Climate change and Bangladesh fisheries and aquaculture: Evidences from the household income and expenditure survey (HIES)2010 data

Azad, Abul Kalam and Wadood, Syed Naimul

Lecturer, Department of Economics, University of Dhaka, Associate Professor, Department of Economics, University of Dhaka

1 July 2017

Climate Change and Bangladesh Fisheries and Aquaculture: Evidences from the Household Income and Expenditure Survey (HIES) 2010 Data

Abul Kalam Azad
Syed Naimul Wadood

Abstract *This paper estimates the impact of climate change on the fisheries and aquaculture sector of Bangladesh by employing appropriate econometric models. The Household Income and Expenditure Survey 2010 (HIES, 2010) data have been used to estimate the Ordinary Least Square (OLS) regressions for examining the impact. Since "climate change" is a long run phenomenon, its impacts may not be discernable in the short run, cross sections data. Our econometric results find some negative impacts of climate change on the household fisheries production, though estimated coefficients are not statistically significant. Climate change therefore does not have any impact on the fisheries and aquaculture sector at the household level at least in the short run. Within HIES 2010 data, regarding geographical locations, respondent households associated with fisheries from Dhaka and Rangpur divisions (and also to a lesser extent, Khulna) have been found to be disproportionately more vulnerable to climate change-related shocks as well as having lower yearly mean household incomes, compared to their counterparts in other divisions.*

Key Words Fisheries, Aquaculture, OLS, HIES, Climate Change, Bangladesh

Introduction

Fish is an important part of food items worldwide. Fish meets protein requirements of a large section of a total of 7.35 billion people of the world (World Bank, 2015). Since Bangladesh is blessed with hundreds of rivers, canals and wetlands across the country, fish has always been found aplenty and been always a popular food item here. Due to their strong preferences for fish,

---

Abul Kalam Azad, Lecturer, Department of Economics, University of Dhaka.
Syed Naimul Wadood, *PhD*, Associate Professor, Department of Economics, University of Dhaka.
[This study has been funded by the Bureau of Economic Research, University of Dhaka. The authors acknowledge and thank the Bureau of Economic Research for the research fund]

the people of Bangladesh are known as being associated with a famous wise saying "*Maach-e Bhaat-e Bangali*" indicating Bangali nation's reliance on fish items traditionally (this means, *fish and rice are two major components of a Bangali's identity*). Around 10 per cent of the Bangladeshi population are involved in fishing activities and earn their livelihoods from this sector (Department of Fisheries, 2010). The contribution of the fisheries sector to the total export earnings, value of the total agricultural products and the national GDP of Bangladesh is around 2 percent, 23.78 per cent and 3.65 per cent respectively (Ministry of Finance, 2016).

Inland capture, *inland culture* (*aquaculture*) and *marine fisheries* are the three categories of the fisheries and aquaculture sector. This sector plays an important role in Bangladesh with respect to meeting protein requirements. Bangladesh has been able to meet demand increases of fisheries caused by population and income increases, by increasing its domestic fisheries and aquaculture production. In 2005, the per capita fish consumption was 14 kilograms/year relative to a recommended minimum requirement of 18 kilograms/year making a deficit in terms of per capita fish consumption (FAO, 2011). By 2011, this per capita fish consumption reached to 19.7 kilograms/year marking a large increase in fisheries and aquaculture production (op. cit.).

With regards to the issue of *climate change*, we can mention that, *variation of statistical distribution of weather over a long period of time can be called "climate change"*. Since climate change is a very long term phenomena, the time period can range from decades to millions of years. An alternative definition of *climate change* is *the variation of average weather conditions or the time variation of climate events around long-run average conditions*. Climate change can be an event in a specific region or it can be a worldwide event (see Yazdi and Shakouri, 2010).

Yazdi and Shakouri (2010) also mentions that variations in solar radiation, deviations in the earth's orbit, mountain-building and continental drift, and changes in greenhouse gas concentrations are the factors responsible for climate change.

The *climate change* has become a major global concern in recent times. According to a report of the Intergovernmental Panel on Climate Change (IPCC, 2014), anthropogenic greenhouse gas emissions have increased ever since the pre-industrial era only in very recent times, and this has been caused by economic and population growth, and are now at a record high level. Greenhouse gas emissions have led to an atmospheric concentration of carbon dioxide, methane and nitrous oxide that are unprecedented in the earth at least for the last 800,000 years. The IPCC (2007), an earlier report of the same Panel, mentions that *climate change* is no longer simply a "potential threat", that it is "unavoidable" and "a consequence of 200 years of excessive greenhouse gas (GHG) emissions from fossil fuel combustion in energy generation, transport and industry, deforestation and intensive agriculture". The climate change issue has become such a massive concern worldwide that *climate action* has already been included in the United Nations Sustainable Development Goals, *SDG Goal 13* (United Nations, 2016).

Bangladesh has been able to increase its fisheries and aquaculture production over the last decade or so. According to the data of FAO (2015), Bangladesh has recently been ranked 5th in the whole world in terms of aquaculture production. At the same time, fish productivity has been raised on an average from 0.33 M.T/ Hectare to 0.60 M.T/Hectare from 2001-02 to 2012-13 implying almost a double increase of productivity during this time. Total fish production has increased from 1.9 million M.T. to 3.41 million M.T. implying an impressive 80 percent increase during these 11 years (Department of Fisheries, 2001-02, 2012-13). Yet this sector is highly vulnerable to natural disasters because of Bangladesh's geographical location, flat and low lying landscape, high population density, poverty, illiteracy, lack of institutional set up, etc. (Biswas, 2013). To state it differently, although the total production and productivity of fisheries and aquaculture sector are increasing over the last decade or so, there are some potential threats of *climate change* to hamper the smoothness of fish production and productivity, in the form of *increased production risks* generating from the climate change variables.

Although there are many literatures about impacts of climate change, unfortunately only a few studies have addressed the issues about the impacts of climate change on fisheries and aquaculture sector using household level data (see Biswas, 2013; Yazdi and Shakouri, 2010), rigorous quantitative analysis is mostly missing in a large section of the literature. Our present study aims at filling up this gap in the literature-- it examines household level data taken from the Household Income and Expenditure Survey 2010 (HIES, 2010) done by the Bangladesh Bureau of Statistics (HIES, 2010 is a nationally representative sample survey of 12,240 households across the entire country). Thus our study will be a new contribution to the existing literature. It might also be useful to the national policymakers with regards to taking appropriate policies to lessen the negative impacts of climate change on the fisheries and aquaculture sector, as per the SDG Goal 13 (see United Nations, 2016).

The organization of this paper is as follows. Background and Motivation are discussed in the *first section* of the paper covered by the introduction and literature review part. The *second section* covers data and methodology issues followed by specification of the econometric models in the

Methodology part. The *third section* covers the results of the study while the *last section* concludes.

Literature Review

There are many literatures in the field of climate change and agricultural sector worldwide. However studies about the impacts of climate change on fisheries and aquaculture are very few. Among them, only a few literatures related to climate change and fisheries & aquaculture sector are available in the context of Bangladesh. Bangladesh has huge potentials in terms of producing fish. Despite huge achievements of the fisheries and aquaculture sector of Bangladesh in reaching global rankings, there are some potential threats to the fisheries sector, *climate change* being one of them. Biswas (2013) showed that high temperature, sea-level rise, cyclone and storm surges, heavy monsoon downpours etc. are the signs of climate change. As a component of climate change, *global warming* has become a cause of concern of the present world, specifically for the fisheries and aquaculture sector. There are two kinds of effect of climate change on the fisheries and aquaculture sector. The first one is the *direct effect* acting on physiology and behavior and altering growth reproductive capacity, mortality and distribution and the second one is the *indirect effect* altering the productivity, structure and composition of marine ecosystems on which fish depends for food (Yazdi and Shakouri, 2010).

The *climate change* has slowed the path of our many development activities. To reduce food security problem, poverty, inequality, illiteracy and many other basic problems, this is increasingly becoming a challenge for a developing country like Bangladesh. Zaman and Islam (2012) mentions climate change and its adverse effects as the “block” to all struggles to lessen the effects of poverty condition. Generally people who are heavily dependent on the fisheries and aquaculture sector are poor as well as vulnerable to adverse shocks. Their livelihoods depend on their daily fishing activities. Due to climate change, the pattern of fishing behavior, altering growth and distribution have been changed. As a result the fishery-associated population group has become more vulnerable than ever before. Zaman and Islam (2012) mentions geographic experiences, low income, and greater reliance on agriculture which is a more climate-sensitive sector as the especial reasons for this vulnerability to climate change. This vulnerability has become more intense due to overexploitation of natural resources in the fisheries & aquaculture sector. The consequences and implications for food security and livelihoods for small, developing and the least developed countries are very large (Yazdi and Shakouri, 2010).

There are three categories of fisheries and aquaculture mentioned in the introduction part. Decomposition of fisheries production of Bangladesh into these three categories shows that the production of inland captures and marine fisheries has remained almost static around a little fluctuation in recent times. The total increase of fisheries production is mostly captured by *inland culture* (*aquaculture*). The same scenario can be observed in the global fisheries production as well. Brander (2007) showed that total increase in fisheries production is due to increase in aquaculture production. The negative growth rates or zero growth rates of the fisheries & aquaculture production in a number of countries might be due to climate change factors. If appropriate measures are not taken, fisheries and aquaculture production might even decrease rapidly in the near future.

Global mean temperatures are rising over time. This rising temperatures are causing rapid reduction of productivity of the fisheries & aquaculture sector as well as the agricultural sector. Emissions are rising currently by more than 3% per annum. This rising rate suggests the world is going to the path of "worse than the worst-case scenario" (Hamilton, 2009). Yazdi and Shakouri (2010) shows that global mean temperature increase of 3 to 4°C would cause serious adverse impacts. If the world temperature exceeds more than 32°C, it is hypothesized that death rate of fish fingerings would increase (Biswas, 2013). We note that we can not accurately forecast future world fisheries and aquaculture production because of uncertainty over future global aquatic net primary production and modeling of the forecast exercise (Brander, 2007). As the climate change is a long term aspect, the consequence of climate change on fisheries and aquaculture will be comprehensible after a long time and hence its sure impacts on fisheries and aquaculture is quite uncertain and ambiguous at this moment (World Fish Center, 2007; FAO, 2008; and Stern, 2007). However, FAO (2008) showed an exact relationship between fisheries and their ecosystem than those that exist in the case of the mainstream agriculture.

There are more than 260 species of fishes in Bangladesh and almost all of them are susceptible to specific climate change issues (Biswas, 2013). Hence there will be potential threats to the existence of fish species (Cheung et al., 2009). Fish production, growth and migration pattern are all affected by the temperature, rainfall and hydrology (Chowdhury, Sukhan and Hannan, 2010). However Cheung et al. (2009) showed that overall lower extinction rates for marine species than for terrestrial species of fish by 15 to 37%.

Methodology

Our study is based on secondary data. The Households Income and Expenditure Survey (HIES) 2010 data has been used for estimating the impacts of natural calamities as an indicator of climate change. The HIES data has been collected from the Bangladesh Bureau of Statistics (BBS). The collected data were analyzed by using Microsoft Excel and Stata 14.

Econometric Specifications

The HIES 2010 data were used for estimating the impacts of climate change at the household level (on the sub-set of households who reported to have derived some income from fisheries or aquaculture, a total of 1,607 households fell into this category out of a total of 12,240 households, around 13% of the total). The dependent variable is the *household fisheries production* and the explanatory variables are socio-economic variables like household non-fisheries income, gender of household head, total land area, education level of household head, number of household members etc. and one dummy variable whether the household is affected by climate change. To show how climate change impacts on growth rate of fisheries production we take the natural logarithm of household fisheries production. We will run simple cross section multiple linear regression models to estimate the impact of climate change on fisheries sector. The econometric model will be:

$$\ln FP = \alpha + \beta X + \gamma D + \mu \quad \text{--(1a)}$$

-- where α is the intercept term, β denotes coefficient matrix, γ is the coefficient of the variable that whether the household is affected climate change, lnFP is the (ln) fisheries production of households, X is the vector of socio-economic explanatory variables and these are education of the household head, gender of the household head, household income, number of household members, total land area and μ is the disturbance term. Our testable hypothesis is:

Null Hypothesis (1): *Climate change has negative impact on household fisheries production*

Alternative Hypothesis (1): Climate change does not have any negative impact on household fisheries production

In case of simple cross section analysis it has been taken that a dummy variable D which equals 1 if the household is affected by climate change and 0 for otherwise. It is also assumed that the income of the household will be affected if the household is affected by climate change. To examine this assumption, another simple cross section regression has been estimated whether the climate change has impact on income of that household. The following regression model will capture the above-mentioned objective:

$$\ln Income = \alpha + \beta X_{-1} + \gamma D + \mu \qquad \text{(1b)}$$

-- where α is the intercept term, β is the coefficient matrix of independent variables, γ is the coefficient of dummy variable and μ is disturbance term. Dependent variable, ln Income, is logarithm of household income to estimate the growth rate of income and X is again socioeconomic explanatory variables and here X_{-1} indicates explanatory variables except income which is now the dependent variable in logarithm form. Again the corresponding hypothesis:

Null Hypothesis (2): *Climate change has negative impact on household total income*

Alternative Hypothesis (2): Climate change does not have any negative impact

We expect *a priori* that the Null Hypotheses (1) and (2) are true.

As mentioned, HIES 2010 data were used for estimating the impacts of climate change. Since climate change is a long term phenomenon, it is difficult to measure the exact impact of climate change at one particular point in time, in a cross-section setting. Due to paucity of data, we have taken "drought", "irregular rains" as proxies of *climate change* (these two terms are included in the HIES 2010 questionnaire, in the shocks and vulnerabilities section). If any household is affected by above natural calamities, it has been assumed that household is affected by *climate change* captured by the dummy variable d (the value of d is either 0 or 1). Since "Flood" and "Land Erosion" are regionally correlated (therefore biased), these terms cannot give the unbiased estimator. And since "Drought" or "Irregular Rains" are perfectly random, it is not needed in our case to use non-experimental methods like Propensity Score Matching (PSM), Difference-in-Difference (DID), etc. to examine climate change impacts. Random assignment of treatment variable solves the selection problem because it makes treatment variables independent of potential outcomes (see Angrist and Pischke, 2008).

Following Angrist and Pischke (2008), we can proceed as follows. Let Y_i the outcome variable, Y_{1i} the outcome variable of those household who are affected by treatment indicator, D_i and Y_{0i} the outcome variable of those household are not affected by treatment indicator, $D_{i.}$

The impact is simply the difference between:

$$E\left[Y_i \mid d_i = 1\right] - E\left[Y_i \mid d_i = 0\right]$$

$$\text{or, } E\left[Y_{1i} \mid d_i = 1\right] - E\left[Y_{0i} \mid d_i = 0\right]$$

$$\text{or, } E\left[Y_{1i} \mid d_i = 1\right] - E\left[Y_{0i} \mid d_i = 1\right]$$

-- where the independence of Y_{0i} and d_i allows us to substitute $E\left[Y_{0i} \mid d_i = 1\right]$ for $E\left[Y_{0i} \mid d_i = 0\right]$ in the second line. In fact, given random assignment, this simplifies further to

$$E\left[Y_{1i} \mid d_i = 1\right] - E\left[Y_{0i} \mid d_i = 1\right]$$
$$\Rightarrow E\left[Y_{1i} - Y_{0i} \mid d_i = 1\right]$$

$$\Rightarrow E\left[Y_{1i} - Y_{0i}\right]$$

One important point is that random assignment of d_i eliminates selection bias. And hence the estimated coefficient of the dummy variable, γ, using simple cross-section regression analysis would provide an unbiased and consistent treatment effect of both econometric models mentioned above (see Angrist and Pischke, 2008, pp. 15).

Results

Fish production has always been a very important part of the household activities in Bangladesh. Besides natural fish catch process people here have started cultivating fish in modern, scientific ways in recent times. This modern cultivation process began at a very small scale but by now it has developed into a large scale exercise. On the other hand in different times, people face natural calamities. Then there arises a natural question, that is: ***are there any adverse effects of natural calamities (to be considered as proxies for climate change) on fish production process or total fish production in Bangladesh?***

Table 1(a) shows summary statistics of our selected data. Households associated with fisheries have an average yearly income of BDT 175,457, and the standard deviation is BDT 226,650 per year. Mean fish production of a household (average number of members 5.11), is 279 kilograms of fish per year, with a large standard deviation of 1,117 kilograms. Land is considered as an important indicator of standard of living of the household. Mean cultivated land owned of the selected sample households are 111 decimals. It is a noticeable observation that 65 per cent of the households have at least one mobile phone. Poor performance has been observed for average number of years of education obtained in the case of the head of the household (only 3.75 years of education). This low average level of education is a cause of concern, since this implies household heads involved with fisheries may have limited access to modern information and technology with regards to fisheries sector. The households are mostly headed by a male member of the household (92 per cent). The average age of the household head is 48 years. In the sample households, only around 5 percent of the households have brick roofs. Only 11 per cent of the households have reported to have been affected by natural calamities, so mean value of the *shock dummy* is 0.11.

Table 1(a): Summary Statistics

Variables	Description	Mean	Std. Dev	Observations
Year_income	Yearly income of household (BDT)	175,457	226,650	1,607
Shock_affected	Dummy (=1, if household is affected by natural calamities)	0.11	0.31	1,607
total_fishprodnh	Total fish production of a household (kilograms)	278.58	1116.65	1,607
Sex_hhead	Dummy (=1 if household head is male)	0.92	0.28	1,607
Member	Number of household members	5.11	1.97	1,607
Culownedland	Total cultivated land owned by a household (decimal)	111.25	225.19	1,607
Education_hhead	Education of the household head (years of schooling)	3.75	4.36	1,607
age_hhead	Age of the household head	47.65	13.48	1,607
Mobilephone	Dummy (=1, if a household	0.65	0.47	1,607

	has a mobile phone)			
brick_roof	Dummy (=1, if a household has brick roof)	0.05	0.23	1,607

Source: Authors' Calculations

Table 1(b) shows some additional summary statistics, with respect to geographical locations and natural calamities variables. Geography matters to a very large extent, with regards to fisheries. The yearly average household fish production varies from only 98 kilograms in Rangpur to 368 kilograms in Khulna, whereas yearly average household income varies from BDT 138,000 of Dhaka to BDT 237,000 of Rajshahi (only fisheries households). Dhaka contains 24 per cent of fisheries households whereas it reports 40 per cent of shocks, again Rangpur contains 16 per cent of households while it reports 22 per cent of shocks, together Dhaka and Rangpur report 62 per cent of all shocks reported, from among seven divisions. With respect to household income, fisheries-associated households in Dhaka, Khulna and Rangpur divisions are the poorest households on an average, each of them reporting less than the national average of BDT 175,000.

Table 1(b): Summary Statistics (by Division and Shock Classifications)

Division	Number of Households (*Per cent*)	Average Yearly Income of Households (BDT)	Average Yearly Fish Production (Kg.)	Number of Shock Affected Households (*Per cent*)
Barisal	139 (*8.65*)	195,108	362	16 (*8.94*)
Chittagong	345 (*21.47*)	235,478	347	9 (*5.03*)
Dhaka	380 (*23.65*)	137,788	256	71 (*39.66*)
Khulna	273 (*16.99*)	147,859	368	31 (*17.32*)

Rajshahi	61 (*3.80*)	237,216	342	7 (*3.91*)
Rangpur	261 (*16.24*)	149,877	98	40 (*22.35*)
Sylhet	148 (*9.21*)	184,368	226	5 (*2.79*)
Total	1,607 (*100*)	175,457	279	179 (*100*)

Source: Prepared by authors

Table 2 shows the OLS regression results of effects of socio-economic variables and variables measured by climate change terms on household fish production. A household with a higher level of income in a particular year produces more fish than a household with lower level of income. The effect of *year_income* on fish production is statistically significant at 1% level (p-value=0.000), this is logical since value of fish strengthens family income. On the other hand more cultivated land reduces fish production significantly. This result is also expected due to the fixed amount of land. Since if a household uses more and more amounts of lands for cultivation--this household would have to use less amounts of land for fish cultivation. Or a higher amount of cultivable land takes away household efforts from fishing activities towards crop agriculture. A higher total number of members of a household reduce fish production, though the estimated coefficient is not statistically significant. The use of mobile phone, the only measure of technology in the study, reduces the production of fish, but this is not statistically significant. More age of a household head increases the fish production of that household. Similarly a household with a male head can have a higher fish production. Except for *yearly income* and *amount of own cultivable land*, no other variables have exhibited statistical significance.

Our main concern is whether natural calamities or shocks faced by a household have any impact on the fish production of a household. As mentioned in methodology part, we identified that a household is affected by natural calamities or affected by shocks if that household is affected by at least any one of the variables of natural calamities. ***According to our estimation results, natural calamities reduce fish production of a household.*** If a household is faced by at least one type of a shock or natural calamity, it would have to face a reduction of fish production by 26 kilograms of fish in the year total. This is a very expected result that natural calamities (and through this, the climate change) has negative impact on fish production at the household level. However this is not a statistically significant implying that natural calamities do not have any impact on fish production in Bangladesh based on data available. Apart from this OLS regression, we also ran a means t-test, where the shock-affected group of 179 households has mean fish production of 227 kilograms of fish per year, which is 58 kilograms lower than the mean fish production of 285 kilograms of the non-shock-affected group of 1,428 households, but still the mean difference is not statistically significant (p-value= 0.168).

Table 2: OLS estimates of fish production function (dependent variable: yearly fish production)

Variables	Estimated Coefficient (*Robust Standard Error)*	t-value	p-value
Year_income	0.002 (*0.001*)***	3.56	0.000
Shock_affected	-26.225(*59.109*)	-0.44	0.657
Culownland	-0.384 (*0.165*)**	-2.34	0.020
Sex_hhead	103.367(*132.579*)	0.78	0.436
Member	-32.111 (*21.851*)	-1.47	0.142
Mobilephone	-58.374(*36.873*)	-1.58	0.114

Brick_roof	151.012 (*279.218*)	0.54	0.589
Age_hhead	7.056 (*8.109*)	0.87	0.384
Agesquared	(-0.076 (*0.079*)	-0.96	0.335
Constant	-61.667 (*173.005*)	-0.36	0.722
Number of Observations: N= 1,607 *Model Significance: F-value* (9, 1597)=2.93, (Prob.>F= 0.002), R-squared = 0.137			

Source: Prepared by Authors
* Significant at 10 percent level, ** Significant at 5 percent level and *** Significant at 1 percent level

We also examined whether natural calamities had any impact on income of households who are involved in fish production. **Table 3** shows the OLS estimates of the impact of natural calamities on yearly income of the fisheries-associated households. According to the Table 3, income of (households who are involved in fish production would be reduced by 6.57 per cent on an average if a household faced natural calamities. Decreases in income are expected due to natural calamities. Again this is not statistically significant implying that climate change measured by natural calamities has no impact on fish production (p-value = 0.239). We also ran a means t-test, where shock-affected 179 households has a mean yearly income of BDT 164,484, which is BDT 12,349 lower than the mean of BDT 176,833 of non-shock affected 1,428 households, yet mean difference is not significant (p-value= 0.267)). The results of Table 3 are very consistent with results of Table 2 which described natural calamities as to have no impact of fish production. If a household owns more cultivated land, average income of that household will be increased. This effect is highly significant at 1 per cent level. The coefficient of sex of household head negatively influences the average income of the household, but this is not statistically significant. On the other hand, if a household has larger number of family members, it will obtain more yearly income. This could have two scenarios. First is that the coefficient might have negative sign if most of the members of the households are dependent. Second is that the coefficient might have positive sign if most of the household members are earning members.

Table 3: OLS estimates of fish production function (dependent variable: Lnyear_income)

Variables	Coefficients (*Robust Standard Error*)	t-value	p-value
Shock_affected	-0 .066 (*0.056*)	-1.18	0.239
Culownland	0.001 (*0.000*)***	7.19	0.000
Sex_hhead	-0.035 (*0.064*)	-0.54	0.589
Member	0.0899 (*0.010*)***	8.90	0.000
Mobilephone	0 .492 (*0 .036*)***	13.51	0.000
Brick_roof	0 .609 (*0.096*)***	6.36	0.000
Age_hhead	0.031 (*0.007*)***	4.13	0.000
Agesquared	-0.000 (*0.000*)***	-3.74	0.000
Constant	10.002 (*0.176*)***	56.78	0.000
Number of Observations: N= 1,607 *Model Significance: F-value* (8, 1598)=91.22, (Prob.>F= 0.000), R-squared = 0.341			

Source: Prepared by Authors
* Significant at 10 percent level, ** Significant at 5 percent level and *** Significant at 1 percent level

Mobile phone and higher number of household members have a positive impact on fish production. Mobile phone has positive impact on household income implying that households with higher income might get benefit from using mobile phone. Mobile phone affects household income significantly. This on the other way is expected since only households with large income can have the ability to purchase the mobile phone. Similarly brick roof and age of the household affect household income positively.

There might be a possibility that geographical locations might affect fish production or income of the fisheries households (see Table 1(b)). In order to address this issue, this study runs regression with administrative division categorical variables taking Rangpur division as the base category (six division dummies have been included out of seven administrative divisions). Findings show that all division dummies jointly affect total yearly household fish production (F-value of joint significance test is 5.81 and p-value is 0.000) where Dhaka, Khulna and Barisal divisions affect statistically positively significantly compared to the base category of Rangpur division. Almost similar result has been found for yearly income of fisheries households (see Appendix Table A1 and A2).

Conclusion

This paper has taken appropriate econometric model to identify the impacts of climate change on the fisheries and aquaculture sector of Bangladesh, by examining HIES 2010 data. According to the findings, *climate change* has negative impact on fisheries and aquaculture sector at the household level and has also reduced mean yearly income for those households, though statistically significance has not been there. Although *climate change* does not affect fisheries and aquaculture sector statistically significantly as of yet, *climate change* can reduce fisheries production and household income sometimes in the near future. Households involved in fisheries sector in Dhaka and Rangpur (also to a lesser extent, Khulna) divisions have been found to be disproportionately more vulnerable to shocks in terms of natural calamities and conduits for climate change effects. This paper suggests that the government should take appropriate steps to lessen the impact of climate change on fisheries and aquaculture production in general, and at the same time government needs to take region-specific climate action plans, concentrate more on vulnerabilities of Dhaka and Rangpur divisions in this regard.

References

Angrist, J. D. and Pischke, J. S. (2008). *Mostly Harmless Econometrics: An Empiricist's Companion*. 1st Edition, New Jersey: Princeton University Press.

Biswas, M (2013). "*Climate Change & Its Impacts on Bangladesh*", pp. 86-95 in Rahman, G., (ed.), *Planned Decentralization: Aspired Development, World Town Planning Day 2013*. Bangladesh Institute of Planners, Dhaka

Brander, K.M. (2007). "Global Fish Production and Climate Change", *Proceedings of the National Academy of Sciences*, 104(50), pp. 19704–19714.

Cheung, W.W.L., Lam, V.W.Y, Sarmiento, J.L., Kearney, K., Watson, R. and Pauly, D. (2009). "Projecting Global Marine Biodiversity Impacts under Climate Change Scenarios". *Fish and Fisheries* 10, 235–251.

Chowdhury, MTH, Sukhan, ZP and MA Hannan(2010). "Climate Change and Its Impact on Fisheries Resource in Bangladesh", *Proceedings of International Conference on Environmental Aspects of Bangladesh* (ICEAB10), Japan, Sept. 2010.

Department of Fisheries (2010). *Fisheries Informatics Centre* (FIC), Department of Fisheries, Ministry of Agriculture and Rural Development, Government of the People's Republic of Bangladesh, website: http://fistenet.gov.bd (Accessed on 16.04.2017).

Department of Fisheries (DoF) (Various Years). *Fisheries Statistical Yearbook of Bangladesh*. Dhaka: Department of Fisheries, Ministry of Fisheries, Govt. of the Peoples' Republic of Bangladesh.

FAO (2008). "Climate Change Implications for Fisheries and Aquaculture", in *"The State of Fisheries and Aquaculture 2008"*. Rome: Food and Agricultural Organization, Rome, Italy, pp. 87–91.*Also cited* FAO (2011).

FAO (2011). "Implications of climate change on fisheries and aquaculture: challenges for adaptation and mitigation in the Asia-Pacific region". Rome: Food and Agricultural Organization, Rome, Italy.

FAO (2015). "*FAO Statistical Pocketbook World Food and Agriculture*". Rome: Food and Agriculture Organization of the United Nations.

Hamilton, C. (2009). "Is it too late to prevent Catastrophic Climate Change?" Lecture to a Meeting of the Royal Society of the Arts, Sydney, 21 October 2009.

IPCC (2007). “Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change” [Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.)]. IPCC, Geneva, Switzerland.

IPCC (2014). “Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change” [Core Writing Team: R. K. Pachauri and L.A. Meyer (Eds.)]. IPCC, Geneva, Switzerland.

Ministry of Finance (2016). *Bangladesh Economic Review 2016*. Dhaka: Economic Advisors’ Cell, Finance Division, Ministry of Finance, Government of the People’s Republic of Bangladesh.

Stern, N. (2007). “The Economics of Climate Change. The Stern Review”. Cambridge: Cambridge University Press.

United Nations (2016). “*The Sustainable Development Goals Report 2016*”. New York: The United Nations.

World Bank (2015). World Bank Population Data. http://data.worldbank.org/indicator/SP.POP.TOTL (accessed on 16.04.2017)

World Fish Center (2007), *Fisheries and Aquaculture Can Provide Solutions to Cope with Climate Change*. Issues Brief No.1701. World Fish Center, Penang, Malaysia, 4 pp. Available at: http://www.worldfishcenter.org/v2/files/CC-ThreatToFisheries1701.pdf (accessed on 16.04.2017)

Yazdi, S. K. and Shakouri, B. (2010). “*The Effects of Climate Change on Aquaculture*”, International Journal of Environmental Science and Development, Vol.1, No.5, pp. 378-382, December 2010

Zaman, A.K.M. H and Islam, MJ (2012). “*Managing Climate Change: Bangladesh Perspective*”. ASA University Review, Vol. 6 No. 1, pp. 1-13, January–June, 2012.

Appendix

Table A1: OLS estimates of yearly fish production (dependent variable: yearly household fish production, in kilograms)

Variables	Coefficient (*Robust Standard Error*)	t-value	p-value
Year_income	0.002 (*0.001*)***	3.49	0.000
Shock_affected	-36.103 (*65.996*)	-0.55	0.584
Culownland	-0.366 (*0.170*)**	-2.15	0.032
Sex_hhead	83.274 (*137.039*)	0.61	0.543
Member	-28.634 (*21.274*)	-1.35	0.179
Mobilephone	-69.537 (*36.884*)*	-1.89	0.060
Brick_roof	153.654 (*273.858*)	0.56	0.575
Age_hhead	5.897 (*7.996*)	0.74	0.461
Agesquared	-.0674 (*0.078*)	-0.86	0.387
Division: Barisal	183.111 (*70.263*)**	2.61	0.009
Division: Chittagong	86.134 (*70.942*)	1.21	0.225

Division: Dhaka	177.067 (*56.967*)***	3.11	0.002
Division: Khulna	252.877 (*90.246*)**	2.80	0.005
Division: Rajshahi	83.363 (*119.365*)	0.70	0.485
Division: Sylhet	89.297 (*62.991*)	1.42	0.156
Constant	-154.212 (*176.394*)	-0.87	0.382
Number of Observations: N= 1,607 *Model Significance: F-value* (15, 1591)=3.95 (Prob.>F= 0.000), R-squared = 0.142 *Joint Significance Test of All 6 Division Dummies*: F-value (6, 1591) = 5.81, Prob.>F= 0.00			

Source: Prepared by Authors
Note. Rangpur is the base division with respect to division dummies
* Significant at 10 percent level, ** Significant at 5 percent level and *** Significant at 1 percent level

Table A2: OLS estimates of household income (dependent variable: natural log of household yearly income, in BDT)

Variables	Coefficient (*Robust Standard Error*)	t-value	p-value
Shock_affected	-0.011 (*0.058*)	-0.19	0.849
Culownland	0.001 (*0.000*)***	7.26	0.000
Sex_hhead	0.023 (*0.065*)	0.36	0.719
Member	0.086 (*0.010*)***	8.50	0.000
Mobilephone	0.469 (*0.036*)***	13.02	0.000
Brick_roof	0.577 (*0.096*)***	6.03	0.000
Age_hhead	0.031 (*0.007*)***	4.27	0.000
Agesquared	-0.000 (*0.000*)***	-3.89	0.000
Division: Barisal	0.195 (*0.076*)**	2.55	0.011
Division: Chittagong	0.240 (*0.052*)***	4.61	0.000
Division: Dhaka	-0.109 (*0.048*)**	-2.27	0.023
Division: Khulna	-0.049 (*0.049*)	-1.00	0.319
Division: Rajshahi	0.137 (*0.101*)	1.36	0.175
Division: Sylhet	-0.077(*0.071*)	-1.08	0.282
Constant	9.931 (*0.176*)***	56.37	0.000
Number of Observations: N= 1,607 *Model Significance:F-value* (14, 1592)=57.78 (Prob.>F= 0.000), R-squared = 0.367 *Joint Significance Test of All 6 Division Dummies*: F-value (6, 1591) = 9.75, Prob.>F= 0.000			

Source: Prepared by Authors
Note. Rangpur is the base division with respect to division dummies
* Significant at 10 percent level, ** Significant at 5 percent level and *** Significant at 1 percent level