Adaptation to climate change in Bangladesh[•]

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Abstract

Climate change is expected to disproportionately affect agriculture in Bangladesh; however, there is limited information on smallholder farmers' overall vulnerability and adaptation needs. This article estimates the impact of climatic shocks on the household agricultural income and, subsequently, on farmers' adaptation strategies. Relying on data from a survey conducted in several communities in Bangladesh in 2011 and based on an IV probit approach, the results show that a 1 percentage point (pp) climate-induced decline in agricultural income pushes Bangladeshi households to adapt by almost 3 pp. Moreover, Bangladeshi farmers undertake a variety of adaptation options. However, several barriers to adaptation were identified, noticeably access to electricity and wealth. In this respect, policies can be implemented in order to assist the Bangladeshi farming community to adapt to climate change.

Policy relevance

This study contributes to the literature of adaptation to climate change by providing evidence of existing risk-coping strategies and by showing how a household's ability to adapt to weather-related risk can be limited. This study helps to inform the design of policy in the context of increasing climatic stress on the smallholder farmers in Bangladesh.

[•] The article has been presented at the Workshop on International Migration, CERDI, 19-20 November 2015.
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1 Introduction

Bangladesh is increasingly exposed to frequent and extreme climatic events, like widespread shifts in rainfall amounts, extreme weather, droughts, and intense cyclones. These serious climate-related difficulties put agricultural production at risk. Indeed, climate change is expected to decrease agricultural GDP by 3.1% each year, a cumulative 36 billion dollars in lost value-added for the period 2005–2050 (World Bank, 2012). However, adaptive strategies may be developed in order for the farming community to cope with these effects.

Empirical evidence recognizes that vulnerable communities in many developing countries are not passive victims (Adger, Huq, Brown, Conway, & Hulme, 2003). Pastoralists in the West African Sahel have adapted to cope with rainfall decreases of 25–33% (Cross & Barker, 1991; Mortimore & Adams, 2001), while resilience in the face of changing climate has been documented for smallholder farmers in many African countries (Barbier, Yacouba, Karambiri, Zorome, & Some, 2009; Mertz, Mbow, Reenberg, & Diouf, 2009; Roncoli, Ingram, & Kirshen, 2001) and in indigenous hunting communities in the Canadian Arctic (Berkes & Jolly, 2002). However, there is still limited information concerning farmers' preferred adaptation strategies. Moreover, since the Fifth IPCC report published in 2014, the framing of adaptation has moved further to the social and economic drivers of vulnerability and people's ability to respond. Several barriers to adaptation have been identified. Yet, there is still disagreement about what developing countries should do to protect themselves (Millner & Dietz, 2015).

Taking into consideration these effects, it is essential to identify Bangladeshi farmers' adaptation strategies and barriers to adaptation (Paul & Hossain, 2013). Very few studies have rigorously analysed farm-level data (Alauddin & Sarker, 2014). This study addresses this limitation by investigating the extent to which rural households in Bangladesh engage in different strategies to cope with risks in agricultural production due to weather-related shocks. This study advances the existing literature in several ways. First, in contrast to previous studies, it avoids concentrating on specific areas of Bangladesh. Instead, it relies on a rich survey, the Bangladesh Climate Change Adaptation Survey (BCCAS) data set, which covers the seven agro-ecological zones of Bangladesh. Second, the challenge lies in identifying correctly the impacts of climate change on the outcome variable (Dell, Jones, & Olken, 2013). The measurement of the impact of climatic shocks on household agricultural income and on households' adaptation strategies through a two-stage least-squares approach is a new way of addressing this concern. Our results show that climatic shocks are an important determinant of agricultural income and that farmers undertake a variety of adaptation options. This helps to inform policy makers of the diversity of adaptation strategies that exist and could be employed. However, several barriers to adaptation were identified: opting for certain adaptation strategies depend upon wealth, education, size of the household, and access to electricity. Therefore, the findings of this study have important policy implications for assisting the Bangladeshi farming community to adapt to climate change.

The rest of the article is organized as follows. Section 2 reviews the literature, while Section 3 introduces the database. Empirical strategy and results are presented in Sections 4 and 5. The determinants of adaptive capacity are investigated in Section 6. Finally, Section 7 summarizes the results as well as highlights their policy implications.

2 Related literature

Starting in the late 1990s, a new topic has gained importance: adaptation (Smithers & Smit, 1997). It refers to the ability of natural or human systems to adjust to climate change in order to cope with the inevitable consequences. The empirical literature on climate change and adaptation has two main purposes. One is to quantify the impacts of climate change or adaptation potentials (Benson & Clay, 2004). Several studies highlight the impacts of climate change on agriculture and discuss the adaptation options in Bangladesh (Ali, 1999; Harunur Rashid & Islam, 2007). The water productivity literature provides one possible adaptation option: the water-saving perspective of agricultural development. Indeed, very low levels of water productivity offer a significant scope for improvement for coping with droughts (Alauddin & Sharma, 2013). The other purpose of the literature is to explore quantitatively who adapts, how, and why. Barbier et al. (2009) compare different responses of households in Burkina Faso to drought by analysing farm decisions after years with poor and good harvests. They conclude that the households have developed strategies for income diversification as a way of reducing dependence on climate, but vulnerability is still considerable. A similar conclusion is reached by Roncoli et al. (2001) who analyse the responses enacted by families of the Central Plateau in Burkina Faso during the year that followed a severe drought in 1997. In addition, Mertz et al. (2009) estimate the relative importance of climate in various adaptive strategies in Senegal. Households identify wind and occasional excess rainfall as the most destructive climate factors. However, they assign economic, political, and social rather than climate factors as the main reasons for change. With respect to Bangladesh, Alauddin and Sarker (2014) identify several adaptation strategies in response to drought such as the cultivation of drought-tolerant rice and non-rice crops or the use of more irrigation water. Similarly, Habiba, Shaw, and Takeuchi (2012) give evidence that, to cope with drought, Bangladeshi farmers have been adapting various practices mainly through agronomic management, crop intensification and water resource exploitation. In addition, evidence shows that people in Bangladesh are used to adjust to cyclones and flooding events by adopting various coping strategies (Del Ninno, Dorosh, Smith, & Roy, 2001, Paul & Routray, 2011; Younus, Bedford, & Morad, 2005).

Moreover, several studies empirically examine which factors influence adaptation. Below et al. (2012) explore the relationship between socio-economic variables and farmers' adaptation behaviour in Tanzania. They find that public investment in rural infrastructure, the availability and technically efficient use of inputs, the quality of the educational system, and the strengthening of social capital, agricultural extension and microcredit services tend to improve the adaptation of the farmers. In a similar study, Bryan, Deressa, Gbetibouo, and Ringler (2009) found that, despite having experienced changes in temperature and rainfall, a large percentage of farmers did not make any adjustments to their farming practices. The main barriers to adaptation cited by farmers were the lack of access to land, information, and credit. Similarly, Fosu-Mensah, Vlek, and MacCarthy (2012) highlighted the importance of several determinants of adaptive capacity such as land tenure, soil fertility, and access to extension service and credit inGhana. In Bangladesh, Alauddin and Sarker (2014) found that inadequate access to climate information, limited irrigation facility and resource base represented major adaptation barriers. Abdur Rashid Sarker, Alam, and Gow (2013) observed that several factors do increase the likelihood of farmers' adaptation such as education attainment, average household income, farming experience, tenure status, and availability of electricity, institutional access and climate awareness. Similarly, Paul and Routray (2011) show that the adoption of a particular set of coping strategies depends on socio-demographic characteristics. Finally, the failure of autonomous adaptation will have huge economic consequences (Younus & Harvey, 2014). An interesting study by Paul and Hossain (2013) finds that a number of measures have been undertaken by the Government and NGOs but the measures are extremely inadequate considering people's needs. Therefore, realizing that changes in climate condition have a strong impact on vulnerability, action is required to enhance the adaptive capacity of the most vulnerable societies.

3 Data

To estimate the impact of climatic shocks on household agricultural income and subsequently on farmers' adaptation options, the first round of the BCCAS is used (IFPRI, 2014). The BCCAS I1 contains cross-sectional data on 800 farming households in Bangladesh. It provides information on demographic characteristics, agricultural production and income, incidence of climatic shocks in the last five years, and adaptation options. A detailed list of the climatic shocks and adaptation options is available in Table 1. The survey was conducted at one point of time between December 2010 and February 2011, covering agricultural data from the previous production year. The unit of analysis is the rural household, which operates as the ultimate decision-making unit in farming and livelihood processes.

3.1 Demographic characteristics

Table 2 on households' localization shows that the study is representative of Bangladesh. In fact, the household survey covers 40 unions randomly selected, which represent the 7 broad agro-ecological zones as grouped by the Bangladesh Center for Advanced Studies. Twenty agricultural households were randomly selected in each union, making a total sample of 800 households.

Table 3 gives information on households' characteristics such as the household size, the gender of the household head, the age of the household head, his/her religion (muslim is a dummy equal to one if the household head is Muslim), the highest education level in the household (education), a dummy equal to 1 if the first (occupation1) or second occupation (occupation2) of the household head is in agriculture and whether the household has access to electricity. Information on assets and land holdings (lands) are given with the quantity of cattle, goat, pig, and chicken owned by the household.

The findings show that about 94% of the households were headed by males. On average, the head of the household is 45 years old. The average household is composed of five members. The majority are Muslims. Education of households is low, with two years of schooling on average. Most of them never attended school and work in the agricultural sector, which constitutes the first occupation for 77%. The majority of the households do not have access to electricity (54%). They are holding on average 3.47 lands and 6.61 assets with 1.17 cattle and 9.67 chickens.

3.2 Agricultural production

Table 4 provides information on the soil type, the crop type, and the agricultural income of the households. The average household produces 6.33 different crops with more plot productions (3.73) than non-plot productions (2.60). They have, in majority, cultivable lands with a clay-loam type of soil. The mean of the agricultural income is 31,426 BDT (domestic currency in Bangladesh) which is equivalent to US$404 . According to the World Bank, the GDP per capita in Bangladesh was US$841.5 in 2011 (65,158 BDT). The mean agricultural income is, therefore, lower than the GDP per capita measure which reflects that the agricultural sector provides employment and income to the poorest members of the Bangladeshi society.

3.3 Climatic shocks

The surveyed households were asked about natural hazards that affected their agricultural harvest. More than half of the respondents (54.65%) reported that their agricultural plot had been affected by a natural hazard in the last five years. Climatic shocks are considered only if at least two (up to five) individuals in the community responded yes to the question: 'Did this natural disaster occur in the community in the past 5 years?' (Table 5). These individuals were chosen according to their functions: the administrative or traditional leader of the community, a teacher/local elite, or working in farming. They represent hazards that happen at the community level and not at the household level as reported in the survey. The most commonly cited hazards were pestilence stricken (60%), floods (55%) and droughts (52.50%).

Two types of hazards are distinguished: the first type refers to weather shocks while the second refers to diseases. In fact, weather shocks have a direct impact on the household agricultural income whereas diseases that concern livestock have an indirect impact through a reduced livestock productivity, for instance.

3.4 Adaptation options

Households are asked whether they had made any adjustments in their farming practices. Twenty adaptation options are considered in the dataset, and they can happen simultaneously. The general case is also considered where the household made at least one change out of the twenty.

Results (Table 6) show that a very high percentage of the households (86.25%) changed their farming practices due to climate change. The results also highlight the importance of each adaptation option: changing crop variety

(64.14%), irrigating fields (62.48%) or intensifying irrigation (63.59%), building a water harvesting system (23.31%), changing crop type (19.59%), increasing the amount of land under production (16.69%) and seeking off-farm employment (16.69%) being the options most frequently cited.

Certain options are less frequently mentioned, which may reflect the fact that the adaptive capacities within agriculture remain low, and also that the nature of the dataset is cross-sectional, which does not allow us to make an analysis of the adaptation of the productive technology over the long run. The level of adjustments to climate change is negligible for change and implement soil and water management techniques (5% in both cases), mix crop and livestock production, mix crop and fish farming production (respectively 4% and 3%), change from crop to livestock production and from livestock to crop production (1% and 2%). Households have limited access to finance: only 1% of households in the sample declare resorting to formal insurance. Another 1% can afford setting up communal seed banks/food storage. Some strategies are more expensive and proactive than others: change crop variety or crop type, change or implement soil and water management techniques, build water harvesting scheme for domestic consumption or for crops, irrigate and irrigate more, change from livestock to crop production, and from crop to livestock production. However, changing the amount of land under production, changing the pattern of crop consumption, mixing crop and livestock production and mixing crop and fish farming production, seeking off-farm employment, and migrating can be implemented ex post, once the natural hazard occurred (reactive adaptations). They correspond to a passive way of adaptation to climate change, requiring less budgetary resources.

4 Empirical strategy

Following Maurel and Tuccio (2016) and Kubik and Maurel (2016), climate is assumed to impact agricultural income (Equation (2)), which in turn obliges farmers to adapt (Equation (1)). Households adopt economic strategies not only to maximize household earnings but also to cope with risk, which is mainly due to natural hazards. The latter do not impact the farmers' decision directly, through an amenity value or through the households' preferences for a given climatic setting. Natural hazards affect rural behaviours solely through the decline in agricultural yields.

In the empirical strategy, weather serves as an instrument for agricultural income which appears as the main explanatory variable in the decision for a farmer i in a village j to adopt an adaptation strategy A_{ij} as expressed in Equation (1):

$$A_{ij} = f\left(Y_{ij}; X_{ij}\right) + u_{ij} \tag{1}$$

where Y is the logarithm of agricultural income, and the vector of controls X refers to household characteristics such as the gender of household head (*gender*), the age of the household head (*age*), the highest level of education in the household (*education*), *muslim* taking the value one if is Muslim, *occupation1* (*occupation2*) if the first (or second occupation) of the household head is in agriculture, *electricity* if the household has access to electricity and holdings (*assets* and *lands*).

Agricultural income is determined as a function of natural hazards $Hazard_j$ in a village j, of land units L_{ij}, soil type S_{ij} and production type P_{ij}:

$$Y_{ij} = f\left(L_{ij}; S_{ij};\ P_{ij};\ Hazard_j\right) + v_{ij} \tag{2}$$

As mentioned earlier, two types of hazards are distinguished: the first type refers to weather shocks like drought, flood, while the second refers to diseases, such as pestilence stricken or livestock epidemic.

5 Results

5.1 The agricultural equation

The impact of weather shocks and diseases on agricultural income is estimated as in Equation (2) in order to assess the viability of the instrument in the IV probit model. Unlike previous studies that use temperature and rainfalls in levels (Mendelsohn, Nordhaus, & Shaw, 1994), temperature and rainfalls shocks (Feng, Krueger, and Oppenheimer, 2010; Kubik & Maurel, 2016; Maurel & Tuccio, 2016), or temperature and temperature squared in the growing season 2008 (Schlenker & Roberts, 2008), this study relies on natural hazards related to climate change. Climatic and diseases variables display a certain level of multicollinearity, implying that they cannot be considered simultaneously in a single model. Therefore, diseases related to livestock and plague are considered on the one hand, and hazards related to the weather are considered on the other hand. The diseases will allow estimating the likelihood of adopting the following options: mix crop and livestock production, change from crop to livestock production, and from livestock to crop production. Those strategies are more likely to result from animal diseases than weather anomalies.

Table 7 displays the results for agricultural income. In columns 1–3, only the natural hazards related to the weather are taken into account as predictors of the agricultural income whereas in columns 4–6, only the diseases are taken into account. The more land a household has, the more the agricultural income it gets. The plot type matters since homestead, cultivable lands, pasture, bush, cultivable pond, and derelict pond have all a significant impact on agricultural income. The soil type considered by clay, loam, sandy, clay loam, and sandy loam decreases the agricultural income. The bigger the size of the land, the higher the agricultural income. Floods, drought, and tidal waves (column 1) and pestilence and livestock epidemic (column 4) significantly lower agricultural income. In order to account for the fact that natural hazards are aggregated at the community level, while the estimation is done at the household level, standard errors are corrected by clustering (columns 2 and 5) and by applying the Moulton procedure (columns 3 and 6).

5.2 The adaptation equation

The adaptation equation consists in estimating the impact of agricultural income instrumented by natural hazards on farmers' adaptation options. First, the farmers' decision to adapt is considered independently from any specific adaptation. Then, each adaptation option is considered separately. Table 8 reports the results. The Wald test confirms the validity of the instruments. Marginal effects are reported for ease of interpretation. For the average household, a 1 percentage point (pp) decrease in agricultural income increases the probability to adapt by almost 3 pp. This result is highly significant. The number of assets significantly influences the decision to adapt: richer households are more likely to change their strategy. However, it is noteworthy that the gender of the household head, the age, education, religion, and occupation as well as having access to electricity do not affect significantly the likelihood of adaptation.

The impact of agricultural income instrumented by natural hazards is estimated subsequently on each adaptation option. The results are given in Table 9, panels A and B. Options that address negative shocks in a passive way and do not require any resource to be invested (Panel A) are distinguished from proactive options that are adopted following an increase in income (Panel B). In order to adapt to a decrease in the agricultural income due to climatic shocks, rural households adopt the following strategies: they change the amount of land under production, the pattern of crop consumption, the field location, seek off-farm employment, and migrate. Other strategies (Panel B) are more resource demanding and correspond to a proactive behaviour. They are chosen if they can be afforded, thanks to an increase in the agricultural income: change crop variety, change crop type, irrigate, irrigate more, and change from livestock to crop production. There is no significant impact of a variation of the agricultural income due to climatic shocks on the probability to opt for the following strategies: implement or change soil and water management techniques, build water harvesting scheme for domestic consumption or for crops and change from crop to livestock production.

Panel A displays the estimates. A 1 pp decrease in the agricultural income increases the probability that the households change the amount of land under production by 2.46 pp, change field location by 1.98 pp, change crop consumption by 1.71 pp, migrate by 1.43 pp and seek off-farm employment by 1.10 pp. As recorded in Panel B, a 1 pp increase in the agricultural income increases the probability that the households opt for a change of crop type by 2.93 pp, intensify irrigation by 2.66 pp, irrigate by 2.56 pp, change from livestock to crop production by 2.17 pp and change crop variety by 1.50 pp. Panel B options are more expensive compared to Panel A options. The results reflect the existence of constraints that restrict the access to the most resource-demanding options. Four candidates that may determine the farmers' adaptive capacity are examined: wealth, education, size of the household, and finally access to electricity.

6 Adaptive capacity

The idea that adaptive capacity may depend on certain conditions is not out of line with the existing literature. Economic condition is a strong determinant of adaptive capacity (Kates, 2000). It is widely accepted that wealthy nations are better prepared to bear the costs of adaptation to climate change impacts and risks (Burton, Huq, Lim, Pilifosova, & Schipper, 2002; Goklany, 2007). This section adds to the literature by focusing on panel B strategies. It provides support to the view that opting for those strategies is constrained by the availability of certain resources: wealth, education, the size of the household and whether the household has access to electricity. Access to electricity is considered in the literature as a proxy for socio-economic status, and as a way to escape from poverty traps (Chaurey, Ranganathan, & Mohanty, 2004; Kanagawa & Nakata, 2007) through a saving of time, which can be invested in educational and health spending, or in infrastructure such as pumps for irrigating. Wealthier households are more able to afford even slightly more expensive strategies (Reardon & Taylor, 1996). Educated farmers are more able to treat the information about climate hazards and they will be more likely to opt for certain adaptation options (Bryan et al., 2009; Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009). Bigger households have more (labour) resources that can be invested in order to diversify the sources of income. Beyond the fact that it represents also a proxy for poverty, access to electricity is needed to resort to options, such as irrigate, irrigate more, as they require pumping water.

6.1 Testing the results for the richest of the sample

Some adaptation options cannot be afforded by the poorest households if the agricultural income diminishes because they are expensive: change crop type, change crop variety, irrigate, irrigate more, and change from livestock to crop production. A household is considered rich if it holds more assets and lands than the average (which is six assets, three lands). The results are provided in Table 10. In order to simplify the comparison, Panel A displays the results for the entire sample whereas Panel B incorporates only the richest households. The results show that richer households are able to react to a decrease in agricultural income by changing crop variety and crop type, and also by changing from livestock to crop production. Finally, richer households do invest significantly more in order to irrigate and irrigate more when their revenue increases. These results provide evidence that wealth matters as relatively richer households are able to react to a decline in their revenue by adopting two more farming strategies. They also invest more in improving the irrigating capacities.

6.2 Testing the results for the most educated

Certain adaptation options might only be considered by the most educated households because of an unequal access to information. Since the majority of the households never attended school, households are considered educated if the highest level of education in the household is equal to one year of schooling or more. As for wealth, Panel A displays the results for the entire sample whereas Panel C show the estimates obtained with only the educated households. There is no significant difference, but for changing crop variety: farmers with at least one year of schooling invest more in the latter strategy. This can be explained by the fact that households are provided with information from other sources: the extension agents who visit/contact the households, coming from various organizations such as Government Agencies, agriculture research stations, NGOs, etc. Of course, households can also receive information through television, radio, newsletter, neighbours or friends, shopkeepers or traders, etc.

6.3 Testing the results for larger households

A natural hypothesis is that the adoption of adaptation options is easier for large households that can send their members away, for instance, in order to diversify their income. A household is considered large if the size of the household is higher than 5. The estimates of Panel D are slightly lower, suggesting that having additional household labour, such as extended family members and older children, relaxes the constraint and might facilitate changing strategy and increase the decision to adapt.

6.4 Testing the results for households that have access to electricity

The households who benefit from an electricity connection (national grid or solar system) are considered. Results show that households that experience a decrease in their income and have access to electricity are coping with this decrease by changing crop variety and crop type, while those who do not have access cannot resort to those strategies. Therefore, households that have access to electricity are less discriminated as the income matters less to cope with climate.

7 Conclusion

The impact of climatic shocks on household agricultural income and, subsequently, on adaptation options in Bangladesh is estimated. The results show that a 1 percentage point (pp) climate-induced decrease in agricultural income increases the probability to adapt by almost 3 pp. Moreover, Bangladeshi farmers have undertaken a variety of adaptation options. However, several strategies are not accessible to everybody, according to his (her) wealth and access to electricity: change crop variety, change crop type, irrigate, irrigate more, and change from livestock to crop production. These options are more demanding, as they require a fixed cost to be paid. We show that the positive association between the most demanding options and agricultural income diminishes with wealth, size of the household, and to a lesser extent education. Noticeably, access to electricity is a powerful way of reducing the discriminatory effect of agricultural income. Farmers provided with such an access face a wider range of options. Reporting evidence that such non-linearities exist allows us to contribute to the debate about what is essential, policies focused on development versus more specific policies.

While policies focused on the specific adaptation options have been the ones mostly recommended by previous studies, they can be complemented by more general policies, like proper wealth distribution along with access to electricity and education, which decreases the distortion in the access to climate change. Indeed, uninterrupted electricity would improve the farmers' adaptive capacity. As suggested by Alauddin and Sarker (2014), the government could use the Rural Electrification Board to provide a continuous electricity supply to farmers as a high priority. Moreover, educational programmes aiming at enhancing awareness are likely to be effective. This necessitates a coordinated intervention on the part of government, private, and non-government organizations to improve farmers' adaptive capacity.

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Tables

Table 1: List of variables

Climatic shocks
Pestilence stricken
Livestock epidemic
Flood
Tidal wave
Drought
River erosion
Cyclone
Adaptation options
Decision to adapt
Change crop type
Change amount of land under production
Change soil and water management techniques
Implement soil and water management techniques
Change pattern of crop consumption
Mix crop and livestock production
Mix crop and fish farming production
Change field location
Build water harvesting scheme for domestic consumption
Build water harvesting scheme for crops
Build water harvesting scheme for livestock
Irrigate
Irrigate more
Buy insurance
Change from crop to livestock production
Change from livestock to crop production
Seek off farm employment
Migrate
Set up communal seed banks/food storage facilities

Source: Bangladesh Climate Change Adaptation Survey I (IFPRI, 2014).

Table 2: Households ' localization

Variable	n	N
District	31	800
Upazila	39	800
Union	40	800
Village	40	800
Agro-ecological zone	7	800

Source: Bangladesh Climate Change Adaptation Survey I (IFPRI, 2014).

Table 3: Households ' characteristics

Variable	Mean	N
Household size	4.99	800
Age household head	45.52	800
Education (years)	1.91	800
Assets	6.61	796
Asset value (Taka)	356 598.3	796
Cattle (Qty)	1.17	800
Goat (Qty)	0.535	800
Pig (Qty)	0.01	800
Chicken (Qty)	9.67	800
Lands	3.47	800
Land value (Taka)	759 584.5	800
Variable	Percentage	N
Male household head	94.13	800
Muslim	88.88	800
Hindu	10.88	800
Christian	0.25	800
Occupation1 in agriculture	76.75	800
Occupation2 in agriculture	20.13	800
Electricity	46	800

Source: Bangladesh Climate Change Adaptation Survey I (IFPRI, 2014).

Table 4: Agricultural production

Variable	Mean	N
Production	6.33	800
Plot production	3.73	800
Non-plot production	2.60	800
Homestead	1.02	800
Cultivable land	3.43	800
Pasture	0.01	800
Non-arable land	0.02	800
Land in river bed	0.01	800
Land in market place	0.01	800
Cultivable pond	0.25	800
Derelict pond	0.04	800
Clay	0.20	800
Loam	1.23	800
Sandy	0.18	800
Clay loam	2.29	800
Sandy loam	0.99	800
Size	163.48	800
Agric income (Taka)	31426.17	780
Ln agric. income	8.08	780

Source: Bangladesh Climate Change Adaptation Survey I (IFPRI, 2014).

Table 5: Climatic shocks at the community level

Variable	Percentage (Yes =1)	N
Pestilence stricken	60	800
Livestock epidemic	37.50	800
Flood	55	800
Drought	52.50	800
River erosion	7.50	800
Tidal wave	7.50	800
Cyclone	27.50	800

Source: Bangladesh Climate Change Adaptation Survey I (IFPRI, 2014).

Table 6: Adaptation options

Variable	Percentage (Yes = 1)	N
Decision to adapt	86.25	800
Change crop variety	64.14	725
Change crop type	19.59	725
Change amount of land under prod	14.63	800
Change soil and water management techniques	5.38	800
Implement soil and water management techniques	4.88	800
Change pattern of crop consumption	5.38	725
Mix crop and livestock production	3.86	725
Mix crop and fish farming production	3.31	725
Change field location	7.17	725
Build water harvesting scheme for dom cons	12.83	725
Build water harvesting scheme for crops	13.38	725
Build water harvesting scheme for livestocks	0.97	725
Irrigated	62.48	725
Irrigate more	63.59	725
Buy insurance	0.83	725
Change from crop to livestock prod	0.97	725
Change from livestock to crop prod	1.79	725
Seek off farm employment	16.69	725
Migrate	2.62	725
Set up communal seed banks/food storage facilities	1.10	725

Source: Bangladesh Climate Change Adaptation Survey I (IFPRI, 2014).

Table 7: Impact of weather shocks and diseases (climate variables) on agricultural income

	(1) OLS	(2) Cluster	(3) Moulton	(4) OLS	(5) Cluster	(6) Moulton
	Impact of weather shocks			Impact of diseases		
Flood	-0.472	-0.472	-0.472			
	(-1.89)	(-0.86)	(-0.92)			
Drought	-0.861***	-0.861	-0.861			
	(-3.31)	(-1.50)	(-1.61)			
Cyclone	-1.813***	-1.813**	-1.813**			
	(-6.12)	(-2.77)	(-3.00)			
Tidal wave	-0.611	-0.611	-0.611			
	(-1.15)	(-0.52)	(-0.58)			
Pestilence stricken				-0.466	-0.466	-0.466
				(-1.72)	(-0.75)	(-0.81)
Livestock epidemic				-0.838**	-0.838	-0.838
				(-3.06)	(-1.33)	(-1.45)
Lands	0.239**	0.239**	0.239**	0.310***	0.310***	0.310***
	(3.25)	(2.65)	(2.73)	(4.26)	(3.40)	(3.53)
Homestead	3.912**	3.912**	3.912**	3.904**	3.904**	3.904**
	(3.13)	(3.13)	(3.13)	(3.06)	(3.06)	(3.06)
Cultivable land	3.381**	3.381*	3.381*	3.403**	3.403*	3.403*
	(2.86)	(2.32)	(2.41)	(2.83)	(2.25)	(2.35)
Pasture	3.937*	3.937*	3.937*	3.935*	3.935*	3.935*
	(2.53)	(2.53)	(2.53)	(2.48)	(2.48)	(2.48)
Bush	3.526**	3.526*	3.526**	3.523**	3.523*	3.523*
	(2.91)	(2.55)	(2.60)	(2.85)	(2.47)	(2.53)
Non arable land	1.941	1.941	1.941	2.029	2.029	2.029
	(1.28)	(1.28)	(1.28)	(1.31)	(1.31)	(1.31)
Cultivable pond	3.237**	3.237*	3.237*	2.958*	2.958*	2.958*
	(2.72)	(2.25)	(2.32)	(2.44)	(1.98)	(2.06)
Derelict pond	4.130**	4.130**	4.130**	3.837**	3.837**	3.837**
	(2.72)	(2.25)	(2.32)	(2.44)	(1.98)	(2.06)
Clay	-3.460**	-3.460	-3.460*	-3.621**	-3.621	-3.621*
	(-2.88)	(-1.93)	(-2.17)	(-2.96)	(-1.93)	(-2.19)
Loam	-3.282**	-3.282*	-3.282*	-3.346**	-3.346*	-3.346*
	(-2.76)	(-2.36)	(-2.44)	(-2.76)	(-2.33)	(-2.42)
Sandy	-3.232**	-3.232*	-3.232*	-3.411**	-3.411*	-3.411*
	(-2.70)	(-2.38)	(-2.43)	(-2.80)	(-2.43)	(-2.50)
Clay loam	-3.312**	-3.312*	-3.312*	-3.400**	-3.400	-3.400*
	(-2.79)	(-1.98)	(-2.09)	(-2.81)	(-1.94)	(-2.07)
Sandy loam	-3.210**	-3.210*	-3.210*	-3.312**	-3.312*	-3.312*
	(-2.70)	(-2.32)	(-2.37)	(-2.74)	(-2.32)	(-2.38)
Size	0.00107*	0.00107*	0.00107*	0.000878	0.000878	0.000878
	(2.24)	(2.04)	(2.09)	(1.80)	(1.63)	(1.68)
cons	7.348***	7.348***	7.348***	6.944***	6.944***	6.944***
	(14.47)	(6.56)	(6.98)	(13.87)	(6.03)	(6.50)
N	780	780	780	780	780	780

Table 8: Impact of agricultural income on the decision to adapt

	Decision to adapt
Ln. agric. income	-0.274***
	(-16.21)
Gender household head	-0.194
	(-1.03)
Age household head	0.00293
	(0.82)
Education	0.00812
	(0.75)
Muslim	0.196
	(1.33)
Occupation 1 in agriculture	0.307
	(1.17)
Occupation 2 in agriculture	-0.174
	(-0.67)
Electricity	0.124
	(1.27)
Assets	0.0868***
	(5.30)
cons	1.605***
	(4.65)
athrho_cons	1.485***
	(5.31)
Insigma_cons	1.206***
	(46.66)
N	776

Note: t statistics in parentheses. Estimates are not reported. Are available upon request; Wald test of exogeneity (/athrho = 0): chi2(1) = 28.24 Prob > chi2 = 0.0000.

*p<.5.

**p<.1.

***p<.01.

Table 9: Adaptation Options

Panel A: Options more likely to be adopted after a decrease in agricultural income

	Change amount of land prod	Change crop cons	Change field location	Seek off farm employment	Migrate
Ln agric income	-0.246***	-0.171***	-0.198***	-0.110	-0.143*
	(-12.11)	(-3.56)	(-5.77)	(-1.94)	(-2.23)
Gender household head	-0.0131	0.0365	-0.259	-0.0807	-0.152
	(-0.06)	(0.12)	(-0.85)	(-0.30)	(-0.38)
Age household head	-0.00120	0.000112	0.000248	-0.000395	0.00340
	(-0.35)	(0.02)	(0.06)	(-0.09)	(0.50)
Education	0.00355	0.00875	0.0238	0.00930	0.0100
	(0.30)	(0.56)	(1.79)	(0.66)	(0.50)
Muslim	0.0858	0.334	0.425	0.0894	0.181
	(0.57)	(1.39)	(1.91)	(0.48)	(0.67)
Occupation 1	0.0379	-0.322	-0.476	-0.680*	-0.419
	(0.13)	(-0.83)	(-1.39)	(-1.99)	(-0.90)
Occupation 2	-0.337	-0.440	-0.856*	-0.433	-0.350
	(-1.13)	(-1.11)	(-2.39)	(-1.22)	(-0.72)
Electricity	0.0405	-0.0282	-0.00887	-0.273*	-0.229
	(0.40)	(-0.19)	(-0.07)	(-2.06)	(-1.14)
Assets	0.106***	0.109***	0.0918***	0.0562*	0.0615
	(6.02)	(4.38)	(4.06)	(2.19)	(1.75)
cons	0.578	-0.606	0.00482	0.196	-0.660
	(1.33)	(-0.79)	(0.01)	(0.33)	(-0.68)
N	776	703	703	703	703

Panel B: Options more likely to be adopted after an increase in agricultural income

	Change crop variety	Change crop type	Irrigate	Irrigate more	Change livestock to crop
Ln agric income	0.150**	0.293***	0.256***	0.266***	0.217**
	(2.65)	(36.04)	(16.40)	(19.50)	(2.94)
Gender household head	0.457	0.341	0.118	0.182	0
	(1.90)	(1.70)	(0.55)	(0.87)	(.)
Age household head	0.00615	0.00377	0.000478	0.00117	0.00540
	(1.78)	(1.31)	(0.15)	(0.37)	(0.85)
Education	0.00616	-0.0172	-0.0172	-0.0175	-0.0378
	(0.48)	(-1.83)	(-1.67)	(-1.71)	(-1.35)
Muslim	-0.180	-0.232	0.182	0.290	-0.118
	(-1.16)	(-1.79)	(1.19)	(1.82)	(-0.36)
Occupation 1	0.870**	0.168	0.0336	0.182	-0.947
	(2.64)	(0.64)	(0.12)	(0.64)	(-1.82)
Occupation 2	0.804*	0.450	0.257	0.375	-0.716
	(2.51)	(1.68)	(0.87)	(1.29)	(-1.25)
Electricity	0.00799	-0.0627	0.0186	0.132	-0.277
	(0.08)	(-0.72)	(0.20)	(1.37)	(-1.27)
Assets	-0.0590**	-.0596***	-0.0375*	-.0675***	-0.0301
	(-2.92)	(-3.84)	(-2.18)	(-4.17)	(-0.75)
cons	-1.485**	-2.219***	-1.867***	-2.071***	-2.122**
	(-3.04)	(-6.20)	(-5.13)	(-5.81)	(-3.27)
N	703	703	703	703	668

Notes: t statistics in parentheses. Estimates available upon request. * p < .5, ** p < .1, *** p < .01

Table 10: Adaptive capacity

	Change crop variety	Change crop type	Irrigate	Irrigate more	Change livestock to crop prod
Panel A: Entire sample					
Ln agric income	0.150**	0.293***	0.256***	0.266***	0.217**
	(2.65)	(36.04)	(16.40)	(19.50)	(2.94)
N	703	703	703	703	668
Panel B: For the richest household					
Ln agric income	-0.285*	-0.397***	0.320***	0.376***	-0.149
	(-2.41)	(-17.89)	(5.93)	(10.03)	(-0.60)
N	179	179	179	179	100
Panel C: For the most educated household					
Ln agric income	0.265***		0.246***	0.248***	0.0253
	(5.76)		(7.06)	(6.36)	(0.08)
N	141		141	141	57
Panel D: For the largest household					
Ln agric income	0.0196	0.266***	0.221***	0.239***	0.0468
	(0.26)	(20.70)	(8.50)	(12.44)	(0.22)
N	237	237	237	237	181
Panel E: For households that have access to electricity					
Ln agric income	-0.158	-0.296***	0.147**	0.174***	
	(-1.86)	(-24.47)	(3.01)	(4.04)	
N	334	334	334	334	

Note: t statistics in parentheses. Estimates available upon request

* p < .5, ** p < .1, *** p < .01