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AN ANALYSIS OF THE IMPACTS OF TEMPERATURE ON DIARRHEAL DISEASE IN BANGLADESH

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ABSTRACT

This paper analyses the impacts of temperature on diarrheal disease in Bangladesh using district wise monthly average temperature and diarrhea (affected) data from Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review and World Food Programme (WFP) (1998-2010). Generalized Least Square (GLS) has been used as estimation method to see whether temperature has any impact on the number of diarrhea patients in Bangladesh. Result of the study has showed that temperature has significant impact on the magnitude of diarrheal patients in Bangladesh. This paper has also calculated the change in the number of diarrheal patients due to increase in average monthly temperature. It has been found that if average monthly temperature in Bangladesh increases by 1 degree Celsius then diarrhea patient increases by 5 percent. Using results of the study, precautions and steps can be taken to minimize diarrhea affected patients due to change in average monthly temperature.

Keywords: Temperature; Diarrheal Disease; Diarrhea; Bangladesh

JEL Classification: I1, Q50, Q54

List of Abbreviations

BBS: Bangladesh Bureau of Statistics

BLUE: Best Linear Unbiased Estimators

EDV: Emergency Department Visit

GLS: Generalized Least Square

UNICEF: United Nations Children's Fund

WFP: World Food Programme

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WHO: World Health Organization

1. INTRODUCTION

Diarrhea is one of the primary causes of morbidity and mortality on a global scale, with the major of deaths occurring in children under five years (Pruss-Ustun and Corvalan 2007). It is a big problem in developing countries (Zhao *et al.* 2012). Diarrhea has been linked to climate mediated changes for susceptible populations such as infants and the elderly who often have relatively poor immunity (Partz *et al.* 2005).

According to the United Nations Children's Fund (UNICEF) and World Health Organization (WHO) (2009), diarrhea is a common symptom of gastrointestinal infections caused by a wide range of pathogens including bacteria, viruses and protozoa. Rotavirus is the leading cause of acute diarrhea, and is responsible for about 40 percent of all hospital admissions due to diarrhea among children under five worldwide.

According to the WHO and UNICEF (2009), there are about two billion cases of diarrheal disease worldwide every year, and 1.9 million children younger than 5 years of age perish from diarrhea each year, mostly in developing countries. This amounts to 18% of all the deaths of children under the age of five and means that more than 5000 children are dying every day as a result of diarrheal diseases. Of all child deaths from diarrhea, 80% occur in the African and South-East Asian regions (UNICEF & WHO, 2009). Three quarters of global childhood diarrheal deaths occur within only 15 countries and Bangladesh is in 7th position with 50,800 annual childhood deaths (UNICEF & WHO, 2009).

The objective of the paper is to find out whether change in temperature has any impact on the number of diarrhea patents in Bangladesh. This paper will also attempt to find out the magnitude of increased number of diarrhea patients due to increase in average monthly temperature.

2. LITERATURE REVIEW

2.1 Literatures on the Impacts of Temperature on Diarrheal Disease

Diarrhea is very much related to sanitation, water, high population density, cleanliness and vector borne diseases in Bangladesh (Khan 2010). Extreme temperature and decayed food also causes high prevalence of diarrheal diseases especially among children under five in Bangladesh (Khan 2010).

According to Xu *et al.* (2014), both heat and cold are associated with increases in emergency department visits (EDVs) for childhood diarrhea, which may be partially explained by three reasons. First, high temperature may impact the food chain, from food preparation stage to

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production process and expose children to more contaminated food. Second, low temperature increases the replication and survival of virus, e.g. rotavirus. Third, extreme low and high temperatures may alter children's hygiene behavior such as water drinking behavior.

According to Bull (1980), sudden changes in weather conditions may affect either humoral or cellular immunity. Very young children have a relatively immature system (Gebra *et al.* 1996), and low self-care capacity (Xu *et al.* 2012), which might result in a greater vulnerability to temperature change. Studies have found that sudden changes in the temperature of inhaled air are associated with the release of inflammatory mediators by mast cells (Togias *et al.* 1985) which could also be related to higher diarrhea prevalence (Feng et al. 2007).

According to D'Souza *et al.* (2007), Rotavirus can remain viable outside the human body from several hours to several months, depending on the environment. The ideal environment for survival of rotavirus consists of low temperature (4- 20°C), low pH (~3), low humidity and protection from ultraviolet radiation. In feces, rotavirus is found to be stable at low and high relative humidity but not in the medium range of relative humidity. Rotavirus infectivity is lost more rapidly at 37°C than at 4°C or 20°C. Even at ambient temperatures above 30°C rotavirus particles stored in feces are stable and may infectious in vitro after 2-5 months of storage.

Seasonal pattern of rotavirus infections may be related to climatic factors. Cold and dry weather have been associated with a higher number of rotavirus gastroenteritis hospital admissions, suggesting weather related increases in exposure to rotavirus infection. Indoor relative humidity has also been speculated to be an important factor for young infants. Rotavirus infection has been reported to occur more in the dry season compared to the wet season in African countries like Morocco, Algeria, Egypt, Bangladesh, India and Costa Rica (D'Souza *et al.*2007).

2.2 Literatures on the Estimation Method

Teshima et al. (2004) performed statistical investigation for the effects of the climate on the epidemic diseases by using the time series of meteorological elements and the number of patients in Bangladesh. Their investigation found that the anomaly of the number of diarrhea patients had different signs for the periods before and after June which corresponds to the two peaks of the number of the patients. Higher maximum temperature and more sunshine in the pre-monsoon period are found to have a tendency to enhance the first peak of the diarrhea occurrence.

Chou et al. (2010) investigated and quantified the relationship between climate variations and diarrhea-associated morbidity in subtropical Taiwan by using a climate variation- guided poisson regression model. Their study results indicated that the maximum temperature and extreme rainfall days were strongly related to diarrhea-associated morbidity. They also found that the impact of maximum temperature on diarrhea-associated morbidity appeared primarily among

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children (0-14years) and older adults (40-64years) but had less of an effect on adults (15-39years).

Xu , Huang, Turner, Su, Qiao and Tang(2013) used a Poisson generalized linear regression model combined with a distributed lag non-linear model to examine the relationship between diurnal temperature range and emergency department admissions for diarrhea among children under five years in Brisbane. A statistically significant relationship between diurnal temperature range and childhood diarrhea was found in the study. They also found that the effect of diurnal temperature range on childhood diarrhea was the greatest at one day lag, with a 3% increase of emergency department admissions per 1°C increment of diurnal temperature range.

3. DATA AND METHODOLOGICAL ISSUES

3.1 Sources of Data

Based on the objectives of the study, district wise monthly average temperature and Diarrhea (affected) data from the year 1998 to 2010 have been used in the study. Data were secondary in nature and were collected from the reports of Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review and World Food Programme (WFP).

3.2 Analytical Technique

Generalized Least Square (GLS) method has been used in the research as the estimation method. According to Gujarati (2004), GLS method takes the criteria into account that observations which come from populations with greater variability are given less weight than those come from populations with smaller variability and therefore capable of producing estimators which are BLUE (Best Linear Unbiased Estimators).

In this research, a cubic equation has been developed to find out impacts of temperature on diarrheal disease in Bangladesh.

$$Y = C + \beta_1 T + \beta_2 T^2 + \beta_3 T^3 + \beta_4 D_1 T + \beta_5 D_2 T + \beta_6 \text{Trend} \qquad (1)$$

Where, Y is the dependent variable which denotes number of diarrhea patients. Independent variables are C which denotes constant term ; β_i are the regression coefficients to be estimated (i=1,2,…,6) ; T is temperature ; D_1 =1 if T <15, 0 otherwise ; D_2=1 if T>25, 0 otherwise and Trend (base 1998).

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4. RESULTS AND DISCUSSIONS

4.1 Analysis of Descriptive Statistics

Using district wise monthly average temperature and diarrhea (affected) data from 1998-2015, descriptive statistics on temperature and diarrhea patients are presented in Table 1 and 2 respectively.

It is observed that monthly average temperature is minimum in January (17.73 degree Celsius). After January temperature increases and reaches maximum in June (28.75 degree Celsius). After June temperature starts to decrease (Table 1 and Figure 1).

TABLE 1: DESCRIPTIVE STATISTICS OF TEMPERATURE FROM 1998 TO 2010

Month	Average temperature in Celsius	Standard deviation	Variance	Skewness	Kurtosis
January	**17.73**	0.87	0.77	-0.36	-0.47
February	21.44	1.05	1.10	0.32	0.77
March	25.48	1.01	1.02	-0.30	-0.33
April	28.21	0.81	0.65	0.37	-0.78
May	28.68	0.59	0.35	-0.27	-0.98
June	**28.75**	0.62	0.38	0.71	-0.55
July	28.47	0.32	0.10	0.63	-0.24
August	28.65	0.34	0.12	-0.04	-0.37
September	28.35	0.32	0.10	-0.78	-0.36
October	27.22	0.45	0.20	0.28	0.23
November	23.71	0.59	0.35	0.24	0.37
December	19.60	0.51	0.04	0.04	-1.52

Source: Author's calculation

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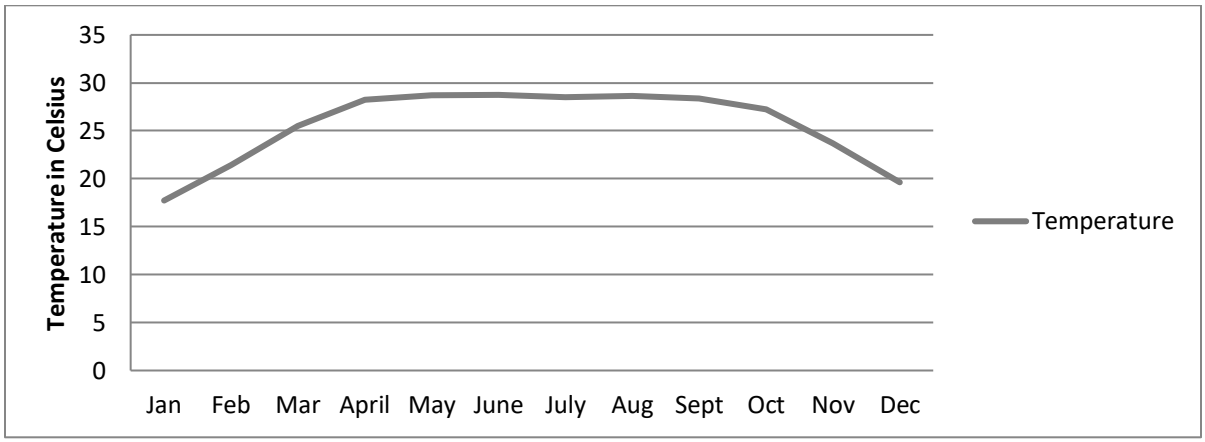
FIGURE 1: MONTHLY AVERAGE TEMPERATURE IN CELSIUS FROM 1998-2010



Source: Author's calculation

From Table 2, it has been observed that in the year 2002, 1.97 percent of total population got affected with diarrhea. Share of population got affected with diarrheal disease in 1998 and 2004 were 1.63 and 1.65 respectively. Between the years 1998 to 2010, share of population got affected with diarrhea was minimum in 2000 (1.20 percent).

TABLE 2: DESCRIPTIVE STATISTICS ON % OF POPULATION DIARRHEA AFFECTED 1998-2010

Year	% of Population Diarrhea Affected
1998	1.63
2000	**1.20**
2001	1.44
2002	**1.97**
2003	1.71
2004	1.65
2005	1.56
2006	1.40
2007	1.65
2008	1.60
2009	1.79
2010	1.64

Source: Bangladesh Economic Review (2014) and WFP

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4.2 Estimated Results

Breusch-Pagan-Godfey test is used for the detection of heteroskedasticity in the model. As the model has heteroskedasticity problem (Appendix), GLS technique has been used. Table 3 shows the estimated results obtained from GLS.

TABLE 3: ESTIMATED RESULTS USING GENERALIZED LEAST SQUARE METHOD (GLS)

Dependent Variable: Number of Diarrhea Affected Patients; Number of Observations: 1170; Number of Groups: 26; Observations Per Group: Min=31, Average=45,Max=47;
R^2: Within=0.0569, Between=0.0919, Overall= 0.0456;
$Wald\ Chi^2(6)$=40.32; prob > Chi^2=0.0000

	Co-efficient	Robust Std. Err	Z	p>|z|
T	37189.65*	8408.024	4.42	0.000
T^2	-1624.502*	363.3851	-4.47	0.000
T^3	22.68555*	5.06424	4.48	0.000
D_1T	268.249	176.0303	1.52	0.128
D_2T	158.3958*	40.20512	3.94	0.000
Trend	232.569*	66.94804	3.47	0.001
C	-268081.9*	62554.38	-4.29	0.000

Note: * Significant at 1% confidence interval; Significant at 5% confidence interval; * Significant at 10% confidence interval**

From Equation (1) and the estimates of the regression model, the following equation is obtained.

$$Y = -268081.9 + 37189.65T - 1624.502T^2 + 22.68555T^3 + 268.249D_1T + 158.3958D_2T + 232.569\,Trend$$ …….. (2)

From the equation (2), it is observed that except D_1T , remaining variables (T, T^2, T^3, D_2T, Trend and C) are significant at 5% confidence interval. By using the estimated results, increased number of diarrhea patients due to increase in temperature is being calculated which is shown in Table 4 and Figure 2.

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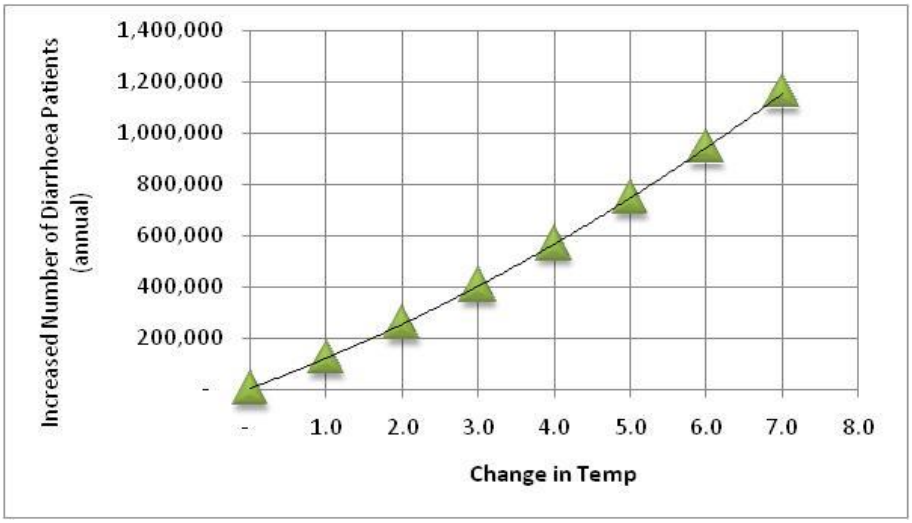
TABLE 4: INCREASED NUMBER OF DIARRHEA PATIENTS DUE TO INCREASE IN TEMPERATURE

Change in Temperature	Increased number of Diarrhea patients (annual)	Percentage rise of Diarrhea Patients
1.0	122,413	5%
2.0	256,471	11%
3.0	403,809	17%
4.0	566,060	23%
5.0	744,858	31%
6.0	941,993	39%
7.0	1,158,782	48%

FIGURE 2: INCREASED NUMBER OF DIARRHEA PATIENTS DUE TO INCREASE IN TEMPERATURE



From the table it is observed that if average monthly temperature increases by 1 degree Celsius then diarrhea patient increases by 5 percent. For 2, 3, 4, 5, 6 and 7 degree Celsius increase in average monthly temperature, diarrhea patient increase by 11, 17, 23, 31, 39 and 48 percent respectively.

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CONCLUSION

This paper analyzed the impact of temperature on diarrheal disease in Bangladesh using data from Bangladesh Bureau of Statistics (BBS) and World Food Programme (WFP) (1998-2010). Generalized Least Square (GLS) is used as estimation method to see the impact of temperature on the number of diarrhea patients in Bangladesh. This paper also found the increased number of diarrhea patients due to change in average monthly temperature. Results of the paper show that if average monthly temperature increases by 1 degree Celsius then diarrhea patient increases by 5 percent. For 2, 3, 4, 5, 6 and 7 degree Celsius increase in average monthly temperature, diarrhea patient increase by 11, 17, 23, 31, 39 and 48 percent respectively. Thus, it is important for the people and the policy makers to be aware of the adverse impact of temperature on diarrheal disease. More research, targeted health policies and programs are needed to carry out to minimize risks due to increased temperature.

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Appendix

Breusch-Pagan / Cook- Weisberg Test for Heteroskedasticity

H0: Constant Variance
Variables: T T2 T3 D1T D2t trend
Chi2(6)= 314.98
Prob > chi2 = 0.0000

