure keeping the needs of environmental protection. The beginning of the industrial revolution in the mid of 19th century creates disruption in the balance of carbon cycle and increasing carbon dioxide concentrations. For that Koyoto Protocol was established in 1992, followed by Paris Climate Agreement in 2015 that provides the target for countries which based on their national priorities and characteristics such as temporary trade zones, poverty eradication etc. Therefore, a country should not limit to climate change goals but to achieve other sustainable development including economic goals. This provides evidence that economic development depends on carbon dioxide emissions, which a need of analysis not only based on environmental aspects but also of economic aspects.

Pakistan is a developing country, has paid attention to and responded to the problems caused by the global carbon dioxide emissions. In the last era, Pakistan got rapid economic growth and extensive consumption of energy because of industrialization and related market reformations (Raza and Lin, 2023) [25].

This has raise the production and led to a steady surge in domestic demand. In 2021, Pakistan emitted 226.4 metric tons of CO_2 with a per capita GDP of $1505.01 and a population of 231.4 million. Furthermore, Pakistan economic growth depends largely on fossil fuel energy that emits 76.1% in total of CO_2 emissions (HDIP, 2021) [15]. Inflation rate is inevitable in the economic world and has positive or negative effects on both developed and developing nation (Writer, H.A, 2020) [39]. Inflation rate is a key determinant that causes economic and social dislocations and is being extensively tested both empirically and theoretically. Pakistan has been facing the issue of macroeconomic instability issue such as inflation over the past 50 years, but the country has mange to evade higher inflation. Concerned with inflation pressures, the State Bank of Pakistan has reduced the interest rate to stimulate home investment essential to attain economic growth, a policy that ignores its environmental degradation. Though, the country has had to deal with severe escapes in his policies. Basically, environmental pollution is an ongoing issue. Undoubtedly, Pakistan is the major carbon emitter in South Asia, with emissions of 0.82 tons after India. Pakistan ranks 16th in total of 48 Asian nations and 42nd out of 198 world economies (World Bank, 2019) [38].

Pakistan has the highest inflation rate among their peer group 7.3% then Bangladesh 5.5%, Nepal 4.6%, India 3.5% and Sri Lanka 3.1%, but highest GDP growth rate in South Asia in in Bangladesh 8.1%, next of Nepal 7.1%, India 6.5%, Pakistan 3.3% and Sri Lanka 2.6%. On the basis of such economic enactment, environmental pollution is likely to be influenced by macroeconomic volatility in Pakistan (Khan, 2019) [18].

Various researchers have discovered the determinants of CO_2 emissions in Pakistan, but the impact of inflation rate couple with unemployment rate have not been studied fully. Therefore, this study contributed to the prevailing works by investigating the impact of inflation rate on CO_2 emissions in Pakistan during the period of 1990 to 2020 by employing Autoregressive Distributed Lag (ARDL) model. The current study is unique in that it covers the country’s major economic factors like as inflation rate, unemployment, financial development and renewable energy consumption which are known to affect CO_2 emissions. Therefore, this research verify the true nexus between inflation rate, unemployment, financial development and renewable energy consumption on CO_2 emissions to help the government and its stakeholders in formulating policy directions to reduce the impact of climate change on Pakistan’s economy.

The next sections of the paper presents past literature, data and methodology, empirical analysis, conclusions as well as policy recommendations based on the findings.

Literature Review

Inflation can affect all the countries negatively and positively. Musarat *et al*, (2021) [24] evaluated the relationship between inflation and prices of construction materials in Malaysia construction industry. They found that reduction in inflation produced an increase in CO_2 emissions. Reduction in inflation stimulates economic growth, resultantly rise in demand for construction work materials which increase industrial production and additional amount of CO_2 omitted. A study carried out by Ronaghi *et al*, (2020) [31] they established that inflation significantly negative effect on Carbon emissions. Increasing inflation is led by rises prices of goods and services. As a consequent demand of consumers will fall and reducing production, which decrease CO_2 emissions. Shpak *et al*, (2022) [33] analyzed the effect of macroeconomic variables on CO_2 emissions in US and Asia Pecific region during the period of 1970 to 2020. They concluded that CO_2 emissions decreases when inflation increases, but unemployment has positive and insignificant effect on CO_2 emissions. Analyzed BRICS countries, investigated the link between inflation and carbon emissions spanning of time 1997-2020. Their findings revealed that CO_2 emissions has significantly and negatively affected by inflation. Ahmad *et al*, (2021) [3] stated that high inflation volatility alleviates the CO_2 emissions, indicating the positive effect of inflation on environment quality. High inflation generates all economic instability and hence depresses the new investment in industrial ventures. This factor enhance hampers the use of industrials goods and finally brings to sinking the Carbon dioxide emissions. Bilal *et al*, (2022) [7] found negative correlation between inflation rate and CO_2 emanations in Germany. Khan (2019) [18] argued that entire economic stability directed more consumption and production of goods and hence increases the CO_2 emission. Concerning this, high inflation rate leads economic uncertainty (Gozgor *et al*, 2019) [12] and therefore this would conclude that higher inflation has negative connection with CO_2 emissions. Regarding to Pakistan, inspected the link between inflation uncertainty and environmental during the period of 1975 to 2018. The results of NARDL model show that negative inflation shocks have positive association with CO_2 emissions.

Liu and Feng (2022) [19] studied the influence of unemployment on CO_2 emissions in 77 nations and region over the period 1991 to 2020. Their result showed that unemployment has negative influence on CO_2 emissions at the whole sample while at regional level like Middle East it has positive impact CO_2 emissions and at the regions o Americas, Africa and Asia pacific have negative influence on CO_2 emissions. Explored the relation between unemployment and CO_2 emissions in China in the period of 1991 to 2020. They concluded that unemployment positive effect on carbon emissions. This suggests that unemployment produces higher carbon emissions. Another study of (Cui *et al*, 2022) [9] conducted on China during the period of 2004 to 2019, employed OLS and GMM approaches. The result shows that unemployment rate enhancing CO_2 emissions in China. High income people usually having large chances to achieve their wants and keep a good lifestyle that increases their environment. Meyer, (2016) [21] indicates that unemployment can deviate environmental friendly behavior because of time and income restriction. The present literature on the relationship between unemployment and environment shows that unemployment worsens health of the people and environmental friendly behavior owing to fall in financial reign (Duart *et al*, 2016) [11]. Unemployment may affect people’s health. It is said that people will fateful on the basis of unemployment such as unemployment increases anxiety levels (Blankenberg and Alhusen, 2019) [8]. Unemployment degrades the quality of environment as well as rises the happenings of social distress, crimes, protests and violence (Rafiq *et al*, 2018) [29]. Wang *et al*, (2022) [37] documented that as the GDP per capita level lies in certain range, if economic level falls, accordingly to improve economy speedily, the government will takings actions to fuel the growth of some high energy consumption industries, so CO_2 emissions will increase.

Stability of financial sector has a vital role in environmental performance. According to the theoretical contextual, an inclusive financial sector stimulates GDP growth by attracting by the inflows of foreign investment in the home country. Foreign investors finance in green technology which is highly efficient as compared to home investors (Khan, 2019; Shahbaz, 2013) [18, 32]. Nasreen *et al*, (2017) [27] studied South Asian economies and argued that stable financial system boost environmental quality. Similarly, Baloch *et al*, (2018) [6] noted that financial uncertainty has no effect on CO_2 emissions in Saudi Arabia. In the recent study of Ullah *et al*, (2020) [34] inspected the nexus between financial development and other variables on CO_2 emissions in Pakistan, utilized time series from 1975 to 2018. They found that financial development has significant positive influence on CO_2 emissions, which implies that financial developments deteriorate environmental quality in Pakistan. Amin *et al*, (2022) [4] examined the linkage between financial developments, FDI on environment in China over the period 1996 to 2020. Their findings indicate that financial developments and FDI adverse effect on CO_2 emissions. Scrutinized the long run relationship between financial development and CO_2 emissions and found that financial development decline Carbon emissions in long run. Studied provincial level data in China, found that the impact of technology and financial development arrangement exceeds reduces per capita CO_2 emissions. Qayyum *et al*, (2021) [28] explored the link between financial development and other factors on CO_2 emissions in India employed ARDL and VECM models on time series data of 1980-2019. Their result confirmed positive association between financial development and CO_2 emissions. Guo *et al*, (2019) [13] examined the relationship between financial development and CO_2 emissions in China during the time period of 1997-2015. The result showed that the strength of transacting stocks and the consistency of financial development enhanced the CO_2 emissions level.

Renewable energy system creates less or no CO_2 emissions and thus has both benefits of alleviating universal warming and stimulating energy security (Adam and Nsiah, 2019; Ji and Zhang, 2019) [2, 17]. For example, the use of renewable energy in production prove the industrial concern for sustainable environment and vice versa (Mahmood, 2022) [40]. Similarly, Hassan *et al*, (2022) [7] asserted that renewable energy can accurate environmental degradation in BRICS countries. They also recommended that utilization of nuclear energy reduces the carbon emissions. Another study conducted on BRICS nations show that financial development, industrialization, trade openness and renewable energy have negative effect on CO_2 emissions. Usman *et al*, (2022) [36] argued that consumption of renewable energy and financial development considerably reduces the environmental deprivation in eight Arctic nations. The same results of (Qayyum *et al*, 2021; Amin *et al*, 2022) [28, 4].

3. Data, Econometric Model and Methodology

3.1. Data

To examine the impact of inflation rate, unemployment, financial development, renewable energy consumption and CO_2 emissions, the current study used tine series data of 1981 to 2020. The data of all the extracted from World Bank development indicators.

3.2. Econometric model

Following the empirical works of (Amin *et al*, 2022; Ronaghi *et al*, 2020; Xin *et al*, 2023) [4, 31], we developed the following model:

$$CO_2 = f(CPI, UEM, FD, REC) \tag{1}$$

$$CO_2 = \beta_o + \beta_1 CPI + \beta_2 UEM + \beta_3 FD + \beta_4 REC + \varepsilon \tag{2}$$

For more stable and unbiased results we convert all the variables in logarithm form.

$$lnCO_2 = \beta_o + \beta_1\, lnCPI + \beta_2\, lnUEM + \beta_3\, lnFD + \beta_4\, lnREC + \varepsilon \tag{3}$$

Where CO_2 emissions is our dependent variable measured by metric ton per capita, CPI shows inflation rate which our main variable, UEM for unemployment measured by % of total labour force, FD indicates financial development measured by bank domestic credits to private sector as %GDP, REC reveals renewable energy consumptions that contains of hydro, solar, wind, bioenergy, ocean energy resources and geothermal, ε shows error term.

3.3. Methodology

3.3.1. Unit root tests

Before applying of econometric model, firstly test stationary of the selected variables. ADF test introduced by Dickey and Fuller in (1979) and PP test invented by Phillips and Perron (1988) has been used. The null hypothesis of both tests have that the variables have a unit root.

3.3.2. ARDL Model

This study used ARDL bound test approach developed by Pesaran *et al*, (2001) for cheking the long run and short run nexus among the variables. The ARDL cointegration test as the following:

$$\Delta Y = \alpha + \Upsilon_t Y_{t-1} + \Upsilon_y X_{t-1} + \sum_{i=1}^{n} \Upsilon y\, \Delta Y_{t-i} + \sum_{i=1}^{n} \Upsilon x\, \Delta Y_{t-i} + \grave{\varepsilon}_t \tag{4}$$

Y is shown dependent variable while X is a vector of explanatory variables. To check the long run relationship existence, F-test is using in the following way:

H_0: $\eta_1 = \eta_2 = \eta_3 = \eta_4 = \eta_5$ (No co-integration)
H_0: $\eta_1 \neq \eta_2 \neq \eta_3 \neq \eta_4 \neq \eta_5$ (co-integration)

For testing the null hypothesis Pesaran *et al*, (2001) proposed critical values. If calculated F-value greater than upper bound test value, the null hypothesis of no co-integration is rejected and indicates long run association. On the other hand if F-value lies below the lower bound test then it suggest no long run relationship exists. As long run link exists between CO_2 emissions and explanatory variables, ARDL long run model is given below:

$$\Delta CO_2 = \Psi_0 + \beta_t + \Psi_1 CPI_{t-1} + \Psi_2 UEM + \Psi_0 FD + \Psi_0 REC + \varepsilon_t \tag{5}$$

The short run impact of inflation on CO2 emissions is the following:

$$\Delta CO_2 = \sum_{i=0}^{n} \omega_2 \Delta CPI_{t-1} + \sum_{i=0}^{n} \omega_3 \Delta UEM_{t-1} + \sum_{i=0}^{n} \omega_4 \Delta FD_{t-1} + \sum_{i=0}^{n} \omega_5 \Delta REC_{t-1} + \varepsilon_t \tag{5}$$

4. Empirical Results

4.1. Descriptive Statistics

Table 1, presents that the average value of Carbon emission is 0.693, the values of standard deviation and the difference between minimum and maximum are small. Similarly, the mean value of CPI proxy for inflation rate is 80.137, the maximum value is 200.08, while minimum value is 17.996, and standard deviation is 0.907. Further, unemployment ranges from 0.398 to 7.8 with value of mean 4.096 and standard deviation being 2.373 respectively. Financial development has average value of 19.791 with standard deviation 4.062, and had the minimum and maximum values 13.877 and 25.474 respectively. At the last, the mean value of renewable energy consumption was 49.295, the maximum and minimum values are 42.1 and 58.09. Skewness measures symmetry and hence some variables skewed negatively while some skewed positively. Kurtosis shows no outlier present in our data set.

Table 1: Descriptive Statistics

	CO_2	CPI	UEM	FD	REC
Mean	0.693	80.137	4.096	19.791	49.295
Median	0.697	55.778	4.28	20.396	47.46
Minimum	0.505	17.996	0.398	13.877	42.1
Maximum	0.918	200.078	7.8	25.474	58.09
Std.Dev	0.139	0.907	2.373	4.062	4.013
Skewness	0.161	0.728	-0.177	-0.064	0.449
Kurtosis	-0.443	-0.822	-1.224	-1.729	-0.394
Jarque-Bera	1.187	2.643	1.532	2.034	1.651
Observations	**32**	**32**	**32**		**32**

***Source*:** Author calculation

4.2. Results of Correlation matrix

The result of correlation matrixes is displayed in table 2. Multi-collinearity exists when the value of correlation is 0.85 or exceed as suggested. The values of correlation coefficient of all the variables are less than 0.85, indicating no multicollinearity exists in our variables.

Table 2: Correlation Matrix

	CO_2	CPI	UEM	FD	REC
CO2	1				
CPI	0.68213	1			
UEM	0.16432	0.03879	1		
FD	0.25657	0.21456	-0.16759	1	
REC	-0.54728	-0.243167	-0.2987	-0.55342	1

***Source*:** Author calculation

4.3. Stationarity Tests

To test the stationarity level of all the variables, we used ADF and PP tests. The results of both tests reveal that half of our variables stationary at first difference but some variables stationary at level. This implies that model of our variables have mixed order of integration as shown in table 3.

Table 3: ADF and PP tests

	ADF		PP		Decision	
	I(0)	I(I)	I(0)	I(I)	ADF	PP
CO2	-2.551***		-4.847***		I(0)	I(0)
CPI	3.215	10.37***	-1.439	-12.34***	I(I)	I(I)
UEM	-2.132	-4.518***	-1.336	-4.951***	I(I)	I(I)
FD	-0.773	-2.352***	-0.834	-5.325***	I(I)	I(I)
REC	-3.268**		-3.135**		I(0)	I(0)

***Source*:** Author calculation

4.4. ARDL bound test Results

Table 4 presents ARDL bounds test results and indicates that there is co-integration at a 5% level, which accepts the null hypothesis. Additional, F-statistics value is 5.7632 is higher than upper bound critical values as confirmed by Narayan (2005) at a 5%.

Table 4: Bound test results

F-value	5.7632**	
Significance	**I(0)**	**I(I)**
10%	3.13	4.01
5%	3.22	4.15
1%	3.55	4.55

***Source*:** Author calculation

4.5. Results of Long run ARDL approach

Table 5 shows the long run association between inflation rate, unemployment financial development and CO_2 emissions. The coefficient of elasticity of inflation rate is positive and significant, that shows one percent increase in inflation this will escalate CO_2 emissions by 0.06%. This mean that as prices increases people may turn to cheaper, more polluting energy sources like coal or wood that leading to raising CO_2 emissions. Our outcomes is within line to those of (Khan (2019; Musarat *et al*, (2021) [18, 24].

Similarly, unemployment has positive association with CO_2 emissions. A 1% increase in unemployment will lead to enhance CO_2 emissions by 0.04%. This implies that unemployment can decrease economic growth, which can result declined investment in clean energy and less attention towards the implementation of climate change eradication policies. Our findings are consistent with (Cui *et al*, 2022; Xin *et al*, 2023) [9].

The coefficient of financial development is positive and statistically significant. This implies that 1% increase in financial development raises the CO_2 emissions by 0.039. The positive result emanates from well financial development system increases investment by channel of low rate credit system. It increases the foreign direct investment, therefore raises directly energy consumption that degrade environment. Our result is consistent to that of (Qayyum *et al*, 2021; Ullah *et al*, 2020) [28, 34].

At the last renewable energy consumption has negative effect on CO_2 emissions. As renewable energy consumption raises by 1%, CO_2 emissions decreases by 0.019%. This suggests that renewable energy resources such as solar, wind and hydroelectric power do not emit carbon dioxide or other greenhouse gases causing less to climate change. This conclusion is same to the empirical findings of (Amin *et al*, 2022; Usman *et al*, 2022) [4, 36].

Table 5: Lon Run ARDL Model

Dependent Variable: $lnCO_2$			
Independent Variables	**Coef**	**t-test**	**p-value**
C	1.5241	16.99 (0.08971)	0.0001
lnCPI	0.06597	4.60 (0.0014)	0.0000
lnUEM	0.04256	2.27 (0.01553)	0.0036
lnFD	0.03918	2.83 (0.01385)	0.0009
lnREC	-0.01952	-13.53 (0.001443)	0.0000

***Source*:** Author calculation. The numbers in parenthesis reveals standard deviations

4.6. Results of Short run ARDL approach

Short run results of ARDL model is indicated in table 6. In the short run the variables like inflation, unemployment and financial development have positive influence on CO_2 emissions. Whereas renewable energy consumption has negative influence on CO_2 emissions. The value of ECM(-1) is -0.62 reveals that disequilibrium is adjusted with a pace of 62% in one year.

Table 6: Short Run ARDL Model

Dependent Variable: $lnCO_2$			
Independent Variables	**Coef**	**t-test**	**p-value**
C	1.5241	16.99 (0.08971)	0.0001
ΔlnCPI	0.06597	4.60 (0.0014)	0.0000
ΔlnUEM	0.04256	2.27 (0.01553)	0.0036
ΔlnFD	0.03918	2.83 (0.01385)	0.0009
ΔlnREC	-0.01952	-13.53 (0.001443)	0.0000
ECM(-1)	-0.6284	-4.762 (1.65)	0.0000
	Diagnostic tests		
F-statistics	4.07552 {0.0000}		
R-squared	0.9687		
Adj R-squared	0.9639		

***Source*:** Author calculation

4.7. Diagnostic Tests

To check the reliability of the outcomes. Various tests such as LM test for serial correlation, Breusch-Pagan-Godfrey for heteroskedasticity and tested Jarque-Bera test for normality. As shown in table 7, all tests have insignificant p-values asserting that residuals are normally distributed and there is no problem of serial correlation and Heteroskedasticity.

Table 7: Diagnostic tests

Test		
Heteroskedasticity Test	Breusch-Pagan-Godfrey	9.39865 (0.3367)
Serial Correlation	Breusch-Godfrey LM Test:	3.17390 (0.2764)
Test for Normality	Jarque-Bera Statistic	0.04365 (0.61534)

***Source*:** Author calculation

As the plot of CUSUM test come between the two straight lines at significant level of 5%, portray the stability of parameters as shown by figure 1.

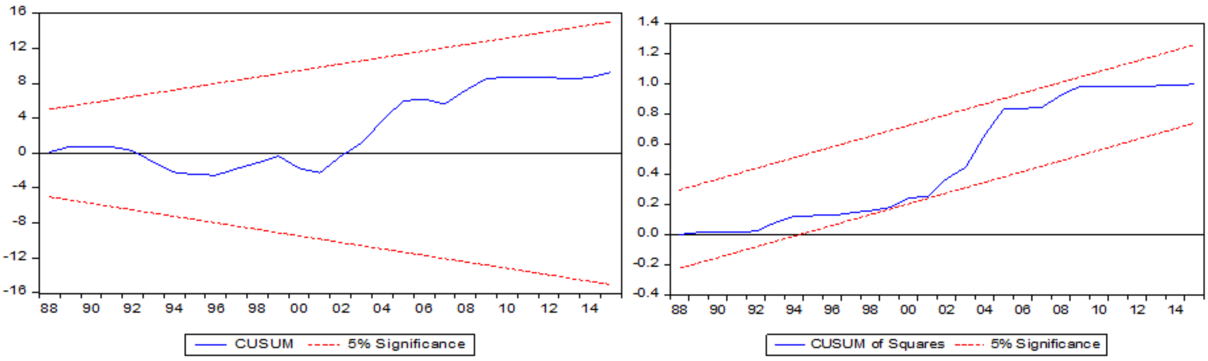

Fig 1: CUSUM and CUSUMSQ

6. Conclusion and Policy Recommendations

The current study inspects the impact of inflation rate, unemployment, financial development and renewable energy consumption on CO_2 emissions, in Pakistan during the time period of 1981 to 2020. The data used in this study retrieved from World Bank development indicators. For stationarity we used ADF and PP tests indicates mixed results that some variables stationary at level and some are at first difference. We applied ARDL model to estimate long run and short association between the variables. The empirical results depicts a significant relation was found between inflation rate, unemployment rate, financial development, renewable energy consumption and CO emissions in the short run and long run.

Based on the results, this study suggested the policy makers to support an important role of inflation stability in achieving objectives associated to the decline of greenhouse gasses. Financial institutions offer subsidies for low-carbon investments. The government should plan subsidies to encourage the development and use of renewable energy resources.

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