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Impact of Income Inequality and Population Density on Carbon Emissions in Pakistan

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Abstract

This research inspects the consequence of the contribution of income inequality towards CO_2 and the role of the urban population in the case study of Pakistan. The purpose of this study is to assess the influence of the high population density of Pakistan and income inequality on carbon emanations. The current study employed statistics of time series of the years from 1985 to 2020 by applying the approach of ARDL bounds testing to achieve this goal. Empirical results for the carbon emissions confirm the occurrence of a long-run co-integration relationship between population density and income inequality. The results of the error-correction visualization of the ARDL model indicate that all predictors and their lagged values influenced the dynamics of CO2 emissions in Pakistan from 1985 to 2020. The outcomes of the current study specify that there is a direct relationship between carbon emission and inequality of income, population density, GDP, GDP square, and urban population. The estimated results specify that as the contribution of low-income groups rises in Pakistan the emission of carbon also rises. This study also confirms that increasing population density will increase carbon emissions. The observed outcomes of this research offer policy implications that should focus on providing subsidies for clean energy to diverse groups, especially in urban areas.

Keywords: *Environmental Degradation, Population Density, Income inequality, Carbon Emission, Sustainable Development*

JEL Classification: Q53, Q23, E24, O1, Q52

1. Introduction

The world has been facing severe environmental as well as social disasters. In the previous few decades, carbon dioxide emissions have rapidly increased. During the previous years, Pakistan contributed continuously to post substantial expansion in carbon emissions and has seemingly postulated certain severe doubts about the atmosphere (Baloch et al. 2017). For different socio-economic classes, the contribution of carbon emissions is different. The poor and underprivileged societies can be a serious threat to contributing towards CO_2 due to the lack of resources in urban areas (Zhu et al., 2018). Essentially, the affiliation between income disparity and environmental degradation has been ignored in the mainstream of emerging countries. Greater income disparity can deteriorate the degradation of the atmosphere for the reason that when a greater disparity in income, it is claimed that natural resources are spoiled by needy people. According to Grunewald et al. (2017), Superior income disparity is associated with higher carbon emissions in high-income and upper-middle-class economies, while larger income disparity is associated with lower carbon emissions in middle-class and low-income economies (Yasmeen et al., 2024).

In developing nations like Pakistan, the source of CO_2 emanations can be due to the higher density of the population, in especially urban areas. Because poor or low-income people exploit more fossil fuels for heating or cooking purposes and owing to this, they emanate additional carbon dioxide into society.

Even in the urban areas of emerging nations like Pakistan, the posh urban area adores additional resources instead of the group of lower income who survive in kachi abadi. Furthermore, these classes of lower income are restricted to living in an area of heavily populated and they cannot have the funds for greenhouses and further resources.

In countries like Pakistan, environmental degradation increases because of rapid urbanization too. This is urbanization at a rapid pace because of a shifting of residents to urban areas from rural areas as well as an urban population increase. Leading to the upsurge in pollution, all main cities of Pakistan face random and unplanned development. In the cities, the wide practice of fuel that is of low-quality and mutually intense extension in the number of vehicles on highways has produced substantial difficulties of pollution of air because of which in most populous cities of Pakistan the level of air pollution is rising and producing serious problems relating health.

In Pakistan, the mainstream of the population uses outmoded automobiles, and folks do not pay enough devotion to their maintenance, which results in contamination in the metropolises. As weighty automobiles consume great diesel, they emanate enough carbon dioxide. Industries and companies trust old, heavy vehicles that are not maintained properly, which results in the emanations of carbon. Furthermore, industries are focused on cities, so all heavy vehicles are liable for the deterioration of the environment. Not every vehicle has the same effect on the atmosphere. The exhaust of electric vehicles does not produce any noticeable pollution. On the other hand, when they are powered by energy produced from non-renewable resources like coal, oil, and natural gas, they release pollutants inadvertently. Outdated diesel vehicles emanate straight contaminants, albeit not all vehicles emanate the same volume. Folks from the well-off can buy electric or newer model vehicles, at the same time as those folks from poor families can only afford old model cars. Thus, the primary source of carbon emanations is the poor circle. Poor quality of air can be created by the removal of toxic areas, public transportation, and traffic mobbing. In Pakistan, poor quality of air and smog are triggered by the smoke from brick kilns, industrial pollutants, and cars, burning of grain crops by residual, and overall solid waste, which has an impact on the whole city. It is destructive to the health of the inhabitants.

According to the widely regarded BP Energy (2021) statistics evaluation of World Energy, countries with a high population density were responsible for 52% of worldwide carbon dioxide emissions in the past year 2020. The main cause of high GHG emissions is the increasing energy demand in transportation brought on by a large population. About 24% of the world's CO_2 emanations are attributable to the transportation industry, with road transportation contributing the most.

There is conflicting data about the connection between income inequality and CO_2 emissions in the body of the current study. Higher-income disparity has been linked to decreased CO_2 emissions, according to certain research (Ravallion et al., 2000; Heerink et al., 2001; Boyce, 2007; Qu and Zhang, 2011; Guo, 2014). Nonetheless, alternative research indicates either that there is no effect (Borghesi, 2006; Wolde-Rufael and Idowu, 2017) or that income inequality is positively correlated with carbon emissions (Gassebner et al., 2008; Baloch et al. 2020; Drabo, 2011; Golley and Meng, 2012; Baek and Gweisah, 2013; Zhang and Zhao, 2014; Hao et al., 2016; Kasuga and Takaya, 2017; Knight et al., 2017; Zhu et al., 2018). In a similar vein, Sager (2019) estimates the number of Environmental Angle curves for the US from 1996 to 2009 and concludes that household carbon is significantly influenced by wealth. Regarding methodology, the majority of studies employ either panel data (Ravallion et al., 2000; Borghesi, 2006; Gassebner et al., 2008; Drabo, 2011; Hübler, 2017; Ahmed, 2024) or cross-sectional data (Heerink et al., 2001; Golley and Meng, 2012; Jorgenson et al., 2017; Kasuga and Takaya, 2017; Knight et al., 2017) for a large sample of nations covering various income levels and time periods. The rest are country-specific and based on time series data (Baek and Gweisah, 2013; Knight et al., 2017) or panel data (Hao et al., 2016).

Most of the research that has already been done usually shows that the results vary depending on the sample nations selected, the econometric methods used, and the income inequality measure. Grunewald et al. (2017) discovered, for instance, that greater disparities in earnings are interrelated to lower CO_2 emissions in low- and middle-income nations and higher CO_2 emissions in upper-middle- and high-income economies. When measuring income inequality in terms of the wealthiest 10% of the population, Jorgenson et al. (2017) found a positive correlation between income inequality and CO_2 emissions; however, when measuring disparities of earnings using the Gini coefficient, the correlation was null. Using quantile regression (QR), Hübler (2017) discovered a negative correlation between emanations of carbon along with disparity of earning; however, fixed effects (FE) regression revealed no such correlation.

There are several reasons why the relationship between CO_2 emissions and income inequality might vary over time. Changes in the rate of urbanization, awareness of and attitudes toward climate change, improvements in environmentally friendly technologies, adjustments to government policies regarding environmental protection, and structural changes are some possible sources of complexity. We make multiple contributions to the body of current literature. This is the first study to calculate the link between CO_2 emissions and income disparity across time for various life stages. To do so, we included the top 10% of income holders, the middle 40%, and lower-income groups separately so that we can see the impact of income inequality on environmental degradation.

A second contribution is that this research included urbanization and transport energy consumption. The contribution of developing countries in CO_2 emissions is surpassing that of developed countries (Batool et al. 2023). In developing countries like Pakistan, there is not much industry and there is enhanced CO_2 emissions. What is the source of this environmental degradation? The answer is simply the contribution of other factors like urbanization, and transport energy consumption. The functions that are specific to a country are especially crucial because different countries have different rates of urbanization, energy, investment, and environmental policies, which lead to varying CO_2 emission levels. As a result, the relationship between income inequality and CO_2 emissions is probably going to exhibit inconsistent trending patterns. The effects of population density, transportation energy, and income inequality on carbon emissions in Pakistan were examined in this study.

This research contributes to the literature by highlighting that poor and low-income groups contribute more to carbon emissions due to high population growth and urbanization. Therefore, this is an important study in Pakistan that examines the relation amongst disparity of income, the density of population along per capita the gross domestic product, population density in cities, and emissions of carbon.

2. Review of Literature

The present study empirically evaluates the connotation amongst income disparity and density of population, sideways with the per capita GDP and the urban population on the emissions of carbon in Pakistan. the examination of the disparity of income sideways with degrading the environment has not been recognized with adequate deliberation and consequently, it arrives as an incipient and warm research occurrence in the experiential literature. Current portions deliberate previously theoretical literature, in addition to detailed literature from preceding research and the research gap.

A study by Ahmed and Luqman (2024) focused on the climate change adaptation tactics embraced by the urban population of Pakistan. The research investigated 450 urbanites in Rawalpindi, using the model Heckman's Treatment effect the results show that education and income positively correlate with urbanites' adoption of suitable adoption methods. The urbanites if they have a strong knowledge about patterns of temperature and rainfall are inclined to apply at hand adoption techniques.

Choi et al. (2010), examine the presence of the Environmental Kuznets curve (EKC) for the emanations of carbon and its causal relation with openness and the growth of the economy. The current study uses the data of time series from the period 1971-2006 of China. China shows an N-shaped curve of the Environmental Kuznets Curve (EKC) while Japan shows a U-shaped Environmental Kuznets Curve (EKC). The current study shows the dynamic relation among the variables by implementing a model of vector autoregression or a Vector Error Correction Model (VECM). The consequences of this study show that there is an indication of large heterogeneity among the impacts of variables and the countries.

Guo (2013), investigates the interesting relationship between the Kuznets curve of income and carbon. The study used the estimated methods of random effects (RE), fixed effects (FE), and feasibly generalized least squares (FGLS). The results show that the disparity of income of a cross-country has an indirect consequence on the average level of emanations of carbon dioxide (CO_2) but a direct consequence on the aggregate elasticity of income of the releases of carbon dioxide (CO_2). Secondly, there is a presence of an inverted-U relation among the emissions of per capita carbon dioxide (CO_2) and income per capita in all samples of countries and the groups of higher income and lastly, the negative or indirect consequence of income discrepancy on the average level of the releases of carbon dioxide (CO_2) diminish alongside with the per capita growth of income.

Another study by Ota (2017), inspected the form of the Environmental Kuznets Curve (EKC) for a sample of 20 member countries of Asian ADB to evaluate the influence of growth of an economy on degrading the environment. This study shows that both Asian trends in the disparity of income and the degrading the environment appear, generally, to follow Kuznets' hypothesized curve up to the lesser level of great income as income increases, although divergent trends could be detected between economies that are in the range of great income. There are Irregularities in the curves that show changing relationships (i.e., the relation between income and the emissions of carbon, and the connection between income and the inequality of income) that seem to develop increasingly difficult.

A recent study in China about a new trend of inequality of carbon footprints in different provinces of China was conducted, and the quantity of additional CO_2 emissions linked with numerous poverty-lessening schemes was used to calculate the climate burden. The results show that eliminating poverty will not stop the nation from meeting its climate goals with an average increase of 0.1%-1.2% carbon footprints annually by the household (Sun, Mi, Du, & Coffman, 2024).

Zhang et al. (2017), evaluate the unequal impacts of consumption of household through different income households overall carbon emissions, by employing a method of hypothetical extraction and the model of semi-closed input-output. The outcomes of the current study show that the impact on the releases of carbon created by the consumption of the households of urban areas is 1.8 times approximately that of consumption of rural households. Secondly, the economy by excluding the consumption of the households of higher income would cause superior reductions in carbon emissions than lower-income households. Thirdly, from the food sector, the relative decline of families the emanation of carbon is the greatest, whereas least from the residential sectors. Another study by Yang, Ali, Hashmi, and Jahangir (2022) also worked on the relationship between income inequality, institutional quality, and CO_2 emissions where the results show that the increase in income inequality leads to an increase in CO_2 emissions.

Islam et al. (2017), analyzed the relationship between the degradation of the environment (carbon emission), total consumption of energy, growth of an economy, and the expansion of the industrial production index in a case study in Bangladesh from period 1998 to 2013. Vector Auto Regression Model and variance decomposition of VAR (Vector Auto regression) were used to evaluate the outcome of such variables on the emissions of carbon. The outcomes of the VAR model suggest that GDP per capita and industrial production have a direct connection with the emission of carbon. Moreover, investigation through variance decomposition indicates over time, emissions of carbon have a reliable influence on industrial production, while industrial production has a greater effect on carbon emanation in the short period that disappears in the long term which is reliable with the hypothesis of Environmental Kuznets Curve (EKC).

Baloch et al. (2018), inspect the consequence of the growth of an economy and income inequality on the degradation of the environment in Pakistan by using the approach of ARDL bounds testing from 1966 to 2011. The estimated outcome of this study shows that emissions of carbon increase with the increase in the gap of income in Pakistan. The study confirms that the growth of an economy in Pakistan comes up with greater emanations of carbon and the hypothesis of the Environmental Kuznets Curve (EKC) is not effective for Pakistan throughout the research period. In another research, Khan & Yahong, (2021), applied the co-integration approach of an Autoregressive Distributive Lag (ARDL) along with Nonlinear Autoregressive Distributive Lag (NARDL) in the framework of Pakistan for the year 1971–2015, investigating the short and long-run influence of poverty, population, income disparity, and GDP per capita on carbon dioxide (CO_2) emissions. The symmetric results of this study reveal that the size of population, poverty, and GDP per capita all raise emanations of carbon in the long and short run, whereas income disparity has no effect. However, in the long run, wealth disparity reduces the degradation of the environment in terms of carbon emissions. The NARDL study backs up the ARDL findings, indicating that poverty, growth of an economy, and population have a direct influence on the emanations of carbon in Pakistan.

Ali et al. (2022), inspect the influence of the development of the economy, usage of fossil fuels, and the size of the population on the emanations of carbon in Bangladesh, Pakistan, and India from the year 1971 to 2014. A panel Autoregressive distributed lags model was in use, as well as a procedure of Vector error correction. The Granger causality examination is performed to evaluate the direction of causality. The results of auto-regressive distributed lags (ARDL) illustrate that the relation between emanations of carbon and the development of an economy is U-shaped, as predicted by the hypothesis of the environmental Kuznets curve. Consequently, in the long haul, the usage of fossil fuels and the size of the population have a favorable influence on carbon emanations. Secondly, CO_2 has a detrimental influence on the development of the economy. The long-term effects of fossil fuels, foreign direct investment, and total exports on the development of an economy have been overwhelmingly beneficial. CO_2, usage of fossil fuel, and FDI Granger cause economic progress in the near run. Last but not least, CO_2 emissions have a detrimental influence on population size whereas the development of an economy has a favorable influence in the long term.

In South Asia, Pakistan is urbanizing at the quickest rate. The research was conducted with the goal of knowing how Pakistan's urbanites are dealing with climate change. A survey was conducted which gathered the data using Heckman's Treatment effect model on social, economic, demographic, and physical aspects. The explanatory variables were age, education, income, and occupation. The outcome of this research shows that age and other explanatory variables are positively and significantly related to climate change adoption. To survive climate change households with major divergences in the yearly average temperature are more presumable to adopt any adoption strategy. There is lesser respondent adoption capacity because of the considerable amount of variables poverty composes which makes them more susceptible to climate change (Ahmed et al., 2023).

3. Methodology

3.1 Theoretical background

Inequality is a concept of multiple dimensions. From the mid-1990s onwards, many economists have produced numerous theoretical explanations to describe the link between economic disparity and degrading the environment such as Khan & Yohang (2021), Wang et al. (2021), Liu et al. (2020), and many more. Whereas some of the explanations imply a direct link, such as Boyce (1994), Torras and Boyce (1998), and Borghesi (2006)'s "equality hypothesis," others believe that more disparity could be indirectly linked with emanations (Heerink et al. 2001; Ravallion et al. 2000; Scruggs 1998).

The relationship between several measures of environmental deterioration and per capita income is theorized to exist, according to the environmental Kuznets curve (EKC). Pollution emissions rise and environmental quality fall during the early stages of economic expansion, but above a certain level of per capita income, the tendency turns around, and at high income levels, economic growth actually improves the environment. This suggests that the relationship between per capita income and environmental damage or emissions is inverted U-shaped.

The theoretical framework encompasses income inequality, which determines the relation between carbon emissions and the levels of income. According to the EKC hypothesis, environmental pressures increase as income level increases at the initial stage of economic development, but later these pressures diminish along with the income levels (Guo, 2015). Boyce (1994) stated that when the income gap between poor and rich widens then the poor are more likely to overexploit natural resources and increase carbon emissions, while the rich may not necessarily increase investment to improve the environment. Another study states that the underprivileged and poor societies are severely influenced by an unbalanced distribution of income subsequently they are mostly a susceptible portion of the society (Khan & Yohang, 2021).

3.2 Econometric Model

To conclude the association among variables of this study, the econometrics model or equation is as follows:

Were,

$$CO_{2t} = \alpha_0 + \alpha_1 IE_t + \alpha_2 PD_t + \alpha_3 GDP_t + \alpha_4 (GDP)^2_t + \alpha_5 URB_t + \mu_t$$

Where CO_2 denotes the carbon emanations that are measured in metric tons per capita. IE represents income inequality and the proxy for this variable is the top 10%, middle 50%, and bottom 50%. PD represents the population density per square kilometer. GDP represents Gross Domestic Product that is measured as constant 2015 US \$. URB represents the urban population that is measured in annual percentage.

The source of variables CO_2 emissions, population density, GDP, GDP square, and urban population is the World Bank (WB). The source of income inequality data is obtained from WID (World Inequality Database).

3.3 Data

The impetus of this study is to investigate the inspiration of income disparity and the density of the population on emanations of carbon. The current research used time series statistics from 1985 to 2020 to attain the objective and assortment of this time period due to the readily available variable data from WID (World Inequality Database) and WB (World Bank). The dependent variable is carbon dioxide CO_2 emission while population density and income disparity for the bottom 50% are taken as independent variables alongside other independent variables such as urban populations, per capita GDP, and GDP square. To identify the objectives of this study, these explanatory variables will help.

The secondary data used to develop the current study came from government organizations. The data on carbon emissions, urban population, population density, and GDP (Gross Domestic Product) and GDP square were attained from the WB (World Bank). Whereas data for income inequality (bottom 50%) is collected from WID (World Inequality Database).

Other explanatory factors, such as GDP per capita, are employed in several research; for example, Kusumawardani & Dewi (2020), Hundle (2021), Mushtaq et al. (2020), Jorgenson et al. (2017), and Hailemariam et al. (2020). Asongu et al. (2020) and Jorgenson et al. (2017) used the urban population.

3.4 Explanation of Variables

3.4.1 Carbon dioxide (CO_2)

One of the greenhouse gases is carbon dioxide (CO_2) which exists naturally in the atmosphere. In this study, carbon dioxide equivalent data CO_2e greenhouse gasses. Data taken from the World Bank (WB) in metric tons per capita. This variable is used in previous research to quantify greenhouse gas emissions (Cui et al. 2021, S Khan & Yahong 2021, Islam et al. 2017 and Wang et al. 2021).

3.4.2 Income inequality

Income inequality is an uneven distribution of income throughout a population. This study has measured the impact of the top 10%, middle 40%, and bottom 50% of income distribution on carbon emissions. Data was collected from the World Inequality Database (WID). This variable is used in various research such as Grunewald et al. (2017), Hundle. (2021), Baloch et al. (2017), Khan et al. (2021), Knight et al, (2017) and Yang et al. (2020).

3.4.3 Population Density

It is the number of individuals per km^2. Data on population density was taken from the World Bank (WB) from the period 1985 to 2018. Population density used in various research e.g., Khan et al. (2021), Muhammad et al. (2020), Rahman et al. (2020), and Aye & Edoja (2017).

3.4.4 Gross Domestic Product (GDP)

GDP is the market value for all finished goods and services that are produced in a specific period and on a border of a country. In this study, the data for per capita GDP measured as constant 2015 US $ taken from the World Bank (WB) from the period 1985 to 2018. The variable per capita GDP used in much research is Khan et al. (2021), Kusumawardani & Dewi (2020), Osadume & University (2021) and Tanchangya & Zhou Ayoungman (2022).

3.4.5 Urban Population

The shifting of population from the countryside to the cities is urbanization. In Pakistan, there is a speedy urbanization because of a shifting of inhabitants to urban areas from rural areas. Data taken from the World Bank (WB) in annual percentage. This variable was used in previous research that is Alabi et al. (2021), Khoshnevis & Dariani (2019), and Khan et al. (2017) to quantify greenhouse gas emissions.

4. Results and Discussions

Table 1 presents a summary of statistics for five different measures (CO2, IE, PD, GDP, and URB) across 35 observations. On average, the CO2 emissions are 0.510 units. The highest observed CO2 emissions are 1.162 units and the lowest observed CO2 emissions are 0.045 units. Similarly, the maximum value of income inequality is 4.312 and the minimum value of IE is 0.045. Population density is also extremely high with an average number of 156 people. This summary provides an overview of the distribution and range of these variables.

Table 1: Descriptive statistics

Measures	CO_2	IE	PD	GDP	URB
Mean	0.510	3.326	156.98	6.321	44.23
Median	0.401	3.283	150.99	6.526	32.36
Maximum	1.162	4.312	252.87	6.440	57.26
Minimum	0.045	3.262	78.012	6.128	40.62
N	35	35	35	35	35

4.1 Unit Root Test Results

The current work used the traditional ADF test has been enhanced, and only the intercepts "at level" [I (0)] and "first difference" [I (1)] are included to assess the unit root problem. The outcome demonstrates that the variables GDP square, income inequality for the poorest 50% of the population, and carbon emissions had unit roots at the first difference mean at the level where they are not stable. The variables that are stationary at the level include income inequality in the top 10%, middle 40%, population density, gross domestic product, and urban population. The estimated findings are displayed in the following table.

Table 2: Unit root results of stationarity

Variables	Augmented Dicky Fuller (ADF) At Level (t-statistic)	Augmented Dicky Fuller (ADF) 1st Difference t-statistic	(P-Value)	Order of integration
Carbon Emission	----	-4.499915	0.0013	I(1)
Income Inequality				I(0)
Top 10% (IE)	-3.008936	----	0.0441	I(1)
Income Inequality Middle 40% (IE)	-2.677192	----	0.0884	
Income Inequality bottom 50% (IE)	----	-3.385672	0.0186	I(1)
Population Density (PD)	-3.686204	----	0.0363	I(0)
Gross Domestic Product (GDP)	-4.056750	----	0.0031	I(0) I(1)
Gross Domestic Product square (GDP^2)	----	-4.789942	0.0012	
Urban Population (URB)	-8.439992	----	0.0000	I(0)

After determining that all of the variables are stationary, the current study has opted to use the method known as ARDL, which stands for Autoregressive Distributed Lag to the co-integration technique in order to estimate the model.

4.2 The Long Run Coefficients

To assess the long-term relation amongst variables, the procedure of ARDL certifies the prospect.

Table 3: Long-run ARDL results

Variables	Coefficients	t-statistics	P-value
I.E Top 10%	3.970932	2.960721	0.0138
I.E Middle 40%	2.260352	3.015679	0.0080
I.E Bottom 50%	2.895955	2.606050	0.0165
P.D	0.013642	2.929674	0.0080
GDP	0.132937	3.044239	0.0062
GDP^2	-0.105233	-8.353006	0.0034
URB	0.307151	3.456691	0.0024

Table 4: Error Correction Representation for the Selected ARDL Model

Variables	Coefficient	t-statistics	P-value
$\Delta\ln (CO_2)_{t-1}$	1.4673267	12.269732	0.0001
$\Delta\ln GDP$	-0.324423	-2.923765	0.0326
$\Delta\ln (GDP)_{t-1}$	-3.078632	-23.17624	0.0003
$\Delta\ln (GDP)_{t-2}$	-2.876342	-15.87354	0.0004
$\Delta\ln (GDP)^2$	0.017923	1.437652	0.1153
$\Delta\ln (GDP)^2_{t-1}$	0.261725	25.72564	0.0001
$\Delta\ln (GDP)^2_{t-2}$	0.167432	16.79873	0.0004
$\Delta\ln$ (I.E Top 10%)	-0.287621	-9.228721	0.0011
$\Delta\ln$ (I.E Top 10%)$_{t-1}$	-0.432661	-9.287381	0.0002
$\Delta\ln$ (I.E Top 10%)$_{t-2}$	0.176254	20.27652	0.0032
$\Delta\ln$ (I.E Middle 40%)	-0.336721	-6.263728	0.0001
$\Delta\ln$ (I.E Middle 40%)$_{t-1}$	-0.238624	-6.736464	0.0021
$\Delta\ln$ (I.E Middle 40%)$_{t-2}$	0.326511	22.78686	0.0062
$\Delta\ln$ (I.E Bottom 50%)	-0.116252	-8.786381	0.0037
$\Delta\ln$ (I.E Bottom 50%)$_{t-1}$	-0.167382	-7.987321	0.0001
$\Delta\ln$ (I.E Bottom 50%)$_{t-2}$	0.272635	21.78563	0.0072
$\Delta\ln (PD)$	1.278934	24.28651	0.0001
$\Delta\ln (PD)_{t-1}$	0.562966	6.046238	0.0002
$\Delta\ln (PD)_{t-2}$	-2.834216	-4.107621	0.0059
$\Delta\ln (URB)$	-0.523763	-2.991243	0.0022
$\Delta\ln (URB)_{t-1}$	4.062389	22.997832	0.0022
$\Delta\ln (URB)_{t-2}$	7.319251	22.043281	0.0022
ECT_{t-1}	-0.432170	-4.87656	0.0062

The assessed consequences illustrate that in the model, on all the variables CO_2 releases have a positive and strong influence. The consequences of the long run suggest that in Pakistan higher levels of carbon emanations are related to higher income disparity and higher density of population.

Most of the researchers have also verified the direct association between releases of carbon and population density and income disparity e.g., Abdullahi Baba et al. (2024), Wajid et al. (2023)

and Khan et al. (2021) in Pakistan propose a positive effect of poverty, economic progress, and inhabitants on the emanations of CO_2 nevertheless also a negative effect of income disparity on the CO_2 emissions. Baloch et al. (2020) assess that an expansion in disparities in earnings increases carbon releases. Baloch et al. (2017) inspect the indirect effect of the density of the population along with the percentage of industry on carbon emanations. Muhammad et al. (2020) in Pakistan show the usage of energy and the size of the population are contributing emanations of carbon.

The error-correction illustration of the model ARDL is given in the above table. The result shows that all predictors and their lagged values affect the dynamics of CO_2 emissions in Pakistan during 1985–2020.

4.3 Diagnostic Test

Following an analysis of the long-term relationships between the study's variables, additionally, an examination for diagnosis, such as the serial correlation to ensure that the results are robust, the LM test is run. The econometric model is at risk due to serial correlation. Consequently, to ascertain whether a serial correlation existed in the calculated model, the Breusch Godfrey LM Test was employed. As a given probability level rises beyond the allowed threshold of 5%, the "serial correlation" null hypothesis is considered rejected. The Breusch Godfrey LM Test is now being used in this investigation to verify the serial correlation.

Table 5: Estimated Results of Serial Correlation (Breusch-Godfrey Serial Correlation) LM Test

F-statistic	Prob. F(2,19)	Obs*R-squared	Prob. Chi-Square(2)
0.712875	0.5029	2.512858	0.2847

Source: Authors' estimations

From the above-mentioned estimations, the detected R-squared probability Chi-Square is 0.2847 which is higher than 0.05. So, accordingly, the null hypothesis was rejected, showing there is no serial correlation in the data.

4.4 **Results of the Stability Test**

The calculated model ARDL's constancy was verified using the CUSUM test, and the results supported the model's stability. The results of the stability test are shown in Figures 2 and 3. It indicates that throughout the research period, parameters are stable, and, at a 5% significance level, all coefficients are steady or there are no structural changes in the model. Within the space between the two essential lines, the CUSUM and CUSUMSQ graphs' directions continue.

Figure 1: CUSUM of Recursive Residuals

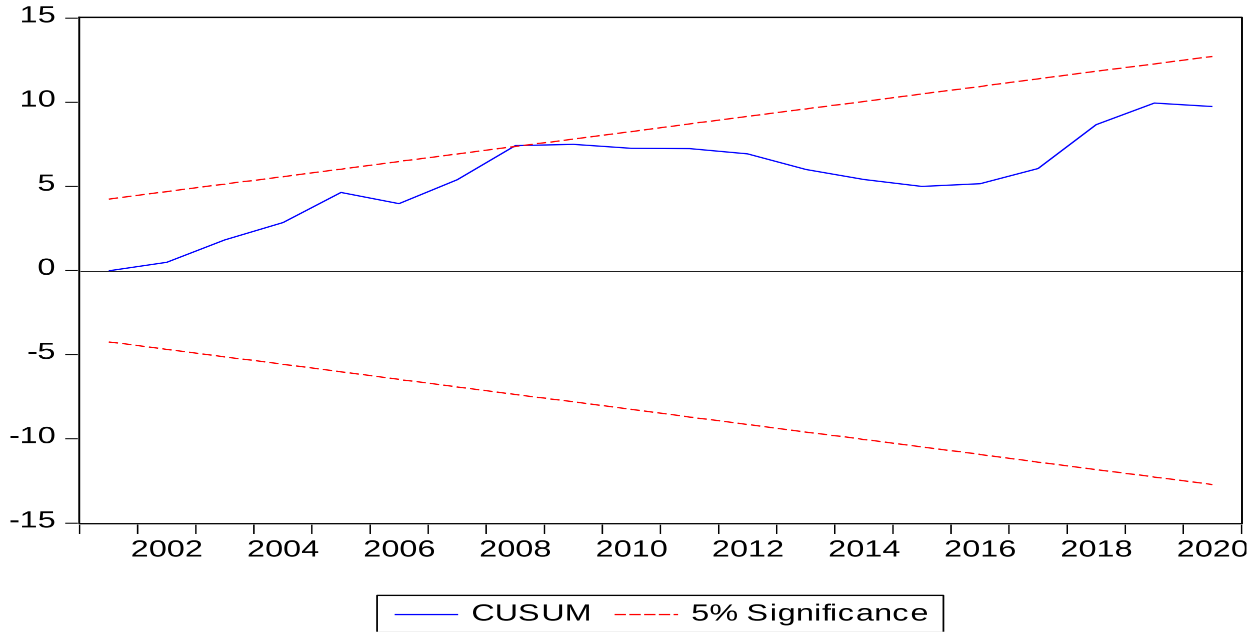
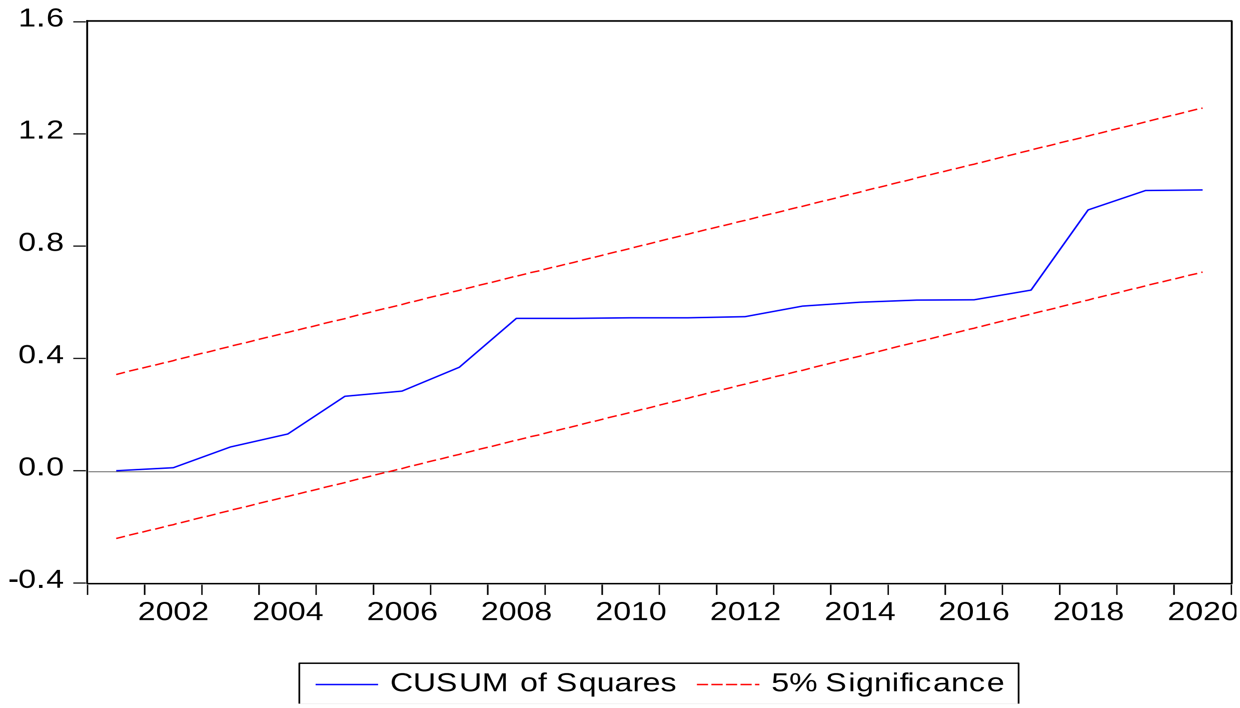


Figure 2: CUSUMQ of Recursive Residuals



5. Conclusions and Policy Implications

To accomplish the goals of this research, the consequences of this research convey a substantial insight by investigating the link between income disparity, population density, and carbon emanations, as well as with urban population and GDP in the model by using the time-series data from 1985 to 2020 for country Pakistan. The purpose of the current research is to accomplish dependable regression consequences. The consequences of current research found that the disparity of income and density of population are crucial features in influencing the CO_2 emissions in Pakistan as the CO_2 emissions are the enormous involvement to the devastation of the atmosphere. Furthermore, due to enhancing the expansion of population and speedy urbanization, at an incredible rate, the climate of the world is growing, which is badly distressing the environment, which is against sustainable goals.

The consequences demonstrate that there is a strong or direct connotation between population density and CO_2 releases. Therefore, between population density and CO_2 releases, there exists a direct relation. From such results, it is inferred that environmental degradation in Pakistan, the population is the leading cause. Higher population density has absolutely enabled social as well as economic progress, but the higher population density is the reason for increasing the emissions of carbon. The outcomes of the present research also determine that there is a direct relationship that exists between carbon emissions and income disparity. Carbon emissions increase when there is an increase in income inequality. As income inequality increases it can drastically deteriorate the degradation of the atmosphere because due to inequality of high earning, asserted that those in poverty often overuse natural resources because they see it as their last chance to survive. Hence, a greater financial status is linked to greater CO_2 emissions. An increasing trend in income inequality has dreadfully distressed the society of different economic classes.

An increase in per capita GDP and urban population increases the emanations of carbon. Thus, there exists a relation that is positive amid carbon emanations with per capita GDP and urban population. More people are moving from rural areas to urban areas for the sake of getting better opportunities. This is the reason that the population of the cities is increasing gradually, which tends to raise the carbon emanations. The pattern of consumption for energy and fuel has transformed as urban lifestyles have enhanced. Due to urban sprawl and the growth of population, the necessity for automobiles for households is growing, which affects a rise in the traffic volume.

5.1 Policy Implications

To limit the degradation of the environment, the authorities or government of Pakistan should take numerous serious activities built on the consequences of their strategies including the deterioration of income inequality and the size of the population, in addition to a maintainable GDP and the strategy for the urban population.

The consequences of this study demonstrate that fair income distribution can minimize carbon emanations. Policies that assist the accumulation of assets that can narrow the gap in income and boost the minimum wage should be implemented for those who are employed. Moreover, it is recommended that lawmakers consider the necessity of rules pertaining to a friendly work environment so that workers with low salaries can help their struggle to proficiently get more when they can receive more, they can buy more sophisticated appliances and sustain their maintenance of cars that will have it running additional efficiently. That as a result lessens carbon releases. Subsidies are also provided to poor folks by government officials.

The organization of potential public transport should be a strategy to minimize the dependence on private conveyance such as vehicles, to lessen CO_2 emanations in cities. The administration should diminish the charges for Metro buses so that deprived folks can effortlessly consume conveyance. Furthermore, for the upcoming extenuation of emanations of CO_2, conscious initiatives of the reasons and effects of altering the environment should be broadly encouraged.

The concerned establishments and the government of Pakistan must improve a thorough strategy to make sure that the profits of all the productive as well as economic activities reach the deprived and needy folks. The government should construct factories outside of the cities so that huge and weighty vehicles and trucks with extreme diesel consumption cannot arrive or travel through urban areas. Emissions of carbon can be diminished by accepting such plans. The government should tax those cars that emanate more carbon and contaminate the atmosphere. With the help of social media, the government of Pakistan should train individuals about the suitable maintenance of cars.

This research shows that poor folks or low-income groups discharge more carbon because of the greater density of population in urban areas and income inequality amid them; so, it concentrated on the poor folks of the bottom 50% of income disparity than this study did not based on the whole inequality of income for every sector of the society. There are negligible emissions from the rich class because they have enough money so they can buy electrical appliances and advanced and new models of vehicles, they can also pay high bills of electricity and adequately maintain their automobiles.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Disclosure statement

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