# Effects of Climate Change Variables on Under-five Child Stunting in Bangladesh

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Master of Science in Applied Economics

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## Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing a degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate references.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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## Approval

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of Summer, 2023 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of M.Sc. in Applied Economics on _____, 2023.

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## Abstract

This research paper explores the impact of geospatial variables and sociodemographic factors on child stunting in Bangladesh, using data from the 2014 wave of BDHS (Bangladesh Demographic and Health Survey) and climate data from Bangladesh Meteorological Department (BMD) spanning 2009 to 2013. It was found that the average age of children under 5 in the sample is approximately 29 months (about 2 and a half years), with mean weights and heights slightly below the expected values. The climate data indicates that Bangladesh experiences mean maximum temperatures of over 34°C and mean minimum temperatures of around 21°C, with a relatively high average relative humidity of 79%. Rainfall averages 738.6 mm (about 2.42 ft) across divisions with low variability. Visual analysis shows that temperature has a limited impact on children's height, while higher relative humidity and rainfall are linked to height stunting. Regression analysis confirms these findings, revealing that increased relative humidity negatively affects the Height-for-Age Z-Score (HAZ) by nearly 2 percent, while rainfall has a minimal to no impact on HAZ. Male children have a 12 percent higher HAZ, and higher parental education and family wealth positively influence children's HAZ scores. These results contribute to our understanding of the factors influencing child stunting in Bangladesh and emphasize the importance of addressing both climate-related variables and sociodemographic factors to improve children's nutritional outcomes.

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## Introduction

In recent decades, there have been changes in the global climate due to natural forces and human activities resulting in environmental pollution, such as greenhouse gas emissions and changes in land-use patterns (IPCC, 2007). This has both directly and indirectly affected child health, especially in parts of the world that are more dependent on their agriculture, and places with a geographical proximity to the occurrence of natural disasters such as floods, cyclones, etc. The resources required to counter the impact of the damage caused by these natural phenomena put these highly vulnerable localities in an even worse position and thus impact child health further.

Climate change is expected to have a significant impact in developing countries like Bangladesh, by adversely affecting the agricultural sector, and eventually, food security, leading to a disproportionate effect on the welfare and incomes of the rural poor (Alam et al., 2018). Bangladesh mostly consists of low, flat lands, and hilly regions in the north and south-east sections of the country, with highlands in the north and north-west. Besides the current climate conditions of the world, what exposes Bangladesh more to a multitude of natural hazards such as floods, heat waves, droughts, cyclones, river-bank erosions, etc., is the fact that 70% of the country is less than one meter above the mean sea level, and floodplains occupy almost 80% of the country (MoEF, 2012).

Although under-five child stunting has globally decreased over the decades, courtesy of tremendous improvements in crop harvesting and preservation technology and countries moving from agriculture-based societies to industrialized and services-based ones, the decrease in Bangladesh has been to a lesser amount. Another matter of concern for Bangladesh is the fact that child stunting and overall child health may deteriorate in the coming decades due to increases in climate change resulting in phenomena such as increasing temperatures, soil erosion, untimely rainfall, natural floods, and other occurrences. These will place a disproportionately heavy burden on the lower-income, rural inhabitants of the nation. Child stunting is a serious issue as it may result in inadequate mental and physical development of a child into adulthood, and the more prevalent this becomes, the greater the concern for the nation overall.

This paper aims to analyze and evaluate the overall impact of climate change on the health of under-five children in Bangladesh by analyzing temperature, precipitation, controlling for other factors affecting the child health- such as healthcare quality and availability, population growth, etc., and socio-demographic factors such as age, family size, education, etc. The study assesses this relationship by examining data available from secondary sources consisting of observations from 2009 to 2014 and aims to identify how climate change is influencing child stunting in Bangladesh, and to what extent, by providing some empirical evidence to the matter and exploring the linkages of climate change with child health better.

## Relevant Literature

Most existing literature on the impact of climate change in Bangladesh have focused on the economic outcomes of the country thus far. Very few studies have explored the effects of climate change on child health and there have been several papers discussing the need to quantitatively analyze the effects of climate change on child health more effectively. Therefore, this study aims to provide a better insight into the impact of climate change on under-five child stunting in Bangladesh by studying the relevant data from a selected cluster of regions from all divisions.

A recent study by Helldén et al. (2021) provided a review of the existing literature on climate change and child health. They found that most of the recent studies were based on upper-middle to high income countries, and that the current inequalities existing in countries, and between one another, greatly influences how climate change affects children. Underprivileged children suffer from a far higher and more unfair health burden from climate change. In addition, there are varying levels of impact of climate change in urban and rural regions within a country. This could be due to the different social or economic factors, such as varying environmental conditions, health care accessibility, etc., making it challenging for most of these studies to decipher the magnitude of health impact climate change has.

Although there exists several extensive strategies, programs and initiatives in Bangladesh to improve the nutrition status of mothers and infants, growth stunting continues to be a matter of major concern since the country is largely affected by the increasing challenges caused by changing climate conditions. Using primary cross-sectional data from the Bangladesh Demographic and Health Surveys (BDHS), Khan et al. (2022) analyzed the relationship between child stunting and environmental characteristics at the community level across the nation. Their study identified that there is a nonlinear correlation between rainfall and child stunting, as well as with distance to water bodies and vegetation index. It was found that temperature is inversely related to stunting, whereas distance to water bodies had a positive correlation with it. In conclusion, the authors suggested that better initiatives and interventions need to be implemented for Bangladesh to be able to mitigate the negative impacts of climate change, along with conducting further research to explain the association between child stunting and environmental factors affecting it.

A two-country analysis of the effect of climate change on child nutrition status by Cooper et al. (2019) suggested that climate change causes huge impacts on food security and nutrition value especially in the rural regions in developing countries which depend heavily on agricultural prosperity. However, it is important to examine further the length and intensity of the climate change shocks, such as temperature extremes and rainfall, and their effects on food security and

child nutrition. The authors, therefore, studied the effects of precipitation extremes on the nutrition value of food and the food security in Ghana and Bangladesh. Their results suggested that there is a correlation between rainfall extremes and lack of food security and high malnutrition in both Ghana and Bangladesh.

Another paper by Cooper et al., 2019 explores the relationship between droughts and child stunting in a global context. Their study incorporated approximately 600,000 observations of children from 53 countries in order to determine how precipitation extremes have been affecting nutrition levels since 1990. The authors found that rainfall extremes, especially drought, is correlated with child malnutrition. Their estimated model relies on the historical data of drought, nutrition outcomes, geographical location and other socio-economic factors to examine whether growth stunting in children would increase in times of drought under present conditions. The authors also discuss the areas that are the most affected by drought and identify the factors and necessary steps that could eventually contribute to improved food security based on their study, which may help policy makers in creating development plans for mitigating negative climate change impacts.

A paper by Thiede & Strube (2020) highlighting the Sub-Saharan African context on this issue suggested that children residing in warmer climate regions are more likely to suffer from malnutrition and other similar health conditions. The results of this study suggested that a rise in the global average temperature of 2 or 3 degrees Celsius may result in disproportionately large increases of 3 to 5 degrees Celsius in these parts of the world. Therefore, governments, donor agencies, and international and national development bodies must promote and invest in more programs to alleviate the negative impacts of climate change.

## Methodology

### 3.1 Data Description

This paper conducts its empirical analysis based on secondary data sources of annual climate variability observations procured for the years 2009 to 2013, from the World Bank online database (World Development Indicators), Bangladesh Meteorological Department (BMD) and Bangladesh Demographic and Health Survey wave of 2014. To examine the effects of climate change on under-five child stunting in Bangladesh, this paper analyzes the following variables: height-for-age Z-score, temperature, rainfall, relative humidity, and other socio-demographic variables, with both qualitative and quantitative analysis being employed.

The World Health Organization (WHO) recommends using the international reference standard, set by the National Center for Health Statistics (NCHS) developed in the United States of America, to compare with the height and weight data for under-five children in order to assess their nutrition levels.

Height-for-age z-scores (HAZ) represent stunting status by comparing it with the NCHS reference standard- a score which is about 2 standard deviations below the mean will refer to "moderate child stunting" and a score higher than 3 standard deviations less than the mean will refer to "severe child stunting". The word "stunting" here refers to a condition where children, given their age, are unable to realize their adequate height. In many cases, growth stunting can be an indicator of past growth failure in children as it is associated with chronic malnutrition and frequent illness, and is highly affected by other external factors, such as family income, education, geographical location, etc. (WHO, 2015)

### 3.2 Descriptive Statistics

In the beginning of this study, it was the intention of the author to include data from multiple waves of the BDHS along with the few main explanatory climate variables of the corresponding period. However, due to the unavailability of region-wise (division) data for temperature, relative humidity, and rainfall 2014 onwards, and the lack of time for collecting the primary data, the paper only looks at the effect of the independent variable on the dependent variable using BDHS 2014 and climate change data from 2009 to 2013.

Based on the sample of around 7,000 observations used in this study, the average age in months for the children (under 5 years) of the respondents of the BDHS 2014 survey is approximately 29

months as shown in Table 1. The mean weight of the infants is about 10.5 kg which is slightly lower than the expected weight for the age group. According to Davis and Wheeler (1989), the mean weight of Bangladeshi-origin infants is expected to be 10.6 kg for males and 10.1 kg for females at 18 months. The mean height of the respondents' infants is approximately 83cm, or 2 feet 8 inches.

***Table 1. Summary Statistics of the Sociodemographic Variables***

| Variable | Observations | Mean | Std. dev. | Min. | Max. |
|---|---|---|---|---|---|
| Child's age (months) | 7,131 | 29.440 | 17.099 | 0 | 59 |
| Weight (kg) | 7,131 | 10.451 | 3.110 | 1.9 | 37.4 |
| Height (cm) | 7,131 | 82.881 | 13.496 | 42.2 | 140 |

It is important to note that, based on the BDHS survey statistics, the minimum weight of a child under 5 is 1.9 kg, which is significantly less than the WHO standard weight for a child at birth-ranging from 2.8 kg to 3.2 kg for both male and female infants, with the females being on the lower end of the range (de Onis, 2009).

***Table 2. Summary Statistics of the Geospatial Variables***

| Variable | Observations | Mean | Std. dev. | Min. | Max. |
|---|---|---|---|---|---|
| Max. Temperature (degree Celsius) | 35 | 34.221 | 0.499 | 33.407 | 35.129 |
| Min. Temperature (degree Celsius) | 35 | 21.032 | 0.804 | 19.747 | 22.519 |
| Relative humidity (%) | 35 | 79.288 | 1.818 | 77.037 | 83.940 |
| Rainfall (mm) | 35 | 738.571 | 318.650 | 283.000 | 1688.000 |

The mean maximum temperature in Bangladesh across the seven divisions between 2009 to 2013 was a little over 34-degree Celsius, whereas the mean minimum temperature is about 21-degree

Celsius. The mean relative humidity across the divisions over the time-period considered for this study is approximately 79%.

The mean rainfall is 738.6 mm and has a relatively low standard deviation, indicating that it is usually quite humid in Bangladesh across all divisions throughout the year.

**Ordinary Least Square (OLS) Method for Regression**

The study conducts a random intercept logistic regression analysis among the variables- height-for-age Z-score, temperature, relative humidity, and rainfall, controlling for some socio-demographic factors, such as gender, rural/urban living, highest education level of child's parents, wealth in the family and which division of Bangladesh the respondent's family lives in.

The regression model specification is as follows:

$$Y=\alpha+\beta_1 (X_1) +\beta_2 (X_2) +\beta_3 (X_3) +\beta_4 (X_4) + \varepsilon$$

where, $Y$= Height-for-Age Z-Score, $X_1$=temperature, $X_2$= relative humidity, $X_3$= rainfall, $X_4$= socio-demographic factors, $\beta$i= coefficient of independent/control variables respectively, $\alpha$= constant, and $\varepsilon$= error term.

### Random-Effects Generalized Least Square (GLS) Method for Regression

Following the OLS regression model, the study also conducts a generalized least-squares (GLS) regression on the same variables, which extends the ordinary least-squares (OLS) estimation of the regular linear model by including any potential unequal error variances and providing correlations between different errors.

## Results and Discussion

### Correlation Matrix

To account for multicollinearity, the paper tests for correlation between the independent variables- temperature, relative humidity and rainfall. As illustrated in Table 3, there is a strong correlation between minimum temperature and maximum temperature, which can be dealt with by either removing one of the problematic variables in the model, or by combining the correlated variables together into one.

However, since both severely high and low temperatures can possibly lead to growth stunting in children, neither of the variables were removed from the regression analysis. Moreover, considering only the minimum or the maximum temperature for regression did not result in any significant difference in the models from the final model that includes both the variables, as presented in Appendix A and Appendix B.

***Table 3. Correlation Matrix of Independent Variables***

| *Observations: 7131* | **Maximum Temperature** | **Minimum Temperature** | **Relative Humidity** | **Rainfall** |
|---|---|---|---|---|
| Maximum Temperature | 1.0000 | | | |
| Minimum Temperature | 0.8224 | 1.0000 | | |
| Relative Humidity | -0.0157 | 0.4785 | 1.0000 | |
| Rainfall | 0.3487 | 0.6387 | 0.6088 | 1.0000 |

Furthermore, combining the variables also resulted in no significant changes in the model, with the adjusted R-squared being relatively similar, as illustrated in Appendix C. Therefore, the study

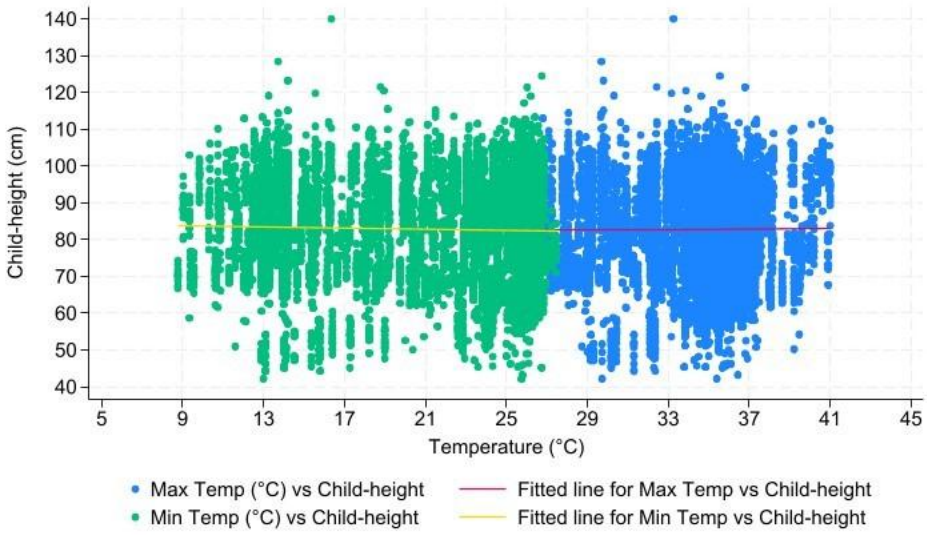
refrained from combining the two variables as well, to observe their impacts on the HAZ score individually.

**Regression Results**

Visual representations of the relationship between the geospatial variables and the children's height, as illustrated in figures A, B and C as follows, suggest that there is little to no impact of climate change in overall child stunting.

For instance, as illustrated in Figure A, the children's height is not directly correlated to changes in temperature across all divisions in Bangladesh overall.

***Figure A. Min. & Max. Temperature and Children's Height***




However, as demonstrated in figures B and C, increase in relative humidity and rainfall is likely to cause height stunting in children under 5 to some extent.

***Figure B. Relative Humidity and Children's Height***

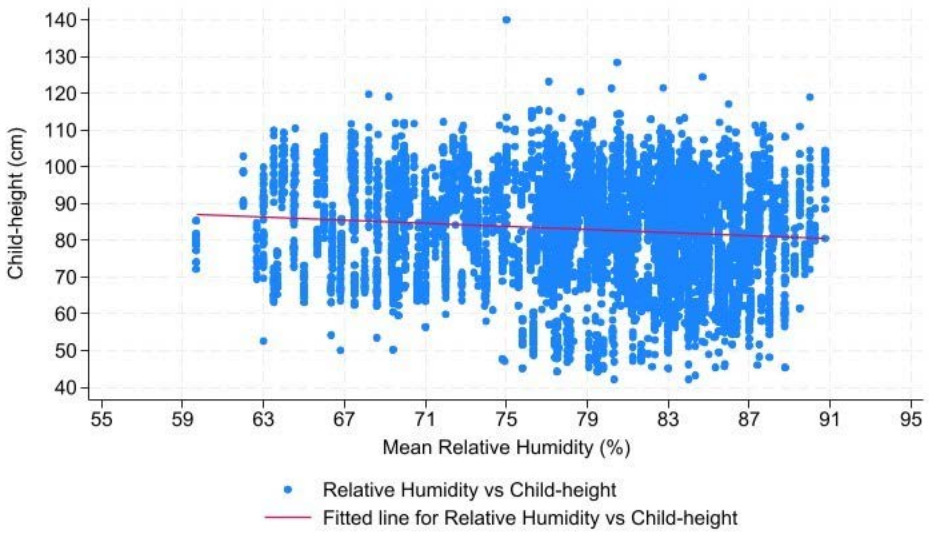



***Figure C. Rainfall and Children's Height***

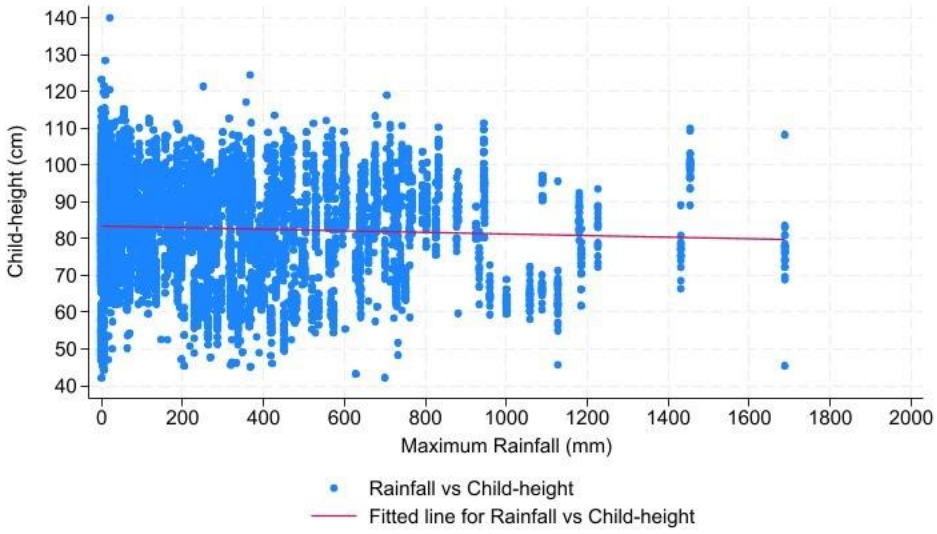



Table 4 represents the OLs estimation results, which indicate that among the geospatial variables only higher relative humidity is likely to HAZ score in children under 5 by almost 2 percent, at a statistically significant level of 0.01, which suggests that humidity negatively affects height stunting. In contrast, rainfall is likely to have a very little negative impact to no impact on the HAZ score in children under 5, at a statistically significant level of 0.01, suggesting that an increase in precipitation is likely to cause height stunting. This is similar to the findings in a study by McMahon & Gray (2021), which indicates that high precipitation levels result in lower nutritional status in crops and leads to a more difficult livelihood for areas that lack proper

sanitation.

***Table 4. OLS Regression: Effect of Climate Change on Child Stunting in Bangladesh***

Observations 7131
R-squared 0.0764

| Variables | (OLS) Height-for-Age Z-Score (HAZ) | Robust S.E. |
|---|---|---|
| Maximum Temperature (mean) | 0.0194 | 0.0144 |
| Minimum Temperature (mean) | -0.0094 | 0.0095 |
| Relative Humidity (mean) | 0.0147*** | 0.0042 |
| Rainfall (mean) | -0.0002*** | 0.0001 |
| Gender of Child (Male) | 0.1245*** | 0.0265 |
| Urban Living | 0.0103 | 0.0319 |
| Parents' Education | 0.1944*** | 0.0173 |
| Wealth | 0.1279*** | 0.0114 |

****p<0.01, **p<0.05, * p<0.1*

The results further indicate that if the child is male, the HAZ score increases by 12 percent, at a statistically significant level of 0.01, suggesting that child stunting is more prevalent among the female children than the male. This result contrasts with a study by Sultana et. al (2019), where the findings indicate that the female children under 5 are 11% less likely to have a stunted growth.

In addition, a one percent increase in the parents' level of education increases the HAZ score by over 19 percent, at a statistically significant level of 0.01. Therefore, it can be inferred that the higher the level of education attained by the child's parents the higher the Z-score for that child, indicating a possibility of a healthier lifestyle in the household. This finding is similar to the results of studies by Caputo et. al (2003) and Aerts et. al (2004), where the authors suggest that educated mothers are better equipped to utilize healthcare facilities for their children.

Finally, family income or wealth is also found to have a positive impact on the HAZ score of a child with a statistical significance level of 0.01. According to a study conducted by Talukder (2013), Bangladeshi children living in the poorer households had 38% higher chances of being malnourished in comparison to the children from the wealthier family.

Table 5 represents the random-effects GLS estimation results controlling for heteroskedasticity amongst the variables, which indicate that among the geospatial variables considered in the study, only rainfall had some impact on child stunting in Bangladesh between the years 2009 to 2013. Although at a statistically significant level of 0.01, average rainfall had a very little negative impact to no impact on the HAZ score in children under 5, suggesting that an increase

in precipitation could potentially lead to height stunting in Bangladeshi infants. This is similar to our findings from the OLS estimation conducted previously.

***Table 5. Random-Effects GLS Regression: Effect of Climate Change on Child Stunting in Bangladesh***

| **Variables** | **(RE GLS) Height-for-Age Z-Score (HAZ)** | **Robust S.E.** |
|---|---|---|
| Maximum Temperature (mean) | 0.005 | 0.0250 |
| Minimum Temperature (mean) | -0.0108 | 0.0170 |
| Relative Humidity (mean) | 0.0085 | 0.0066 |
| Rainfall (mean) | -0.0003*** | 0.0001 |
| Gender of Child (Male) | 0.1172*** | 0.0370 |
| Urban Living | 0.0009 | 0.0295 |
| Parents' Education | 0.1750*** | 0.0186 |
| Wealth | 0.1335*** | 0.0119 |
| Division | -0.0197** | 0.0083 |
| *Std. err. adjusted for 60 clusters in hw1* | | |
| Correlation (error, X) | | 0 |
| sigma_u | | 0.4132 |
| sigma_e | | 1.0478 |
| Intraclass Correlation rho (fraction of variance due to error) | | 0.1346 |
| | | |
| Total number of observations | | 7131 |
| Number of groups (by age in months) | | 60 |
| Observations per group | | 118.8 |
| | | |
| R-squared | | 0.0697 |
| Wald chi2(9) | | 489.06 |
| Prob > chi2 | | 0.0000 |

****p<0.01, **p<0.05, * p<0.1*

The results for the control variables are quite similar to the OLS estimations, where the gender of the child, parents' level of education and household wealth reduces height stunting in children under 5. For instance, the gender of the child continues to affect the HAZ score positively. Therefore, if the child is male, the HAZ score increases by almost 12 percent, at a statistically significant level of 0.01. Moreover, a one percent increase in the parents' level of education increases the HAZ score by over 17 percent, at a statistically significant level of 0.01, signifying

that the higher the level of education attained by the child's parents the better chance there is of the household incorporating better healthcare habits and behaviors. Furthermore, household wealth impacts the child's growth positively by over 13 percent, at a statistically significant level of 0.01.

It can further be deduced from table 4 that there is no correlation between the random effects entity errors and the regressors in the model. In addition, the table illustrates that about 13 percent of the variance in the results due to the errors in the model can be explained by the difference across the entities, which suggests that the error term is random. It is also important to note that the Wald Chi-square is statistically significant at 1 percent level, indicating that this model is a good fit for the study and an accurate representation of the relationship between height stunting, the climate change variables and the sociodemographic variables examined in this paper.

A further IV regression analysis would have checked the specificity of the variables in the model, placing relative humidity as the explanatory variable. However, as data on carbon emissions were not found for the areas that this research covers, it could not be conducted, and therefore, is one of the limitations of the paper.

## Conclusion

This study investigates the determinants of child stunting in Bangladesh, focusing on geospatial variables and sociodemographic factors. The findings suggest that while temperature has limited impact on child height, higher relative humidity is associated with a negative effect on Height-for-Age Z-Scores (HAZ), indicating an increased risk of height stunting. In contrast, rainfall has a minimal to no effect on HAZ. Male children exhibit a higher HAZ score, and parental education and family wealth positively influence children's nutritional status.

These results underscore the complex interplay of environmental and sociodemographic factors in child stunting and emphasize the need for multifaceted interventions to address this issue. Policymakers and public health practitioners should consider both climate-related variables and socioeconomic factors when designing strategies to improve child nutrition in Bangladesh. Additionally, further research is needed to explore the mechanisms through which these variables impact child growth and to develop targeted interventions to mitigate the negative effects of humidity on child stunting.

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## Appendix A: Effect of Climate Change on Child Stunting in Bangladesh (Minimum Temperature Only)

Observations 7131
R-squared 0.0761

| Variables | (OLS) Height-for-Age Z-Score (HAZ) | Robust S.E. |
|---|---|---|
| Minimum Temperature (mean) | 0.0025 | 0.0032 |
| Relative Humidity (mean) | 0.0103*** | 0.0025 |
| Rainfall (mean) | -0.0002*** | 0.0000 |
| Gender of Child (Male) | 0.1246*** | 0.0265 |
| Urban Living | 0.0105 | 0.0319 |
| Parents' Education | 0.1952*** | 0.0172 |
| Wealth | 0.1270*** | 0.0114 |

****p<0.01, **p<0.05, * p<0.1*

## Appendix B: Effect of Climate Change on Child Stunting in Bangladesh (Maximum Temperature Only)

Observations 7131
R-squared 0.0762

| Variables | (OLS) Height-for-Age Z-Score (HAZ) | Robust S.E. |
|---|---|---|
| Maximum Temperature (mean) | 0.0060 | 0.0049 |
| Relative Humidity (mean) | 0.0115*** | 0.0027 |
| Rainfall (mean) | -0.0002*** | 0.0001 |
| Gender of Child (Male) | 0.1244*** | 0.0265 |
| Urban Living | 0.0101 | 0.0319 |
| Parents' Education | 0.1948*** | 0.0173 |
| Wealth | 0.1274*** | 0.0114 |

****p<0.01, **p<0.05, * p<0.1*

## Appendix C: Effect of Climate Change on Child Stunting in Bangladesh (Mean Temperature)

Observations 7131
R-squared 0.0761

| Variables | (OLS) Height-for-Age Z-Score (HAZ) | Robust S.E. |
|---|---|---|
| Temperature (mean) | 0.0038 | 0.0040 |
| Relative Humidity (mean) | 0.0107*** | 0.0026 |
| Rainfall (mean) | -0.0002*** | 0.0001 |
| Gender of Child (Male) | 0.1245*** | 0.0265 |
| Urban Living | 0.0103 | 0.0319 |
| Parents' Education | 0.1951*** | 0.0173 |
| Wealth | 0.1272*** | 0.0114 |

****p<0.01, **p<0.05, * p<0.1*