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Population Growth and Climate Change: Implications for Human Development in Pakistan

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Abstract: *The study examines how population growth and climate change affect human development in Pakistan. The rapid population growth and escalating climate change impacts in the country necessitate an understanding of their implications for human development. The study utilized time series data from 1990 to 2020 and employed descriptive analysis, an Autoregressive distributed lag (ARDL) model, a unit root test, and a bounds test for cointegration to analyze the data. The study considered the variables for analysis, such as Human Development, Climate change, and Population growth. The findings revealed that population growth and climate change have significantly influenced human development outcomes in Pakistan, with higher population growth and climate change leading to lower human development levels in the long run. The implications of the study underscored the need for urgent action to address the negative impacts of rapid population growth and climate change on human development in Pakistan. The study derived several suggestions from the findings, including implementing a family planning program, investing in education, promoting climate change awareness campaigns, integrating climate change considerations into national policies, empowering local communities, and encouraging research and innovations in sustainable development and climate change adaptation.*

Key Words: Human Development, Population Growth, Climate Change, and Pakistan

Introduction

Human development is a crucial goal for achieving the social and economic development of a country. It is directly influenced by factors such as population growth and climate change. In this century, all nations worldwide aspire to maximize human development while effectively managing climate change and population growth. Therefore, this study aims to provide the current situation in Pakistan.

Human Development

Human development encompasses the expansion of people's opportunities and choices, focusing on the well-being of human life rather than the wealth of a country. In 2018, Pakistan had a Human Development Index (HDI) value of 0.56. As stated by Dr. Mahbub ul Haq, "The real wealth of a nation lies in its people." The HDI measures a nation's progress based on factors such as opportunity, social justice, and potential rather than solely economic growth (UNDP, 2020). The study of Human Development encompasses an exploration of the human condition, extending beyond a simple analysis of shifts in national income or economic growth. It focuses on the choices individuals make and the expansion of opportunities available to them in life. Additionally, it involves the assessment and improvement of individuals' overall well-being (Javaid *et al.*, 2018). In the 1990s, the United Nations introduced the HDI as a highly successful indicator of

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welfare (Sen, 1987). Human development encompasses three fundamental dimensions: health, education, and material well-being, which are highly relevant to human welfare (Herrero *et al.*, 2019).

Development is divided into two categories: economic development and social development. Economic development focuses solely on increasing national income, while social development places emphasis on crucial aspects such as health and education. In economic development, the primary concern is the overall national income of a country, whereas in social development, the focus is on the quality of life for the people residing within the country (Potter *et al.*, 2018). With this perspective in mind, the United Nations Development Program (UNDP) was established in 1990, introducing the HDI as a multidimensional measure of development. The HDI aims to evaluate the education, health, and well-being of individuals. Considering all these factors, it becomes evident that social development holds significant importance alongside economic development in a country as it examines the social conditions of its inhabitants. Additionally, the HDI serves the purpose of comparing a country's development with that of other nations (Ferjan, 2014).

The meaning of human development, both physically and mentally, lies in the enhancement of fundamental abilities within the population. This enhancement, in turn, fosters greater opportunities for individuals to engage in the process of development. The three key values crucial for successful development are sustenance, self-esteem, and freedom (Desriandra & Murialti, 2016). The UNDP introduced the index in its annual Human Development Report of 1990. This index was constructed by incorporating three fundamental dimensions: longevity and well-being, education, and a standard of living (Muslikhati, 2018).

The HDI holds significant influence and can effectively guide long-term national development plans. Additionally, it has the potential to shape international policies, enabling its creators to exert considerable influence over the future prospects of upcoming generations worldwide. The HDI should be seen as a significant collective benefit for humanity, not just a GDP-like component (Lind, 1992). The HDI's potential as a tool for global social development is considerable (Selén, 1985; Johnston, 1988; Hart, 1990).

Population and Population Growth

Population characteristics play a vital role in the human development and climate change of a country. A nation's human resources are crucial for the social well-being of its people. The term "population" encompasses individuals, family members, citizens, and a collective quantity of people residing in a specific area (Damanik *et al.*, 2021). The world's population has surpassed 7.884 billion people. UN projections indicate that the global population will rise to approximately 8.5 billion by 2030, 9.7 billion by 2050, and 10.4 billion by 2100. Although population growth has been increasing over the last two centuries, the most substantial expansion occurred during the twentieth century (UNDESA, 2022).

Pakistan, the world's fifth most populous country, has 224.78 million people. The population density is 282 per square km, with 82.83 million in urban areas and 141.96 million in rural areas (GOP, 2022). Developing countries worldwide continue to face the ongoing challenge of population growth, while developed nations are experiencing a contrasting trend of declining or negative population growth (Zahonogo, 2016; Saghir & Santoro, 2018). Population development varies across different countries. Technologically advanced nations have the potential to increase production and generate employment opportunities, while developing countries may experience different outcomes (Purba *et al.*, 2021).

The population growth rate functions as a concise representation of patterns in population density or abundance. It provides valuable insights into the direction and rate at which changes occur in density and abundance, thereby indicating whether they are increasing, remaining stable, or decreasing (Sibly & Hone, 2002). The change in population is evidently not the sole source of concern or opportunity worldwide, but its effects often trigger and ignite further dilemmas that confront human society (Weeks, 2020).

Climate Change

Climate change is a big problem that makes it difficult for humans to reach their full potential and live better lives. It limits our freedom and the choices we can make, and it goes against the idea that things will keep getting better in the future (Chandram, 2015). Climate change means that the Earth's weather and

temperature patterns are changing over a long period of time. These changes can occur naturally or as a result of human activities (UN, 1993; UNDP, 2023b). It encompasses the changes in the Earth's climate caused by human influence, affecting the atmosphere all around the world. These changes are distinct from natural climate changes occurring over comparable time periods (UN, 1992).

The global surface temperature has risen considerably since the late 1800s, and the increase over land has been greater compared to the oceans. In the first two decades of the 2000s, the temperature was nearly 1 degree Celsius higher than the average temperature in the 19th century. This rise in temperature is primarily caused by human activities, specifically the emission of greenhouse gases. Global warming will intensify until 2040, primarily due to rising CO_2 emissions, making it highly probable to surpass the 1.5-degree Celsius threshold, even with low greenhouse gas emission scenarios (IPCC, 2023). The impacts of climate change, particularly caused by global warming, are increasingly evident. It is expected that the adverse consequences of climate change will become more pronounced in the future (Shahvari *et al.*, 2019).

The global effects of climate change vary across different regions, but developing countries tend to experience more pronounced and severe impacts (Rahman & Lateh, 2017). This is attributed to various factors, including limited awareness and understanding of effective mitigation measures, inadequate institutional capabilities, constrained resource and their inefficient utilization, as well as socioeconomic conditions (Ullah *et al.*, 2019). According to IPCC, from 1895 to 1995, the temperature increased by approximately 0.4 degrees Celsius. This rise in temperature has resulted in the occurrence of extreme weather events, including heat waves, as well as an increase in both daytime and nighttime temperatures (Meehl & Tebaldi, 2004; Rauf *et al.*, 2017).

Pakistan is expected to face significant impacts from climate change, including the depletion of its hydrological reserves, accelerated melting of glaciers, and an increased frequency of floods and droughts (Chaudhry *et al.*, 2009). Global warming trends have been on the rise over the past five decades, posing a grave concern for all nations worldwide, including Pakistan. According to a report by the Asian Development Bank, Pakistan is projected to experience a significant increase in annual average temperatures by the end of the 21st century, ranging from 3 to 5 degrees Celsius. These projections are not only alarming for the future but also for the present time. In response to these challenges, the National Climate Change Policy of 2012 recommended the option of climate-resilient development strategies in Pakistan, focusing on integrating climate change considerations into socially and economically vulnerable sectors of the country. Additionally, approximately six percent of Pakistan's from 2010 to 2014 was allocated to climate change-related expenditures (Chaudhry, 2017; Zhongming *et al.*, 2017). The population of Pakistan is rapidly increasing, which has a negative impact on the climate. As the population grows, it leads to deforestation and the degradation of the environment. This, in turn, results in air pollution and an increase in surface temperature in urban areas of Pakistan. Pakistan is currently working on developing a National Adaptation Plan to address climate change (GOP, 2023).

Research Problem

The world is facing complex challenges, and Pakistan is no exception. The urgent need to comprehend the effects of a swiftly expanding population and escalating climate change on human development in the country is the focus of this research. The current research aims to address the following problem:
How do population growth and climate change interact and affect human development in Pakistan?

Review of Literature

Relationship between Human Development and Population Growth

Güney (2017) discovered that in developing countries, a high rate of population growth has a detrimental effect on sustainable development. However, in developed countries, it was found to have a beneficial impact on sustainable development. Herrero *et al.* (2019) revealed that countries with advanced development have a HDI and low rate of population growth. On the other hand, developing countries exhibit a moderate HDI and a high rate of population growth. The findings suggest a negative association between population growth and the HDI. Pradana (2019) discovered a positive correlation between population density and the HDI.

Adeosun & Popogbe (2020) found that population growth has a negative impact on human resource utilization. The authors suggested that the government should control population growth and prioritize the quality of education to promote human development. Sheykhi (2021) emphasized the importance of effective population control measures for achieving sustainable development, with a particular concern for Africa's high population growth rate. Amin (2022) found a negative association between HDI and population growth and a positive association between HDI and literacy rate.

Relationship between Human Development and Climate Change

Maccari (2014) found a negative relationship between human development and environmental temperature, emphasizing the need to control environmental depletion for human well-being. Chandram (2015) revealed the negative impact of climate change on human development in India. Lai & Chen (2020) identified a significant positive association between environmental performance and human development. Hossain & Chen (2021) revealed that climate change exerted a detrimental effect on human development. Arab *et al.* (2022) found a positive relationship between human development and environmental sustainability. Opoku *et al.* (2022) revealed that an increase in human development had a positive impact on environmental sustainability, evidenced by a reduction in CO_2 emissions, temperature, and air pollution. Adhikari *et al.* (2023) found a statistically significant long-term negative relationship between human capital and climate change, implying that an increase in human capital leads to a decrease in climate change. The study suggests that greater investment in education is necessary to effectively address climate change in the long run.

Materials and Methods

Data and Data Sources

Time series data were used from 1990 to 2020. The time series data were collected from different secondary sources, including the World Development Indicators (World Bank), the Economic Survey of Pakistan, the Pakistan Bureau of Statistics, and the Food and Agriculture Organization of the United Nations (FAO UN).

Variables

The variables in this study encompassed key dimensions of Human Development, Population Growth Rate, and Climate Change. Human Development was assessed using the widely recognized HDI, which provided a comprehensive measure of human well-being. The HDI was calculated to measure variations in Human Development across the studied time period. To capture the dynamics of Climate Change, an essential proxy variable, namely the Annual Surface Temperature Change in Degree Celsius, was employed. This variable offered valuable insights into the evolving patterns and trends associated with Climate Change throughout the analysis.

Definitions of Variables

These terms, namely human development, Human Development Index, population growth rate, climate change, and surface temperature change, are explained by the definitions discussed in the sections below.

Human Development (HD)

The concept of human development, also known as the human development approach, aims to enhance the quality of human existence, as opposed to solely prioritizing economic prosperity within a given society. Its focus lies on the well-being and capabilities of individuals, emphasizing their potential and freedom to make choices (Ul Haq, 1995; Stewart, 2013; UNDP, 2015; UNDP, 2020).

Human Development Index (HDI)

The HDI represents a concise evaluation of the overall progress in fundamental aspects of human development, encompassing longevity, education, and living standards. It is computed as the geometric mean of normalized indices pertaining to each of these three dimensions (UNDP, 2022a; UNDP, 2022b; UNDP, 2023a).

Life expectancy at birth serves as the indicator for assessing the dimension of health, while the dimension of education is measured by considering the average number of schooling years among adults aged 25 and above, as well as the expected duration of education for children at the age of entering school. Gross national income per capita is utilized as the measure for evaluating the standard of living dimension (UNDP, 2022a; UNDP, 2022b; UNDP, 2023a).

Population Growth Rate (PGR)

It refers to the average rate at which the population of a specific country changes during a specific time period (UNDESA, 2004; PAHO, 2015; WHO, 2023).

According to the WHO formula of PGR and Annual change in the Population size

$$\text{PGR} = \frac{\text{Annual change in the population size}}{\text{Total population for that year}} \times 100$$

Annual Change in the Population size =(Births - Deaths) + (Immigrants - Emigrants)

Annual Change in the Population size = (Births + Immigrants) - (Deaths + Emigrants)

Source: PAHO, (2015); WHO, (2023)

The term "population" encompasses individuals, family members, citizens, and a collective quantity of people residing in a specific area (Damanik *et al.*, 2021).

Climate Change (CC)

Climate represents the average weather conditions, including temperature, humidity, and rainfall patterns at a regional or global level. At the same time, weather can change rapidly in the short term. Climate change refers to enduring alterations in average weather patterns that persist for many decades or longer. These prolonged shifts differentiate climate change from natural variations in weather (World Bank, 2021).

Climate change means that the Earth's weather and temperature patterns are changing over a long period of time. These changes can occur naturally or as a result of human activities (UN, 1993; UNDP, 2023b). It encompasses the changes in the Earth's climate caused by human influence, affecting the atmosphere all around the world. These changes are distinct from natural climate changes occurring over comparable time periods (UN, 1992).

Surface Temperature Change (STC)

It represents the average surface temperature over a long-term period (FAO, 2022; IMF, 2022). The average surface temperature comprises both land air temperature and sea surface temperature. It serves as a measure of global or regional climate variability. The change in surface temperature is determined by comparing the average temperature for a specific year with the long-term average for the baseline period (NOAA, 2022; IPCC, 2022).

Descriptive Statistics

In the initial phase, descriptive statistics analysis was used to analyze the characteristics and nature of the data. Descriptive statistics provide a snapshot of the sample under study without drawing any inferences based on probability. They are used in the initial phase of data analysis to understand the characteristics and nature of the data.

Unit Root Test

In the second phase of analysis, a unit root test was employed to test the stationarity of a series. A unit root test is used to determine if a series has a unit root. The unit root test used in this study was the Agumented Dickey-Fuller (ADF) test method.

Autoregressive Distributed Lag Model (ARDL Model)

The third phase of analysis employed the ARDL model to obtain the outcomes of the study. The ARDL model was used to describe the relationship among variables in the long run and short run. The description and overview of the model are discussed below.

In the case where variables of interest exhibit a combination of different orders of integration. The Autoregressive Distributed Lag model is a model based on ordinary least squares (OLS) that can be applied to analyze both non-stationary time series and time series with mixed orders of integration. In general to specific modeling framework, this model includes an appropriate number of lags to effectively capture the data-generating process (Pesaran & Shin, 1995; Pesaran & Pesaran, 1997).

This model is based on two components that correspond to the short-run and long-run dynamics of the model. To show the ARDL modeling approach, one may consider the following simple model.

Equation (3.1)

$$HD_t = \gamma + \delta PGR_t + \varepsilon CC + e_t$$

Equation (3.2)

$$\Delta HD_t = \gamma_0 + \sum_{i=1}^{p} \delta_i \Delta HD_{t-i} + \sum_{i=1}^{p} \varepsilon_i \Delta PGR_{t-i} + \sum_{i=1}^{p} \theta_i \Delta CC_{t-i} + \pi_1 HD_{t-1} + \pi_2 PGR_{t-1} + \pi_3 CC_{t-1} + \mu_t$$

The equation is divided into two parts, with δ, ε, and θ showing the short-run dynamics of the model. The second part with π_s shows a long-run relationship. The H_0: $\pi_1 + \pi_2 + \pi_3 = 0$, which means the absence of a long-run relationship.

Bounds Test for Cointegration

In the fourth stage of analysis, the Bounds test for cointegration was employed after the ARDL model. This test confirms whether variables are cointegrated in the long run. The initial step in the ARDL bounds testing approach involves estimating an equation to examine the presence of a long-term association among the variables through an F-test.

Statistical Model

The study aims to analyze the impacts of population growth and climate change on human development in Pakistan. To achieve the objective, the statistical regression model is developed in this section, and the subsequent section discusses the results obtained from this model.

$$HD_t = \alpha + \beta PGR_t + \gamma CC_t + \mu_t$$

HD represents human development, PGR represents population growth rate, and CC refers to climate change. The model examines how population growth and climate change affect human development in Pakistan.

The subscript "t" represents time for each variable. In the model β, and γ are coefficients, α represents the constant term, and μ_t is the error term.

Results and Discussion

Descriptive Statistics

Table 1

Descriptive Statistics

Statistics/ Variables	Human Development	Population Growth	Climate Change
Mean	0.481194	2.414081	0.577452
Median	0.486000	2.296422	0.576000
Maximum	0.557000	2.955562	1.423000
Minimum	0.402000	1.978320	-0.375000
Standard Deviation	0.049934	0.321389	0.488964
Observations	31	31	31

Source: Authors own estimations using EViews

Table 1 examined three variables: Human development, Population growth, and climate change. The descriptive statistics were computed to summarise the data for these variables. For the Human Development variable, the mean value was 0.481194, indicating an average level of human development. The median value of 0.486 suggests that the majority of observations are concentrated at this value. The minimum value of 0.402 and maximum value of 0.557 indicate the range of human development levels observed in the data. The standard deviation of 0.049934 suggests that the data points are relatively close to the mean, indicating a low amount of variability. Regarding the Population Growth variable, the mean value was 2.414081 percent, representing an average population growth rate. The median value of 2.296422 percent indicates that the middle value in the dataset is slightly lower than the mean, suggesting a slightly skewed distribution. The range of population growth rates observed ranged from a minimum of 1.9783 percent to a maximum of 2.9555 percent. The standard deviation of 0.32138 proposes a moderate amount of variability in the data points. For Climate change, the mean value was 0.5774 degrees Celsius, indicating an average level of climate change. The median value of 0.5760 degrees Celsius recommends that the majority of observations cluster around this value. The minimum value of negative 0.3750 degrees Celsius and maximum value of 1.4230 degrees Celsius indicate the range of climate change values observed in the data. The standard deviation of 0.488964 degrees Celsius recommends a moderate amount of variability in the data points. The analysis was based on 31 observations for all these variables.

Results of Unit Root Test (ADF)

Table 2

Unit Root Test (ADF)

Include in the test equation	Intercept			Trend and Intercept			None			Decision
Variables/ Statistics	t-statistic	Critical Value	Prob.	t-statistic	Critical Value	Prob.	t-statistic	Critical Value	Prob.	Data Stationarity
Human Development	-10.1822	-2.9718	0.0000	-6.5078	-3.5875	0.0001	-10.3350	-1.9533	0.0000	Second Difference
Population Growth	-6.5498	-2.9810	0.0000	-6.5544	-3.5950	0.0001	-6.5283	-1.9544	0.0000	Second Difference
Climate Change	-7.1903	-2.9677	0.0000	-7.1285	-3.5742	0.0000	-7.3075	-1.9529	0.0000	First Difference

Source: Authors own estimations using EViews

The results of the unit root test, specifically the Augmented Dickey-Fuller (ADF) test, as shown in Table 2, indicate the stationarity of the data. A variable is considered stationary if $|t_c| > |t_t|$ or $-t_c < -t_t$, with a p-value < 0.05. The t-statistics for Human Development are -10.1822, -6.5078, and -10.3350 for the three different specifications (intercept, trend, and intercept, none) in the test equation. In each case, the t-statistic is considerably larger in absolute value than the corresponding critical values (-2.9718, -3.5875, -1.9533) at the 5 percent significance level. Additionally, the p-values for all specifications are very close to zero (0.0000, 0.0001, 0.000). The decision for all specifications is to reject the null hypothesis of a unit root (non-stationarity) in favor of the alternative hypothesis of stationarity. Therefore, it may be concluded that the variable of human development is stationary at the second difference. For the variable of Population Growth, the t-statistics are -6.5498, -6.5544, and -6.5283, which are substantially larger in absolute value than the corresponding critical values (-2.9810, -3.5950, -1.9554). The p-values for all specifications are also close to zero (0.0000, 0.0001, 0.0000). The null hypothesis of a unit root is rejected for all specifications, indicating that Population Growth is stationary at the second difference. Regarding the variable of Climate Change, the t-statistics are -7.1903, -7.1285, and -7.3075, which are significantly larger in absolute value than the corresponding critical values (-2.9677, -3.5742, -1.9529). The p-values for all specifications are close to zero (0.0000, 0.0000, 0.0000). The decision is to reject the null hypothesis of a unit root of all specifications, indicating that Climate Change is stationary at first difference. In summary, based on the ADF test results, it may be concluded that all three variables (Human Development, Population Growth, and Climate Change) exhibit stationarity. The stationarity transformations required are indicated in the "Data Stationarity" column (the second difference for Human Development and Population Growth and the first difference for Climate Change).

Results of the ARDL Model

Table 3

Results of the ARDL Model

Dependent Variable: HD	Dynamic Regressors: PGR and CC		Fixed Regressors: C	
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
HD $_{(-1)}$	0.915721	0.031571	29.00515	0.0000
PGR	-0.013843	0.005690	-2.432796	0.0232
CC	-0.000898	0.001182	-0.759555	0.0455
CC $_{(-1)}$	0.001799	0.001242	1.447757	0.1612
CC $_{(-2)}$	-0.002043	0.001315	-1.553726	0.1339
C	0.079325	0.028195	2.813443	0.0099

Source: Authors own estimations using EViews

Estimated Equation of the ARDL Model

$$HD = 0.915721\ HD_{(-1)} - 0.013843\ PGR - 0.000898\ CC + 0.00179\ CC_{(-1)} - 0.002043\ CC_{(-2)} + 0.079325$$

Table 3 shows the ARDL regression model, with human development (HD) as the dependent variable and population growth rate (PGR) and climate change (CC) as the independent variables. The coefficients of the current and lagged values of the independent variables represent the short-term effects, while the coefficients of the long-term variables (PGR and CC) represent the long-term effects.

In the long-term, the coefficient of PGR is negative 0.013843, indicating that a one percent increase in population growth rate leads to a 0.013843 index, score decrease in human development, ceteris paribus. The coefficient is statistically at a 5 percent level, with a t-statistic of negative 2.432796 and a p-value of 0.0232. The coefficient of CC is negative 0.000898, implying that a one-degree Celsius increase in surface temperature is associated with a 0.000898 index score decrease in human development, controlling for other factors. The coefficient is marginally significant at a 5 percent level, as the t-statistic is negative 0.759555, and the p-value is 0.0455. The intercept term C represents the constant term in the model. The coefficient is 0.079325, suggesting that when all other variables are zero, the expected value of human development is 0.079325. The coefficient is statistically significant at a 5 percent level, with a t-statistic of 2.813443 and a p-value of 0.0099.

In the short term, the coefficient of lagged human development $HD_{(-1)}$ is 0.915721. This indicates that a one-index score increase in the previous period's human development is associated with a 0.915721 index score increase in the current human development, holding other variables constant. The coefficient is statistically significant at a 5 percent level, as indicated by the t-statistic of 29.00515 and a p-value close to zero. The coefficients of $CC_{(-1)}$ and $CC_{(-2)}$ are 0.001799 and negative 0.002043, respectively. These coefficients represent the effects of climate change in the previous two periods on human development in the current period. In the short run, a one-degree Celsius increase in surface temperature in the previous period is associated with a 0.001799 index score increase in human development, while a one-degree Celsius increase in surface temperature two periods ago is linked to a 0.002043 index score decrease in human development. However, neither of these coefficients is statistically significant at conventional levels, as the t-statistics are 1.447757 and negative 1.553726, and the corresponding p-values are 0.1612 and 0.1339.

The ARDL model results reveal that population growth and climate change have significant long-term effects on human development outcomes in Pakistan. A higher population growth rate and an increase in surface temperature are associated with lower levels of human development in the long run. In the short run, however, only past human development has a positive and significant impact on current human development. The short-term effects of climate change on human development are negative but not statistically significant.

The study's model results revealed that population growth had a negative impact on human development in Pakistan. This finding is consistent with many previous studies that have confirmed the negative relationship between population growth and human development. Tolba (1992) found that population growth adversely affected human development. Williamson & Fisk (2006) showed that

population growth had a negative impact on the education dimension of development, as the education level was negatively affected by the pressure from population growth. Chen & Lu (2012) conducted a panel data analysis of countries and concluded that population growth was negatively associated with human development indicators such as education, health, and living standards across the countries. Ochinyabo (2021) reported that rapid population growth negatively affected human development in Nigeria, leading to various problems for human beings, including issues in education and healthcare. Ngalande-Banda (2017) also confirmed the negative impact of population growth on various dimensions of human development, including education, health, and income in Sub-Saharan Africa. Chauhan & Mukherjee (2019) provided evidence of a negative relationship between population growth and human development in Asian countries.

The study's model revealed that climate change had a negative impact on human development in Pakistan. This finding is consistent with many previous studies that have confirmed the adverse effects of climate change on human development. Costello *et al.* (2009) found that climate change negatively affected human health, which is a dimension of human development. Maccari (2014) also indicated a negative relationship between human development and environmental temperature. Abdulkadir *et al.* (2017) investigated the effects of climate change on human existence in Nigeria and revealed that climate change directly affected human health, as rising temperatures had a detrimental impact. Çakar *et al.* (2021) examined the association between human capital and environmental degradation in European countries and found a negative relationship between them. Hossain & Chen (2021) showed that climate change had a negative impact on human development in Bangladesh. Kewalani & Saifudeen (2021) investigated the impact of climate change on life expectancy, using temperature as a measure of climate change and considering life expectancy as a dimension of the HDI. The results of their study indicated that climate change and warming had negative effects on life expectancy. In a more recent study, Hao (2022) revealed a negative relationship between HDI and climate change, suggesting that an increase in climate change led to a decrease in human development. All these results from previous studies support the findings of the present study.

Table 4

ARDL Model Summary

Statistic	Value
R-squared	0.998012
Adjusted R-squared	0.997579
Standard error of the regression	0.002319
Sum squared residual	0.000124
F-statistic	2308.950
Prob (F-statistic)	0.000000
Akaike information criterion (AIC)	-9.113295
Durbin Watson statistic	2.053295

Source: Authors own estimations using EViews

Table 4 presents the summary of the ARDL model, which aims to analyze the impact of population growth and climate change on human development. The R^2 value measures the proportion of variation in human development that can be explained by population growth and climate change. In this model, the R^2 value is 0.998012, indicating that population growth and climate change explain approximately 99.88 percent of the variation in human development. The adjusted R^2 value is 0.997579, suggesting that the model fits well with the data and does not suffer from overfitting. The standard error of the regression is 0.002319, indicating that the model has a relatively low-level error in predicting human development based on population growth rate and climate change. The sum squared residual is 0.000124, indicating a relatively small amount of unexplained variation in human development. The F-statistics is 2308.950, and the probability (p-value) is 0.0000, which is less than 0.05, indicating a highly significant relationship between population growth, climate change, and human development at a 95% confidence level. The AIC is negative 9.113295, indicating a relatively good fit of the ARDL for the given data. The Durbin-Watson statistic is 2.053295, which indicates that there is no substantial autocorrelation problem in the ARDL regression

model. Overall, the model suggests that population growth rate and climate change have a strong relationship with human development.

Table 5

ARDL Bounds Test Results

Null Hypothesis: No long-run relationships exist among HD, PGR, and CC		
Test Statistic	**Value**	**K**
F-statistic	10.28717	2
Significance	**Critical Value Bounds**	
	I0 Bound	**I1 Bound**
10 %	3.17	4.14
5 %	3.79	4.85
2.5 %	4.41	5.52
1 %	5.15	6.36

Source: Authors own estimations using EViews

Table 5 presents the results of the ARDL bounds test for the model, which examines the existence of a long-run relationship between human development, population growth, and climate change. The null hypothesis is that there is no cointegration among the variables. The F-statistic is 10.28717, which exceeds the upper critical values at all significance levels (10%, 5%, 2.5%, and 1%). Therefore, the null hypothesis is rejected, and it can be concluded that there is a cointegration relationship between human development, population growth, and climate change in Pakistan. This implies that population growth and climate change have a statistically significant long-run impact on human development in Pakistan.

Conclusion

The primary objective of this research is to examine how population growth and climate change affect human development in Pakistan. The results of the ARDL model indicate that both population growth and climate change play substantial roles in influencing human development outcomes in Pakistan. A higher rate of population growth and an increase in climate change are linked to a decrease in human development levels in the long term. Moreover, in the short term, an increase in past human development positively impacts current human development. Conversely, the effect of climate change on human development in the short term is negative but statistically insignificant.

Implications

1. The study highlights the negative impacts of rapid population growth and climate change on human development in Pakistan, indicating the need for urgent action to address these challenges.
2. It underscores the importance of sustainable human development and climate change mitigation efforts to safeguard the well-being and future of the population.

Recommendations

The following recommendations are made in light of present results:

1. Implement family planning programs and initiatives to manage population growth effectively and achieve a more balanced demographic structure.
2. Enhance investments in education at all levels, focusing on improving access to quality education for all segments of the population.
3. Promote education and awareness campaigns on climate change mitigation and adaptation to encourage sustainable practices among the population.
4. Integrate climate change considerations into national development policies and plans, ensuring a more resilient and adaptive approach to development.
5. Empower local communities to participate in the climate change adaptation and mitigation efforts.

6. Encourage research and innovations in areas related to sustainable development and climate change adaptation. This can lead to the development of context-specific solutions and strategies to address human development challenges in Pakistan.

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