# Adaptation to Natural Disasters through the Agricultural Land Rental Market: Evidence from Bangladesh [*]

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**ABSTRACT** We examine the effects of natural disaster on agricultural households who make rent-in or rent-out transactions. Our econometric approach accounts for the effects of disaster-exposure both on the adjustments in the quantity of operated land and agricultural income conditional on the land quantity adjustments. Using a household survey dataset from Bangladesh, we find that farmers were able to partially ameliorate their losses from exposure to disasters by optimizing their operational farm size through these land rental transactions. Land rental market may be an effective instrument in reducing disaster risks, and post-disaster policies should consider this role more systematically. (JEL Q24, Q54, D13, D64, Q15)

*JEL Codes:* Q24, Q54, D13, D64, Q15.

*Keywords:* Bangladesh; Natural Disasters; Extensive and Intensive Margins; Land Rental Market.

## 1. Introduction

Do rental transactions benefit disaster-affected agricultural households? We investigate this question in the context of low- and middle-income countries who are highly susceptible to exposure to climate-induced natural disasters such as floods and storms (e.g., Adams *et al.* 1998).

Widespread poverty among rural households limits their ability to invest in defensive measures especially when markets are incomplete or non-existent. Consequently, natural disasters often force rural households and farmers to adopt coping strategies such as cutting back on consumption of basic food and nutrients and selling of productive assets (Jensen 2000). Other responses include selling agricultural land and seeking off-farm employment (Banerjee 2007; Mueller and Quisumbing 2011). However, because arable agricultural lands are scarce, and the sales markets are often incomplete in rural areas, farmers also engage in land rental transactions (Ward and Shively 2015). Some farmers facing exposure to disaster risks choose to rent-in agricultural land, whereas others rent-out land. These land rental transactions enable farmers to adjust their operational farm size, and thus indirectly, agricultural production.

While separate streams of literature have investigated agricultural land rental transactions as a response to disaster exposure (e.g., Ward and Shively 2015) and the revenue effects of land rental transactions (Chamberlin and Ricker-Gilbert 2016), farmers using the land rental market to adapt to natural disaster has rarely been addressed and not yet been addressed for floods or storms. Against this backdrop, we investigate the role of the land rental market in ameliorating the agricultural revenue effects of disaster exposure through a case study of Bangladesh.

Bangladesh is predominantly an agricultural country that is impacted by frequently recurring damaging disaster events. From 1900 to 2015, it experienced 89 floods, 172 storms and 71 other natural disasters (EM-DAT 2021). More recently, nine floods and 15 storms took place between 2011 and 2015 with aggregate reported losses of $264 million. Most of these losses occur to agriculture, which employs around 38 percent of the labor force and accounts for 13 percent of gross domestic product (World Bank 2021). Banerjee *et al.* (2015) found that climate change resulted in a 1.23 percent reduction in agricultural GDP, while the reduction in overall GDP is only 0.11 percent, in Bangladesh. Low average farm size and high incidence of rural poverty necessitate the optimal management and utilization of the available land. Land rental transactions serve this purpose especially in the wake of a disaster and its impact on agriculture and rural livelihoods.

We examine agricultural adaptation to natural disaster exposure via the land rental market using an econometric model of farmers' rent-in and rent-out choices. For this purpose, we adopt the standard empirical model that accounts for both the extensive margin, i.e., the revenue effect of disaster-induced adjustments in the quantity of operated land, and the intensive margin, i.e., the direct revenue effect of disaster-exposure (e.g., Moore, Gollehon, and Carey 1994; Pfeiffer and Lin 2012 and 2014). We estimate the extensive margin by a Poisson pseudo-maximum likelihood (PPML) regression model. Next, we employ a two-way fixed effect regression model to estimate the intensive margin, or the direct effect of disaster-exposure on agriculture, conditional on land rental transactions. We then calculate the total marginal effect as the sum of intensive and extensive margins of natural disaster exposure on crop profits. Data come from two rounds of the Bangladesh Integrated Household Survey (BIHS), which is the most comprehensive source of household-level socioeconomic and agricultural data in Bangladesh (Ahmed 2013). BIHS provides household-level information on exposure to natural disasters between the survey years, which allows us to examine the effects of disaster-exposure in inducing variations in crop profits for estimating the direct effect on agriculture and land rental transactions for estimating the indirect effect.

Existing literature mainly focuses on the direct effects of natural disasters on agriculture (e.g., Deschênes and Greenstone 2007; Mendelsohn, Nordhaus, and Shaw 1994). Huang, Wang, and Wang (2015) consider applied farm management measures in China in response to severe drought and flood as adaptation to climate change, and find that adaptation through farm management measures significantly increases rice yield and reduces the risk and downside risk of rice yield. In addition, some studies of the land rental market examine the welfare effects of rental transactions, but very few previous studies explore their potential role as a response to natural disasters. For example, Chamberlin and Ricker-Gilbert (2016) investigate the welfare effects of land rental transactions in Zambia and Malawi. While renting in results in positive economic returns, renting out results in negative or negligible positive returns, with both outcomes conditional on farming ability and landholding. Ward and Shively (2015) examine the effects of village-level income shocks on land rental market participation in China. They find that Chinese households engage in land rentals as a response to covariate shocks. Kusunose and Lybbert (2014) identified short-term land tenancy arrangement as a household-level coping strategy in response to drought exposure in Morocco.

To our knowledge, these are the only previous studies on the role of the land rental market in facilitating adaptation to disasters. However, their analysis did not consider the indirect effects of land rental transactions in response to a disaster on agricultural outcomes. We contribute to existing literature by estimating the resulting revenue effects of such agricultural land rental transactions. In particular, we take into account the possibility that farmers might be able to mitigate or reduce the adverse effects of disaster on crop revenue and profit through land rental transactions. We find that both flood- and storm-affected Bangladeshi farmers can use land rental transactions to overcome or reduce the direct losses from disaster exposure. We find that such mitigating effects of rental transactions are considerably greater for farmers that rent-in rather than rent-out land. Although larger farmers receive higher total marginal benefits, smaller farmers can also benefit from rent-in transactions.

Our results have important implications for Bangladesh in terms of the role of land management within a community for disaster risk reduction. In response to a natural disaster, if farmers in a rural community manage and utilize their land to increase their agricultural production, this coping strategy has been found to ameliorate adverse impacts and might even compensate for the losses from disaster-exposure (Deininger, Savastano, and Carletto 2012; Masterson 2007). In this paper, we show that access to a well-functioning land rental market can be a crucial part of the coping strategy that allows farmers to adjust their revenues. Improving and facilitating the functioning of such markets in rural areas should be an important component of government disaster risk-reduction strategies. These findings are consistent with related studies (e.g., Chamberlin and Ricker-Gilbert 2016; Kusunose and Lybbert 2014; Ward and Shively 2015), and could apply to other developing countries, although this requires further study given that sharecropping and tenural arrangements, landholding and disaster exposure can differ elsewhere compared to Bangladesh.

The outline of this paper is as follows. Section 2 discusses the background information on land rental market and natural disasters in Bangladesh. Section 3 outlines the analytical framework and identification strategy. Section 4 describes our data and variables. Section 5 reports and discusses results. Finally, Section 6 summarizes and concludes by discussing the key policy implications of the analysis.

## 2. Background

### Recent Natural Disasters in Bangladesh

Most of the land in Bangladesh is formed by a deltaic plain at the confluence of the Ganges-Brahmaputra-Meghna (GBM) rivers and their tributaries, making its alluvial soil highly fertile but vulnerable to natural disasters such as floods and storms. It has a subtropical monsoonal climate characterized by heavy seasonal rainfall, moderately warm temperature, and high humidity. Geographic location and land characteristics make Bangladesh one of the most disaster-prone countries in the world: 26 percent of the population are affected by storms and 70 percent live in flood-prone regions (Cash *et al.* 2014). Widescale flooding has been the most recurrent type of disaster striking Bangladesh, and the country remains one of the worst affected by tropical storms globally. Bangladesh experienced 172 storms and 89 floods during 1900-2015 (EM-DAT 2021). Large natural disasters with profound impacts on lives and livelihoods striking Bangladesh include the 1970 cyclone, 1986 flood, 1991 cyclone, 1998 flood and 2007 and 2009 cyclones. Apart from these major disasters, there were many smaller disasters with considerable harmful effects.

In general, cyclonic storms primarily affect the coastal regions of Southern Bangladesh whereas the northern regions are the primary victims of floods. We are particularly interested in the exposure to disasters taking place during 2013-14, i.e., the year before the second round of the BIHS survey. Between 2013 and 2014, Bangladesh experienced 2 floods and 5 storms. These natural disasters resulted in more than 100 reported deaths, whereas around 4.7 million people were affected at different degrees (EM-DAT 2021). Availability of data before (i.e., BIHS round 1) and after (i.e., BIHS round 2) allows us to consider household-level exposure to these disasters as a natural experiment.

## Common Adaptation Practices in Bangladesh

Traditional methods of farmers' adaptation to climate change and climatic extremes include use of different crop varieties, tree planting, soil conservation, early and late planting, adoption of new technologies, and irrigation (Deressa *et al.* 2009; Adams *et al*. 1998). Common adaptation practices in response to disaster-exposure in Bangladesh include crop switching, migration, and increased labor supply. For example, Moniruzzaman (2015) employed a multinomial logit model to identify that farmers adapt to changing temperature and rainfall by switching to more climate-resilient crops. However, climatic extremes require immediate responses to overcome the immediate harms, whereas a change in cropping patterns requires longer planning horizon and is more pertinent to continuous measures of climatic changes such as longer-term variations in rainfall and temperature. In addition, Penning-Rowsell, Sultana, and Thompson (2013) found that rural Bangladeshi people are less likely to permanently migrate even in the face of extreme disasters, although they may temporarily migrate to safer places. This tendency is historically true for Bangladesh: even the people affected by the 1970 great Bhola Cyclone did not migrate permanently (Sommer and Mosley 1972).[1]

In addition, as operational farm size is directly related to agricultural labor employment, using the land rental market to adjust operational farm size in response to disaster is likely also to impact labor supply in agriculture. In related research, Banerjee (2007) identified that there can be increased supply of unskilled labor in the aftermath of floods, especially to plant agricultural lands. Therefore, it is reasonable to assume that farmers may intensify farming in response to disaster-exposure; and therefore, our investigation into the role of rental transactions becomes relevant.

## Land Rental Market in Rural Bangladesh

Rural households in Bangladesh predominantly depend on agriculture for their livelihood and employment. Agriculture employs around 38 percent of the labor force in Bangladesh and contributes around 13 percent of its gross domestic product (World Bank 2021). However, due to a high level of land fragmentation and increasing population, per-capita arable land declined from 0.174 ha in 1961 to 0.049 ha in 2013 (World Bank 2021), creating increased pressure on limited land resources to produce sufficient food and other commodities. Since Bangladesh has one of the lowest average farm sizes globally, estimated at 0.344 ha per rural household (Bangladesh Bureau of Statistics 2014), many farmers rely on the land rental market to better manage and utilize the available arable land.

A study by Manusher-Jonno-Foundation (2014)[2] finds that 1 percent cultivable land diminishes annually in Bangladesh, whereas their studied households lost on average 64.3 decimals of land in last 10 years. Moreover, more than 60 percent of their studied households are marginal farmers, owning between 0.01 to 0.49 acres of agricultural land, who overwhelmingly depend on rural agricultural land rental transactions to increase the volume of their operated land.[3]

Consistent with academic literature and global practices (e.g., Allen and Lueck 1992), the most prevalent land rental categories in Bangladesh are share-cropping arrangements and cash-renting at fixed predetermined rates. Sharecropping arrangements involve the landlord to supply land for an agreed, or a pre-determined, share of crop depending on whether or not they also share the inputs necessary for agricultural production. There are two alternative sharecropping arrangements according to the Land Reform Act of 1984: 1) landlords receive 33 percent of the harvest when the sharecropper bears entire cost of production, and 2) landlords receive 50 percent if the landlord and sharecropper equally share the cost of production (Government of Bangladesh 1984; Rahman 2010). While sharecropping arrangements normally follow these official rules, cash-renting arrangements on the other hand are normally made at locally determined rates and often without any formal documentation. Unlike sharecropping, landlords do not share the crop or the cost of production in this alternative arrangement.

These rental arrangements are particularly useful to those households that do not have sufficient number of family members involved in agricultural production or that cannot afford all inputs necessary for cultivation (Taslim and Ahmed 1992). Although formal regulations are present, most land tenure arrangements are customary. Therefore, due to scarce supply of land, establishing and maintaining land ownership requires constant supervision and physical presence of the owner. The Land Reform Act of 1984 requires both the landlords and tenants to sign formal agreements according to the terms and conditions outlined in it. However, in absence of proper enforcement of existing laws, most of the agricultural land rental agreements take place without any documentation through informal markets. Consequently, such transactions normally take place between known associates with common social ties where both the parties have common knowledge about relevant information on land prices and rents, soil quality and land productivity, among others.

Although rental arrangements do not change the land ownership structure, the presence of a land rental market, mostly informal in Bangladesh like many other developing countries, is an effective way of redistributing the operational farm size among the farmers. Farmers often manage their agricultural plots to equalize the size distribution of the operating farms by either renting in additional land or renting out surplus land (Teklu and Lemi 2004; Rahman 2010). Typically, smallholders rent in land from larger farmers to increase their operational farm size, and vice-versa. For example, in 2008, 33.8 percent of rural households in Bangladesh rented at least a part of their total operated land, whereas 24.2 percent operated a combination of owned and rented lands. In addition, 9.6 percent of them operated only rented lands (Bangladesh Bureau of Statistics 2014).

## 3. Methodology

### Analytical Framework

Available studies suggest that, in areas subject to high risk but with poorly developed capital markets, land sales will likely be few and limited mainly to distress sales (Deininger and Jin 2008). In fact, most rural households consider land as a source of regular income, a security against famine and the foundation of livelihood. Moreover, especially in the rural areas, land ownership is an important element of social, political, and economic empowerment. Therefore, most of the land transactions are rentals, and not sales, in a country like Bangladesh.

Land rentals can serve as a risk coping strategy if rental decisions are made in response to shocks resulting in income losses (Ward and Shively 2015). Farmers make livelihood decisions based on their owned land, and such decisions may often be motivated by exposure to extreme climatic events. The key idea behind quantity adjustments through a land rental market is that larger farmers rent-out their surplus lands to smaller farmers, who rent-in to optimize their operational farm size. We hypothesize that this phenomenon is accelerated when such transactions take place in response to exposure to a natural disaster.

We develop a conceptual model that is similar to Skoufias (1995), Deininger and Jin (2008) and Deschênes and Greenstone (2007).[4] For simplicity, we assume that the land rental market always clears irrespective of whether or not a disaster takes place. This assumption implies that, in combination with high population density and low per-capita arable land, any increased rental transaction in response to disaster exposure must be captured by observed heterogeneity in the socioeconomic and agricultural attributes associated to the groups of households involved in rent-in and rent-out transactions. Therefore, for a representative farmer, optimal rent-in and rent-out amounts, respectively, are:

$$l^I = l^I(\tau;\ \Theta^I)$$
$$l^O = l^O(\tau; \Theta^O)' \qquad [1]$$

whereas $\Theta^I$ and $\Theta^O$ are the observed household attributes associated with a rent-in and rent-out farmer, respectively, $\tau = 1$ represents exposure to a natural disaster, and $\tau = 0$ indicates no such exposure. We suppress time and household subscripts to avoid confusions and to simplify notations.

The representative farmer produces a given mix of crops using its given endowment of productive resources including land. The farmer also obtains earnings from non-farm economic activities at an exogenously determined wage rate.[5] However, farmers normally supply non-farm labor during lean seasons (Deininger and Jin 2008), and often experience credit constraint in doing so (Woldenhanna and Oskam 2001). Therefore, rural farm labor supply can be treated as inelastic in farm wage due to lack of labor mobility between sectors and locations.[6] Considering these facts, we express output and cost as functions of operational land $l$ only. Consequently, the representative farmer maximizes the following profit function by choosing land rental amounts $l^I$ and $l^O$, which captures the effects of operational farm size adjustments on crop profits:

$$\pi = p \times (1 - \alpha\tau) \times q(l + l^I - l^O) - c(l + l^I - l^O) - I \times (r + T^I)l^I + O \times (r - T^O)l^O, \quad [2]$$

subject to equation (1). $p$, $q$, $l$, $c$ and $r$, respectively, denote agricultural price, output, amount of owned land, cost of production and the pre-fixed rent per-unit of land. Total operational farm size is $l + l^I - l^O\ \forall l^I \geq 0, l^O \geq 0$. $\alpha \geq 0$ indicates the losses in crop profits due to disaster exposure that results in lowering the productivity of operated land. $I$ is an indicator variable for rent-in: 1 if rent-in and 0 otherwise. Similarly, $O$ is an indicator variable for rent-out: 1 if rent-out and 0 otherwise.

We assume that the land rental rates are predetermined by either by the government (in case of sharecropping) or by locally practiced norms (especially in case of cash rentals) independently of the occurrence of a disaster, which is consistent with The Land Reform Act of 1984. Rental transactions also involve transaction costs, $T^I > 0$ for rent-in and $T^O > 0$ for rent-out, which are proportional to respective transaction amounts, and also not symmetric so that the net benefits from per-unit of rent-in and rent-out transactions are different (e.g., Deininger and Jin 2008). This assumption follows the theoretical finding of Carter and Yao (1999) who suggest that rent-in transaction costs are higher than the simple rental rate due to associated search costs, while the rent-out receipts are lower than the pure rental rate due to redistribution costs.

We focus on total agricultural revenue instead of per-acre yield. Since farmers maximize profits, predetermined rent allows us to normalize the productivity of each type of land, whereas the non-symmetric transaction costs ensure the existence of institutional differences in returns from rent-in and rent-out transactions.

Prices of agricultural goods can be volatile, and an increase in crop profits may largely be due to increased prices resulting from post-disaster production shortages. We empirically tackle this issue by considering farm-gate and local market prices, whichever one is available, when calculating agricultural revenues. When farm-gate and local market prices are not available, we normalize price to more aggregate levels (e.g., district or national level) by taking into account that potential relocation of agricultural operations through rental transactions to different plots of land might normalize prices over regions in a specific production year.

Since disaster-exposure affects rent-in and rent-out amounts as well as the output, we need to disentangle the direct and indirect effects of disaster exposure. Based on equation (2), changes in the representative farmer's profits due to disaster for three alternative rental market participating decisions, i.e., autarky, rent-in and rent-out, are given below in equations (3) and (4). First, for an autarkic farmer who does not participate in the land rental market:

$$Autarky: \pi_1 - \pi_0 = -\alpha p q(l), \quad [3]$$

which implies that an autarkic farmer cannot overcome the losses in crop profits $\forall \alpha > 0$, and breakeven only when $\alpha = 0$. Subscripts $0 \ and \ 1$ denote $\tau = 0 \ and \ \tau = 1$, respectively. Next, for rent-in and rent-out farmers:

$$\begin{array}{ll} rent\ in: & \pi_1 - \pi_0 = p\Delta q^I - \Delta c^I - (r + T^I)\Delta l^I \\ rent\ out: & \pi_1 - \pi_0 = p\Delta q^O - \Delta c^O + (r - T^O)\Delta l^O, \end{array} \quad [4]$$

where for a rent-in farmer, $\Delta q^i = (1-\alpha)q(l + l_1^I) - q(l + l_0^I)$; $\Delta c^I = c(l + l_1^I) - c(l + l_0^I)$; and $\Delta l^I = l_1^I - l_0^I$. Here, $\alpha \geq 0$ governs the direct effect of disaster exposure, whereas $l_1^I$ and $l_0^I$ govern the indirect effect of disaster on agriculture through the land quantity adjustments. The expression $(r + T^I)$ refers to the per-unit cost for rented in land, i.e., the cash and kind payments made for the use of rented in land. On the other hand, for a rent-out farmer, $\Delta q^O = (1-\alpha)q(l - l_1^O) - q(l - l_0^O)$; $\Delta c^O = c(l - l_1^O) + c(l + l_0^O)$ ; and $\Delta l^O = l_1^O - l_0^O$. Similar to the case for a rent-in farmer, $\alpha \geq 0$ governs the direct effect of disaster exposure, whereas $l_1^O$ and $l_0^O$ govern the indirect effect of disaster for a rent-out farmer. The expression $(r - T^O)$ refers to the per-unit cash and kind receipts from rented out land. In addition, we must have

$\Delta l^I > 0$ *and* $\Delta l^O = 0$ for a rent-in farmer, $\Delta l^O > 0$ *and* $\Delta l^I = 0$ for a rent-out farmer and $\Delta l^I = \Delta l^O = 0$ for an autarkic farmer.

Rental market participating roles are therefore affected by disaster exposure, and their corresponding transactions have indirect effects on crop profits. However, rental transactions are conditional on a number of socioeconomic factors. Rent-in and rent-out farmers must exhibit sufficient heterogeneity in their socioeconomic attributes, i.e., $\Theta^I \neq \Theta^O$, in order for the indirect beneficial effects of land rental transactions to exist. That is, socioeconomic attributes vary across farmers' rental market participating roles and, therefore, optimal adjustment of farm size through rental transactions must be conditioned on them.

**Empirical Specifications**

We examine the effects of disaster-exposure on agricultural outcomes, controlling for land quantity adjustments through farmers' participation and transaction decisions in the land rental market, using an econometric approach that accounts for extensive and intensive margins. The intensive margin measures the direct effects of disaster on crop profits, whereas the extensive margin considers the potentially mitigating effects of disaster-induced land quantity adjustments on the harms of disaster. Note that, we restrict our estimation to agricultural plots to avoid any potential bias that might arise from multiple uses of land plots.

We estimate the effects of disaster exposure on land quantity adjustment through the rental market. However, as Figure 1 shows, both the rent-in and rent-out amounts are left-censored due to farmers' participation decisions: a positive amount of land brought into rental market for either renting-in or renting-out is observed only when a farmer decides to participate in the rental market. Moreover, Figure 2 confirms that both the rent-in and rent-out amounts are left-censored for the subsamples of flood and storm affected and unaffected households. Thus, the participating samples are nonrandom, and are drawn from a wider population of farmers.

*[Figure 1]*

*[Figure 2]*

Therefore, to capture their participation decisions, we employ a Poisson pseudo-maximum likelihood (PPML) model proposed by Silva and Tenreyro (2006) and Silva and Tenreyro (2010). The PPML model estimates Poisson regression by pseudo-maximum likelihood to identify and drop regressors that may cause the nonexistence of the (pseudo-) maximum likelihood estimates. Based on the maximum-likelihood estimation method, the PPML can be used for any kind of outcome variable provided that the mean function is correct (Wooldridge 1999). There are multiple benefits of using this approach instead of alternatives such as tobit models. First, PPML provides fully robust estimator of conditional mean parameters, and overcomes many restrictive assumptions that the tobit estimates are based on. Next, it allows controlling for time and panel fixed effects – an important limitation that makes tobit estimates less attractive. It, therefore, overcomes heterogeneity problem pertinent to many panel datasets. Third, instead of only basing the estimates only on the participants as in tobit models, the estimating sample in PPML is representative of both the participants and non-participants in the whole sample. Therefore, estimated coefficients are more directly interpretable, and can be compared to corresponding OLS estimates. Finally, in statistical package stata, this approach directly fits a semi-log specification where the outcome variable is automatically expressed in natural log form so that the estimated coefficients are interpreted as semi-elasticity with respect to the respective explanatory variable.

Although the same group of farmers can be involved in both rent-in and rent-out transactions (Rahman 2010),[7] only around 5 percent of farmers from our estimating sample make simultaneous rent-in and rent-out decisions on different plots of agricultural land. Moreover, related literature generally treats rent-in and rent-out farmers as two separate groups of people with distinct attributes (e.g., Kung 2002; Deininger, Zegarra, and Lavadenz 2003; Teklu and Lemi 2004; Deininger and Jin 2005; Vranken and Swinnen 2006; Masterson 2007; Holden, Deininger, and Hosaena 2007). Therefore, assuming that rent-in and rent-out are two independent decisions, our econometric investigation involves separate estimations different rental market roles.

At any point in time, the decision to participate in the land rental market and the optimal rent-in and rent-out amounts by each farmer can be estimated as a two-step process. First, a farmer $i$ participates in the land rental market in time $t$ according to the following linear probability model (LPM) with two-way fixed effects:

$$\begin{aligned} I_{it} &= \beta_{I0} + \beta_{I1}(flood_i \times post_t) + \beta_{I2}(storm_i \times post_t) + x_i\gamma_I + \Delta_i + \rho_t + \varepsilon_{I,it} \\ O_{it} &= \beta_{O0} + \beta_{O1}(flood_i \times post_t) + \beta_{O2}(storm_i \times post_t) + x_i\gamma_O + \Delta_i + \rho_t + \varepsilon_{O,it}, \end{aligned} \quad [5]$$

where the binary outcome variables representing farmer's willingness to participate in the land rental market, $I_{it}$ and $O_{it}$, are defined as $I_{it} = 1$ if the farmer rents in land and 0 if not and $O_{it} = 1$ if the farmer rents out land and 0 if not. Despite the binary nature of the dependent variable, LPMs provide good estimates of the partial effects for average values of the explanatory variables, suffer less from measurement errors, and the coefficients allow for a straightforward interpretation of the effects (Wooldridge 2010). We report robust standard errors, clustered at union level, to overcome the heteroskedasticity problem.

The dummy variable $flood_i$ denotes flood exposure: 1 if household $i$ is affected by any flood between the BIHS rounds 1 and 2 and 0 if not. Similarly, $storm_i$ denotes storm exposure: 1 if household $i$ is affected by any storm between the BIHS rounds 1 and 2 and 0 if not. $post_t$ denotes post-disaster year: 1 if BIHS round 2 and 0 if BIHS round 1. $\Delta_i$ and $\rho_t$ are the household and survey round fixed effects to control for any potential omitted variable bias. Due to the inclusion $\Delta_i$ and $\rho_t$, collinear variables $flood_i$, $storm_i$ and $post_t$ drop out from our estimating regressions.

We are interested in the coefficients of the interaction terms. In particular, $\beta_{I1}$ and $\beta_{O1}$, the coefficients of $(flood_i \times post_t)$, estimate the effects of flood exposure on rental participations, whereas $\beta_{I2}$ and $\beta_{O2}$, the coefficient of $(storm_i \times post_t)$, estimates that for storm exposure. Since disaster-exposed farmers either experience floods or storms, we do not consider the possibility of multiple disaster types in our empirical specification.

Farmers' adaptation is also associated with characteristics of households and local communities (e.g., Skoufias 1995). Therefore, our empirical approach to estimating (5) involves specifying the components of the vector $x_i$ based on the information available in the BIHS dataset. We follow existing literature to specify generic determinants, $x_i$, of agricultural land rental decisions, which commonly include household- and farm-level characteristics (e.g., Taslim and Ahmed 1992; Deininger, Zegarra, and Lavadenz 2003; Teklu and Lemi 2004; Deininger and Jin 2005; Rahman 2010; Skoufias 1995). A household is a group of people who live together and take food from the same pot. The BIHS considered a household member as someone who has lived in the household at least 6 months, and at least half of the week in those months (Ahmed 2013). Household characteristics include the age of the household head, years of schooling of the highest educated family member, and household size. Farm-level characteristics include ownership of tractor or plough-yoke and access to agricultural facilities; whereas agricultural facilities include agricultural extension services (defined as 1 if the household has access to agricultural extension services and 0 if not) and subsidy (defined as 1 if the household has received agricultural subsidy and 0 if not).[8,9]

We also control for infrastructural variables: proximity to public transportation (defined as 1 if the household is located within 1 kilometer of a bus stop, main road or train station; 0 if otherwise) and public finance (1 if the household is located within 2 kilometers of a Bank or a microfinance NGO; 0 if otherwise). Typically, proximity to public transportation measures both the access to market and access to non-agricultural employment which might also have mitigating effects on the harms of disaster-exposure. Controlling for access to non-agricultural employment is important. For example, Kung (2002) found that Chinese households with active participation in off-farm labor markets have rented less land. On the other hand, proximity to public transportation and public finances indirectly controls for the non-agricultural and commercial use of a plot of land. Generally, better access to such infrastructural facilities lowers the dependency on agriculture, and, therefore, may affect rental market participation and transactions. Moreover, in absence of a direct measure of migration in response to disaster-exposure, infrastructural variables also control for farmer's likeliness to migrate to unaffected or urban areas. Finally, we additionally control for exposure to idiosyncratic shocks and long-term variations in monsoon rainfall.

In our empirical analysis, household's endowments of family labor, tractor, and access to facilities such as subsidy, extension services and transportation are treated as exogenous. However, these resources are often endogenous since households may determine their optimal levels through different means. For example, family labor can be adjusted through migration and gestation, and tractor can be traded in the market. However, such adjustments can take a longer planning horizon. To be effective, migration or gestation can only adjust labor endowment after a certain time. Therefore, it can be assumed exogenous in the short run. Similarly, in agricultural society, selling of tractors or plough-yoke is extremely rare and done mostly during extreme liquidity crises. Finally, in Bangladesh, access to abovementioned facilities becomes publicly available only when such facilities are built by the government.

While this will remain a limitation, since appropriate instruments for these potentially endogenous variables are either unavailable or difficult to conceive, we follow the tradition of Skoufias (1995) and treat them to be determined outside of the model.

We next investigate rental transactions using the PPML regression models:

$$\begin{aligned} \ln LI_{it} &= \alpha_{I0} + \alpha_{I1}(flood_i \times post_t) + \alpha_{I2}(storm_i \times post_t) + x_i\delta_I + \Delta_i + \rho_t + \xi_{I,it} \\ \ln LO_{it} &= \alpha_{O0} + \alpha_{O1}(flood_i \times post_t) + \alpha_{O2}(storm_i \times post_t) + x_i\delta_O + \Delta_i + \rho_t + \xi_{O,it} \end{aligned}, \quad [6]$$

where $\xi_{I,it} \sim (0, \sigma_{\mathrm{I}}^2)$ and $\xi_{O,it} \sim (0, \sigma_{\mathrm{O}}^2)$. Vector $x_i$ is as described for equation (5). We define the outcome variables, $\ln LI_{it}$ and $\ln LO_{it}$, as the natural logs of hectares of agricultural land rented in and rented out by farmer $i$ in time $t$. The PPML approach directly fits a semi-log specification where the outcome variable is automatically expressed in natural log form so that the estimated coefficients are interpreted as semi-elasticity with respect to the respective explanatory variable.

Effects of disasters on crop profits are conditional on rent-in and rent-out amounts, which are determined by equation (6), according to farmers' corresponding participating roles in the rental market. We employ following two-way fixed effect panel regression models to estimate the effects of disaster on farmer $i$ in time $t$ by participating roles $I$ (i.e., rent in) or $O$ (i.e., rent out):

$$\begin{aligned} Y_{I,it} &= \varpi_{I0} + \phi_I \widehat{LI}_{it} + \varpi_{I1}(flood_i \times post_t) + \varpi_{I2}(storm_i \times post_t) + \Delta_i + \rho_t + \epsilon_{I,it} \\ Y_{O,it} &= \varpi_{O0} + \phi_O \widehat{LO}_{it} + \varpi_{O1}(flood_i \times post_t) + \varpi_{O2}(storm_i \times post_t) + \Delta_i + \rho_t + \epsilon_{O,it} \end{aligned}, \quad [7]$$

where $\widehat{LI}_{it}$ and $\widehat{LO}_{it}$ are predicted rental transactions amounts from equation (6). $Y_{it}$ represents the measure of agricultural outcomes: crop *profits*. We include all harvested crops and their local market prices reported by farmers when calculating profits, which are then expressed in thousands of US$ in PPP terms. We deduct the cost of production and the monetary value of all the cash and kind payments made for rented-in land from the market value of total harvested crops, and then add the monetary value of all the cash and kind receipts from rented-out land, to calculate crop profits.

In fact, we adopt a modified Ricardian model in (7) where we use total crop profits as our outcome variable instead of land value to capture the effects of disaster exposure in agriculture. The use of profits is particularly appropriate in this set-up since land markets are often imperfect in Bangladesh like many other developing countries (Di Falco, Veronesi, and Yesuf 2011), and the use of land values requires fully functioning land markets so that land prices reflect the present discounted value of land rents into the infinite future (Deschênes and Greenstone 2007).

Predicted rent-in and rent-out amounts in equation (7) connect the coefficients of the components of $z_i$ in (6) with the outcome variable in (7) and, therefore, yield the indirect effects or extensive margins of disaster-exposure through land rental transactions. On the other hand, $\varpi_1$ and $\varpi_2$, i.e., the coefficients of $(flood_i \times post_t)$ and $(storm_i \times post_t)$ in (7), yield the direct effects or intensive margins of disaster-exposure on crop profits. Following Moore, Gollehon, and Carey (1994), the total margins, or total marginal effects, of disaster-exposure is the sum of the effects along the intensive and extensive margins for the land rental market participants:

$$\begin{matrix} \frac{dY_{I,it}}{dflood_i \times post_t} = \varpi_{I1} + \phi_I \times \frac{d\widehat{LI}_{it}}{dflood_i \times post_t} & \frac{dY_{I,it}}{dstorm_i \times post_t} = \varpi_{I2} + \phi_I \times \frac{d\widehat{LI}_{it}}{dstorm_i \times post_t} \\ \frac{dY_{O,it}}{dflood_i \times post_t} = \varpi_{O1} + \phi_O \times \frac{d\widehat{LO}_{it}}{dflood_i \times post_t} & \frac{dY_{O,it}}{dstorm_i \times post_t} = \varpi_{O2} + \phi_O \times \frac{d\widehat{LO}_{it}}{dstorm_i \times post_t} \end{matrix}, \quad [8]$$

where $\varpi_{I1}$ and $\varpi_{I2}$ are the intensive margins from rent in transactions in response to flood and storm exposures, respectively. Similarly, $\varpi_{O1}$ and $\varpi_{O2}$ are the intensive margins from rent out transactions in response to flood and storm exposures.

The corresponding extensive margins for flood and storm are $\phi_I \times \frac{d\widehat{LI}_{it}}{dflood_i \times post_t}$ and $\phi_I \times \frac{d\widehat{LI}_{it}}{dstorm_i \times post_t}$ for rent in transactions, and $\phi_O \times \frac{d\widehat{LO}_{it}}{dflood_i \times post_t}$ and $\phi_O \times \frac{d\widehat{LO}_{it}}{dstorm_i \times post_t}$ for rent out transactions. Respective coefficients of the interaction terms in (6) are expressed as semi-elasticity, which were then transformed to marginal effects according to:

$$\begin{array}{ll} \frac{d\widehat{LI}_{it}}{dflood_i \times post_t} = \frac{\alpha_{I1}}{100 \times LI_{it}} & \frac{d\widehat{LI}_{it}}{dstorm_i \times post_t} = \frac{\alpha_{I2}}{100 \times LI_{it}} \\ \frac{d\widehat{LO}_{it}}{dflood_i \times post_t} = \frac{\alpha_{O1}}{100 \times LO_{it}} & \frac{d\widehat{LI}_{it}}{dstorm_i \times post_t} = \frac{\alpha_{O2}}{100 \times LO_{it}} \end{array}. \qquad [9]$$

## 4. Data and Variables

Data for our analysis comes from two rounds of the Bangladesh Integrated Household Survey (BIHS). The USAID-funded survey was designed and supervised by the International Food Policy Research Institute (IFPRI), administered by Data Analysis and Technical Assistance, Dhaka, Bangladesh, and approved for publication by the Government of Bangladesh (Ahmed 2013). The first round of the BIHS dataset was collected between October 2011 and March 2012. Statistically, BIHS is nationally representative of the rural areas of each of the seven administrative divisions of Bangladesh, with a sample size of 6,500 rural households from 325 primary sampling units. The second round of the survey was collected from January to June in 2015 (Ahmed 2016), which was administered on the same sample of households surveyed in the baseline creating a two-round panel, when 6,260 households from the baseline survey were re-interviewed. However, we exclude 1,127 households who have not reported their agricultural revenues and rental transactions, and 5 households who were affected by both floods and storms. Therefore, our estimating sample consists of 5,128 rural agricultural households. Table 1 describes and summarizes the variables we use in the empirical analysis of this paper.

The BIHS dataset reports information on a household's exposure to any negative shock – both idiosyncratic shocks (e.g., death of main earner, loss of a regular job, loss of assets, crop loss and loss or decrease of remittances) and covariate shocks (e.g., natural disasters). We are particularly interested in household-specific reporting of exposure to natural disasters such as floods and storms. These disasters affect 3% of the surveyed households in between BIHS rounds 1 and 2 (Table 1). We use the self-reported household-level exposure to disaster from the BIHS in our subsequent analysis, therefore overcoming the limitations of regional level disaster-exposure data. Most of the small-scale disasters affect specific regions of Bangladesh. However, certain regions experience recurring events of natural disasters, therefore making it difficult to identify random treatment and control groups at the regional level. Moreover, the EM-DAT database only reports a disaster if one of these four criteria is fulfilled: 1) 10 or more people are reported killed, 2) 100 or more people are reported affected, 3) declaration of a state of emergency, and 4) call for international assistance. In many cases, this restricts identification of the number of affected people, and therefore, underestimates the potential effects of disaster exposure at the household level.

*[Table 1]*

The BIHS dataset contains information on farm and non-farm incomes in addition to detailed reporting on revenues and costs associated to crop cultivation, which we used to derive our outcome variables measuring welfare. All monetary values are expressed in thousands of US dollars in PPP terms at the rates of 26.61 and 21.87 Bangladeshi Taka per US$ for BIHS rounds 1 and 2, respectively. Table 1 reports that on average, crop profits are evaluated at $1,695 and $887 in 2011 and 2015, respectively. Crop profits are adjusted for the cost of production, cash and kind (imputed) receipts from rented out land and cash and kind (imputed) payments made for rented in land.

Table 1 also reports land management variables, including farmers' land rental market participation and transaction decisions. All land measures are expressed in hectares, where 1 decimals = 0.00405 hectares. In 2011, a total of 40 percent farmers participate in the land rental market in order to rent-in 0.13 ha lands on average, whereas 22 percent farmers participate in the land rental market to rent-out 0.08 ha land on average. These rental transactions increase operational farm size from 0.13 ha (which is farmer's owned-operated land) to 0.26 ha (which includes rented-in land and excludes rented-out land). Similarly, in 2015, a total of 37 and 26 percent farmers participate in the land rental market to rent-in 0.12 ha and rent-out 0.09 ha of agricultural land. Operational farm size remains at similar levels, 0.26 ha in 2011 and 0.25 ha in 2015, albeit these rental transactions.

However, such rental transactions are conditional on a number of socioeconomic factors such as household, farm and regional attributes. Table 1 reports the baseline summary statistics of all the explanatory variables used in the empirical analysis in this paper. All data comes from the BIHS dataset round 1. On average, household size is 4.24 and household heads are 45 years old, whereas 85 percent of them are males. The highest educated member in the family has 6.6 years of schooling on average. Eleven percent of farmers owns tractors or plough-yokes which is an important technology for cultivation in rural Bangladesh. Seven and 10 percent of farmers, respectively, benefit from agricultural extension services and agricultural input subsidy. On average, 62 percent households are located within 1 kilometer of a bus stop, main road or a train station; whereas 26 percent are located within 2 kilometers of a bank or a source microcredit.

We use rainfall data from Bangladesh Department of Meteorology (BMD) which is an organization under the Ministry of Defense of the Government of Bangladesh responsible for maintaining the weather stations and collecting daily weather data including rainfall and temperature at the station-level. BMD website provides monthly average rainfall data from 1980 to 2013. We take the difference between the average rainfall over the monsoon months of June-September for 2006-10 and 1980-2010 for BIHS round 1, and 2009-13 and 1980-2010 for BIHS round 2.

## 5. Results and Analysis

### Preliminary Results

Table A2 reports unconditional mean comparison between affected and unaffected households for both the participation and transaction decisions. Results provide preliminary confirmation of increased participation in and transaction of rented lands due to disaster-exposure.

Using data from BIHS round 1 only, results in Table A3 confirm that flood and storm affected and unaffected do not have different rental transactions before their exposure to those disasters. Therefore, regression specification (6) provides causal relationship between disaster exposure and rental transactions.

However, Table A3 provides mixed results from base year variations in outcome variables by flood and storm exposures. In particular, we do not observe any statistically significant variations in outcome variables for storm exposure. However, participation in rent in transactions is statistically significantly higher for flood affected households in the base year. Furthermore, Table A4 reports base year variations in control variables by flood and storm exposures. Once again, some of the household and farm level attributes vary by disaster exposure. Therefore, we keep baseline control variables in all our regressions based on specifications (5) and (6).

## Rental Market Participation and Transactions

Table 2 reports the determination of farmers' land rental market participation decisions. Participation choices, i.e., rent-in and rent-out, are estimated using two-way fixed effects linear probability models according to specification (5), where the binary dependent variables are rent-in (i.e., 1 if the farmer rents in land and 0 if not) and rent-out (i.e., 1 if the farmer rents out land and 0 if not). Control variables are jointly significant, and exhibit expected directions of relationship with the corresponding dependent variable. Inclusion of control variables does not change the directions of relationship of our key parameters of interest, rather improves the model's explanatory power.

We find that both flood and storm exposures increase the probabilities of rent-in and rent-out by affected households. In particular, the probability of renting in increases by 4.6 percent for the flood affected households and 4.7 percent for the storm affected households. On the other hand, the probability of renting out increases by 2.9 percent for the flood affected and 2.1 percent for the storm affected households. That is, affected households have similar land adjustment in response to either of the disasters.

*[Table 2]*

Next, Table 2 also reports the determination of land rental market transactions using PPML regressions with two-way fixed effects regression models according to equation (6). Outcome variables are natural log of hectares of agricultural lands rented in and rented out by the households. As expected, estimated directions of relationships for rental transactions corroborate those from LPM regressions for rental market participations.

We find that both flood and storm exposures increase both rent in and rent out transactions. Flood exposure increases the rent-in amount by 31.4 percent and rent-out amount by 33.9 percent. On the other hand, storm exposure increases the rent-in amount by 13.2 percent and rent-out amount by 33.5 percent. These results confirm that disaster exposure stimulates the land rental transactions.

Among the household characteristics, age of the household head represents an indirect, but commonly used, measure of farming experience. Experienced farmers may be more dependent on agriculture and require more operational lands. Our results quite fittingly identify a statistically significant positive relationship between age and rent-in and rent-out amounts. These results are consistent with Kung (2002) and Vranken and Swinnen (2006) who found positive influence of age on land rental transactions.

Family size represents subsistence pressure on the household (e.g., Rahman 2010; Teklu and Lemi 2004; Kung 2002). Therefore, larger families that may have higher number of dependent members will need higher operational farm size. Consistent with this prediction, we identify a statistically significant positive relationship between family size and rent-in amounts. However, we do not find any significant relationship between family size and rent out amounts. Therefore, higher subsistence pressure necessitates increasing operational farm size, and, therefore, results in increased dependency on agriculture. These results are consistent with the findings Kung (2002) that higher dependency ratio increases the likeliness to rent in.

We find that the households with better education level, measured by the years of education of the highest educated household member, rent-in more. Although schooling is an indicator of household's likeliness to have a non-agricultural source of income (Eskander, Barbier, and

Gilbert 2018), and education increases the opportunity cost of agricultural income (e.g., Teklu and Lemi 2004), these rural households have only 6.6 average years of education in 2011 and 7.5 years in 2015. Therefore, instead of substituting their time away from agricultural production, they find it more suitable to increase their agricultural activities.

Our results also confirm the stylized fact behind land quantity adjustment: larger farmers rent-out and smaller farmers rent-in to optimize their corresponding operational farm sizes. We find that owning 1-hectare additional land decreases rent in amounts by 90.4 percent and increases rent out amounts by 110.3 percent.

Among the farm-level characteristics, owners of tractor or plough-yoke have higher rent-in amounts and lower rent-out amounts. Although they can use their tractor and plough-yoke commercially, they rather find it more beneficial to rent more lands in (and less lands out) so as to be able to increase their agricultural incomes. These results are consistent with the stylized fact that rural agricultural households have lower opportunity cost of cultivating their own land.

Households availing agricultural extension services and receiving agricultural subsidies have higher amounts of rent-in and rent-out. On the other hand, households with better access to have lower rental transactions. Finally, the proximity to public transportation, an indicator of access to market which can make agricultural activities more profitable, increases both the rent-in and rent-out amounts.

### Direct Welfare Effects of Disaster Exposure

Next, we move to the investigation of direct effects of disaster exposure on crop profits, controlling for rental transactions. Table 3 reports the results from employing two-way fixed effect panel regressions for different rental market participating roles according to equation (7).

*[Table 3]*

Table 3 reports the effects of flood and storm exposures on crop profits for both the groups of farmers. Estimated effects are similar by the types of disaster: both the flood and storm exposures reduce crop profits of both the rent-in and rent-out farmers.

For rent-in farmers, flood and storm exposures lower crop profits by $570 and $788, respectively. Similarly, for rent-out farmers, flood and storm exposures lower crop profits by $470 and $751, respectively.

The coefficients of estimated rental transactions, which connect the rental effects of disaster-exposure on crop profits along the extensive margins, confirm that the rent-in transactions can have mitigating effects. Results show that 1 ha additional rented-in land increases crop profits by $571. However, rent-out transactions further reduce crop profits: 1 ha additional rented-out land decreases crop profits by $91. That is, such mitigating effects of rental transactions are considerably greater for rent-in than rent-out transactions, which can be explained by the distribution of crop revenues: rent-out farmers only receive the rent whereas rent-in farmers receive the benefits from harvested crops.

**Intensive and Extensive Margins**

We are mainly interested in the total marginal effects of disaster-exposure on crop profits, which can be calculated using the equation (8) as the sum of intensive and extensive margins. All the calculations are based on the coefficients of rent-in and rent-out amounts and disaster exposure, as reported in Tables 2 and 3 according to equations (6) and (7). Table 4 reports the intensive, extensive and total margins for both the participating roles, where the top and bottom panels report the margins for flood and storm exposures, respectively.

First, Table 3 reports the effects of disaster on crop profits along the intensive margins conditional on land quantity adjustments for both the participating roles (i.e., $I$ and $O$) separately. We then use these estimated coefficients to calculate the intensive margins as defined in equation (8).

Table 4 reports intensive margins that come directly from Table 3. Apparently, irrespective of the type of disaster and rental market participating role, farmers experience negative intensive margins from their exposure to floods or storms.

Following equation (8), we multiply the estimated effects of disaster-exposure on land rental transactions from Table 2 with the estimated effects of rent-in and rent-out land on crop profits from Table 3 to calculate the corresponding extensive margins.

*[Table 4]*

The estimated extensive margins are zero for autarkic farmers, whereas they are positive for rent-in and negative rent-out transactions. Calculated results in Table 4 show that the indirect effects of disaster exposure along the extensive margins for rent-in transactions are [$0.2, $221] with an average of $12 for flood-affected, and [$0, $93] with an average of $5 for storm-affected rent-in farmers. On the other hand, renting out, which works as a channel of risk avoidance, is associated with extensive margins of [-$77, $0] and [-$76, $0] for flood and storm affected rent-out farmers, respectively.

Finally, we obtain total marginal effects of disaster-exposure as the sum of intensive and extensive margins according to equation (8). The calculated total margins are [-$570, -$349] and [-$788, -$695] for flood and storm exposures for rent-in farmers, respectively; and [-$546, -$470] and [-$827, -$751] for rent-out farmers.

Although some rent-in farmers have negative extensive margins, a comparison between intensive and total margins reveals that all the rent-in farmers on average were able to reduce their losses from disaster exposure through land rental transactions. Overall, positive, or less negative, ranges of total margins then suggest that the rent-in transactions convey sufficient indirect benefits for the participating farmers so as to overcome the losses from exposure to floods and storms.

Therefore, rent-in farmers are better-off by increasing their operational farm size. Evaluated at the respective mean values, flood-exposure results in $570 direct decrease in crop profits (average intensive margins), which is then partially compensated by $12 indirect increase in profits through rent-in transactions (average extensive margins). Altogether, we find a $559 net decrease in crop profits of the flood-exposed rent-in farmers. On the other hand, storm-affected rent-in farmers were on average able to reduce their direct losses of $788 (average intensive margins) by $5 (average extensive margins). Overall, our estimates of average marginal effects of disaster-exposure for rent-in farmers are consistent with the general findings of Mendelsohn (2008) that adaptation by farmers will partially offset some of the worst predicted damages to agriculture due to warming in developing countries over the next century.

For rent-out farmers, although renting out lands can outsource the risks associated to carrying out agricultural operations, they were not able to reduce the harms of disaster exposure. Their direct losses from disaster exposure have further been exacerbated by a small indirect loss of $3 due to rent out transactions.

## 6. Conclusions

We examine the role of agricultural land rental transactions as an indirect source of adaptation to direct losses from exposures to floods and storms in Bangladesh. For disaster exposure, we compare farmers who rent-in or rent-out with the autarkic farmers by employing an econometric approach based on Moore, Gollehon, and Carey (1994) and Pfeiffer and Lin (2014) that accounts for both the intensive and extensive margins for disaster-induced rental transactions. We find that, while a natural disaster directly harms farmers through lowering crop profits and income, they can reduce those losses by adjusting their operational farm size by renting in more agricultural land.

Our results have important implications for Bangladesh and other developing countries in terms of land management, economic welfare and disaster risk reduction. In general, low and middle-income countries have a high degree of land fragmentation, severe incidence of rural poverty and low per-capita arable land, contributing to increasing number of farms to increasingly depend on rented lands for managing operational farm size (Deininger, Savastano, and Carletto 2012; Jin and Jayne 2013; Masterson 2007). Here, we find another important function of the land rental market in poor rural areas, which is to assist farmers in adapting to the adverse impacts of natural disasters on agriculture. Such a mechamism may become increasingly important, if climate change results in more frequent and intense natural disasters, such as floods, cyclones and other hazardous events. As farmers appear to employ the land rental market to adjust the quantity of operational land in response to the losses of past disasters and to mitigate the potential losses of future disasters, the land rental market provides a useful mode of adaptation relevant for managing recurrent disaster exposure.

As access to a well-functioning land rental market might be a crucial to enabling farmers to respond to natural disasters, improving and facilitating the functioning of such markets in rural areas should be an important component of government's post-disaster relief policies. Of particular concern is that the land rental market in rural areas of Bangladesh, as well as in many other developing countries, is an informal institution. More research needs to be conducted on how well such informal land rental markets function in the aftermath of natural disasters, and whether more formal markets would facilitate the role of the rental market in assisting farmers to adjust to the agricultural revenue impacts of disasters. Future research may also explore the environmental impacts of such land quantity adjustment as an adaptation strategy.

Finally, while the estimates of total marginal effects confirm that both the storm- and flood-affected farmers were able to benefit from land rental transactions, our results for flood exposure need to be interpreted with caution due to increased soil fertility at the aftermath of floods. Floods probably provide open-access irrigation coverage for the affected land plots in the subsequent cropping seasons (Banerjee 2010a), which may result in increased agricultural income of the flood-affected farmers (Banerjee 2010b). Future research on this topic may also consider incorporating such flood-induced soil fertility effects. Moreover, future work could also extend the analysis here to include newer rounds of the BIHS data. Such an extension could also benefit from high-resolution locational meteorological data, especially when they become available at the village level, for comparing satellite and self-reported data on natural disasters (Guiteras et al. 2015).

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# Tables

**Table 1**

Summary Statistics

| Variables | Description of the variable | Survey Rounds BIHS 2011 | BIHS 2015 |
|---|---|---|---|
| Flood | 1 if the household was exposed to floods between BIHS 1 and 2; 0 if not | 0.0314<br>(0.174) | 0.0314<br>(0.174) |
| Storm | 1 if the household was exposed to storms between BIHS 1 and 2; 0 if not | 0.0324<br>(0.177) | 0.0324<br>(0.177) |
| Profit | Total farm profits from cultivation, adjusted for rental transactions and costs of production | 1.695<br>(2.734) | 0.887<br>(1.924) |
| Tenants | 1 if participates in rent in transactions; 0 if otherwise | 0.399<br>(0.490) | 0.366<br>(0.482) |
| Rent in land | Total area of rented in and operated arable land (ha) | 0.130<br>(0.268) | 0.124<br>(0.301) |
| Landlords | 1 if participates in rent out transactions; 0 if otherwise | 0.220<br>(0.414) | 0.256<br>(0.436) |
| Rent out land | Total area of rented out arable land (ha) | 0.0766<br>(0.259) | 0.0903<br>(0.275) |
| Landholding | Total area of owned arable land (ha) | 0.208<br>(0.427) | 0.218<br>(0.450) |
| Age | Age of the household head (completed years) | 44.99<br>(13.68) | 47.84<br>(13.35) |
| Family size | Number of family members in the household | 4.245<br>(1.562) | 4.875<br>(1.827) |
| Education | Years of education of the highest educated family member | 6.612<br>(3.657) | 7.452<br>(3.604) |
| Extension | 1 if the household was in contact with agricultural extension services in the last 12 months; 0 if otherwise | 0.0727<br>(0.260) | 0.0811<br>(0.273) |
| Subsidy | 1 if the household holds an agricultural subsidy card; 0 if otherwise | 0.105<br>(0.307) | 0.168<br>(0.374) |
| Transportation | 1 if the household is located within 1 kilometer of a bus stop, main road or train station; 0 if otherwise | 0.621<br>(0.485) | 0.701<br>(0.458) |
| Finance | 1 if the household is located within 2 kilometers of a Bank or a microfinance NGO; 0 if otherwise | 0.264<br>(0.441) | 0.242<br>(0.428) |
| Tractor | 1 if the household owns a tractor or plough-yoke; 0 if otherwise | 0.109<br>(0.311) | 0.0764<br>(0.266) |
| Idiosyncratic shock | 1 if the household experienced any idiosyncratic shocks between BIHS 1 and 2; 0 if not | 0.363<br>(0.481) | 0.363<br>(0.481) |
| Rainfall deviation | Deviation of monsoon rainfall from long-term average level of rainfall | -18.92<br>(25.02) | -21.86<br>(23.49) |

*Notes.* Standard deviations are shown in parentheses. All data comes from the Bangladesh Integrated Household Survey (BIHS) dataset rounds 1 and 2. All monetary values are expressed in '000 US$PPP at the rates 26.61 and 21.87 Bangladeshi Taka for BIHS rounds 1 and 2, respectively. All land measures are expressed in hectares, where 100 decimals = 1 acres = 0.405 hectares.

**Table 2**

Participation and Transaction Decisions

| | Participation | | Transactions | |
|---|---|---|---|---|
| Variables | Pr(Rent in) | Pr(Rent out) | Rent in | Rent out |
| Flood × Post-year | 0.046 | 0.029 | 0.314** | 0.339 |
| | (0.060) | (0.055) | (0.144) | (0.250) |
| Storm × Post-year | 0.047 | 0.021 | 0.132 | 0.335** |
| | (0.049) | (0.039) | (0.101) | (0.133) |
| Age | 0.005 | 0.002 | 0.021** | 0.025* |
| | (0.005) | (0.003) | (0.010) | (0.013) |
| Family size | 0.003 | -0.003 | 0.056* | 0.001 |
| | (0.011) | (0.009) | (0.030) | (0.036) |
| Landholding | -0.267*** | 0.501*** | -0.904*** | 1.103*** |
| | (0.073) | (0.088) | (0.198) | (0.287) |
| Education | 0.004 | -0.000 | 0.020** | -0.021 |
| | (0.004) | (0.003) | (0.010) | (0.016) |
| Extension | 0.091*** | -0.001 | 0.205*** | 0.047 |
| | (0.026) | (0.022) | (0.054) | (0.136) |
| Subsidy | 0.044* | -0.019 | 0.080 | 0.024 |
| | (0.023) | (0.021) | (0.067) | (0.101) |
| Transportation | 0.026* | 0.015 | 0.085** | 0.060 |
| | (0.014) | (0.014) | (0.038) | (0.048) |
| Finance | 0.014 | 0.003 | -0.042 | -0.023 |
| | (0.016) | (0.015) | (0.044) | (0.069) |
| Tractor | 0.079* | -0.053 | 0.207*** | -0.097 |
| | (0.043) | (0.035) | (0.075) | (0.185) |
| Idiosyncratic shocks × Post-year | 0.013 | 0.020 | 0.032 | 0.126 |
| | (0.020) | (0.017) | (0.067) | (0.078) |
| Rainfall deviation | -0.000 | 0.000 | 0.001 | -0.001 |
| | (0.000) | (0.000) | (0.001) | (0.001) |
| Rainfall deviation × Post-year | 0.000 | -0.001 | 0.001 | -0.001 |
| | (0.001) | (0.000) | (0.001) | (0.002) |
| Constant | 0.139 | 0.043 | -2.245*** | -3.153*** |
| | (0.229) | (0.151) | (0.502) | (0.606) |
| No. of Obs. | 9,578 | 9,578 | 4,798 | 2,986 |
| $R^2$ / Pseudo-$R^2$ | 0.777 | 0.802 | 0.214 | 0.309 |
| HH FE | YES | YES | YES | YES |
| YEAR FE | YES | YES | YES | YES |

*Notes:* Robust standard errors clustered at union level are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. Results for participation choices come from LPM regressions with two-way fixed effects according to the specification (5); whereas the results for rental transactions come from PPML regressions with two-way fixed effects according to (6). Outcome and explanatory variables follow the definitions in Table 3. All monetary values are expressed in '000 US$PPP at the rates 26.61 and 21.87 Bangladeshi Taka for BIHS rounds 1 and 2, respectively. All land measures are expressed in hectares, where 100 decimals = 1 acres = 0.405 hectares.

**Table 3**

Effects on Agricultural Income

| Variables | Rent in | Rent out |
|---|---|---|
| Land rent in | 0.571 | |
| | (0.713) | |
| Land rent out | | -0.091 |
| | | (0.083) |
| Flood × Post-year | -0.570* | -0.470 |
| | (0.339) | (0.301) |
| Storm × Post-year | -0.788*** | -0.751*** |
| | (0.283) | (0.278) |
| Constant | 1.116*** | 1.370*** |
| | (0.281) | (0.028) |
| | | |
| No. of Obs. | 9,578 | 9,578 |
| $R^2$ | 0.818 | 0.819 |
| HH FE | YES | YES |
| YEAR FE | YES | YES |

*Notes:* Standard errors are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. The two-way fixed effect panel regression models follow the specification (7). Outcome and explanatory variables follow the definitions in Table 3. All monetary values are expressed in '000 US$PPP at the rates 26.61 and 21.87 Bangladeshi Taka for BIHS rounds 1 and 2, respectively. All land measures are expressed in hectares, where 100 decimals = 1 acres = 0.405 hectares.

**Table 4**

Rent-in and Rent-out Margins

| | Rent-in Margins | | | | Rent-out Margins | | | |
|---|---|---|---|---|---|---|---|---|
| Margins | Mean | SD | Min. | Max. | Mean | SD | Min. | Max. |
| Flood | | | | | | | | |
| Intensive Margin | -0.570 | 0 | -0.570 | -0.570 | -0.470 | 0 | -0.470 | -0.470 |
| Extensive Margin | 0.0116 | 0.0130 | 0.000172 | 0.221 | -0.00291 | 0.00467 | -0.0765 | -7.34e-05 |
| Total Margin | -0.559 | 0.0130 | -0.570 | -0.349 | -0.473 | 0.00467 | -0.546 | -0.470 |
| Storm | | | | | | | | |
| Intensive Margin | -0.788 | 0 | -0.788 | -0.788 | -0.751 | 0 | -0.751 | -0.751 |
| Extensive Margin | 0.00487 | 0.00532 | 7.25e-05 | 0.0933 | -0.00282 | 0.00450 | -0.0755 | -7.25e-05 |
| Total Margin | -0.784 | 0.00532 | -0.788 | -0.695 | -0.754 | 0.00450 | -0.827 | -0.751 |

*Notes:* rent-in and rent-out margins are calculated according to equations (5) – (9).

# Figures

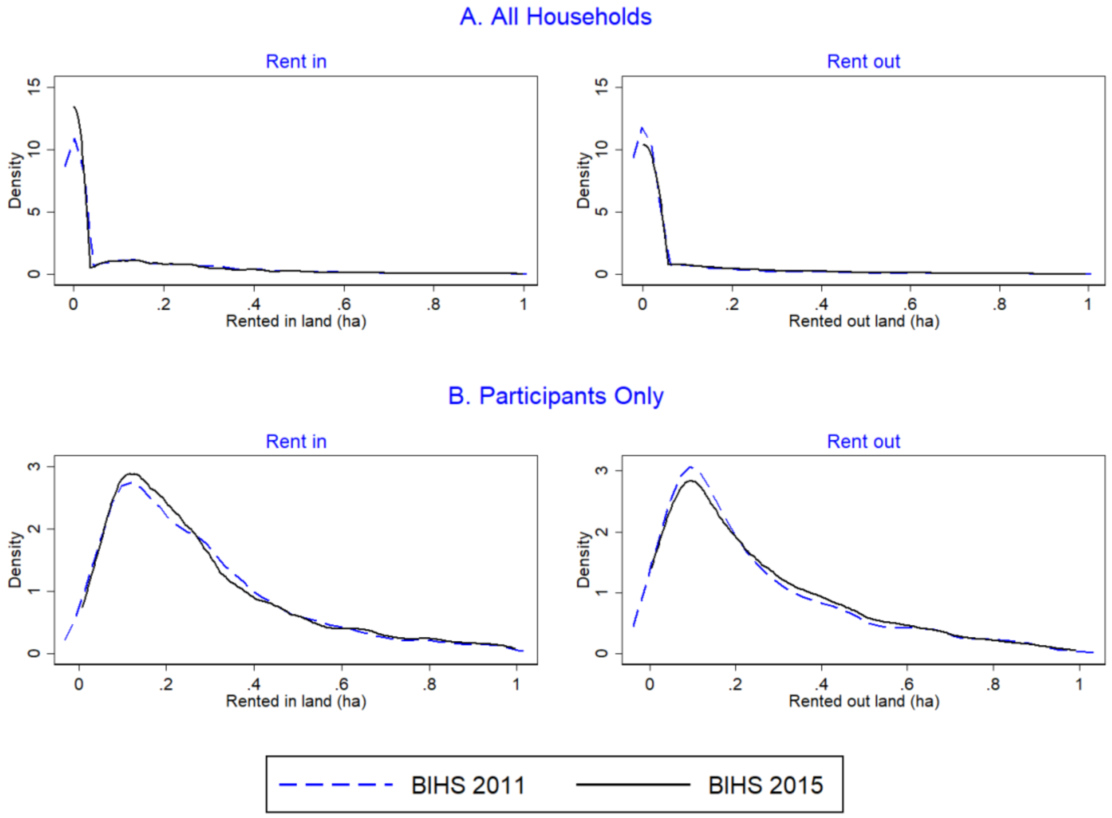


**Figure 1 – Distributions of land rental transaction**

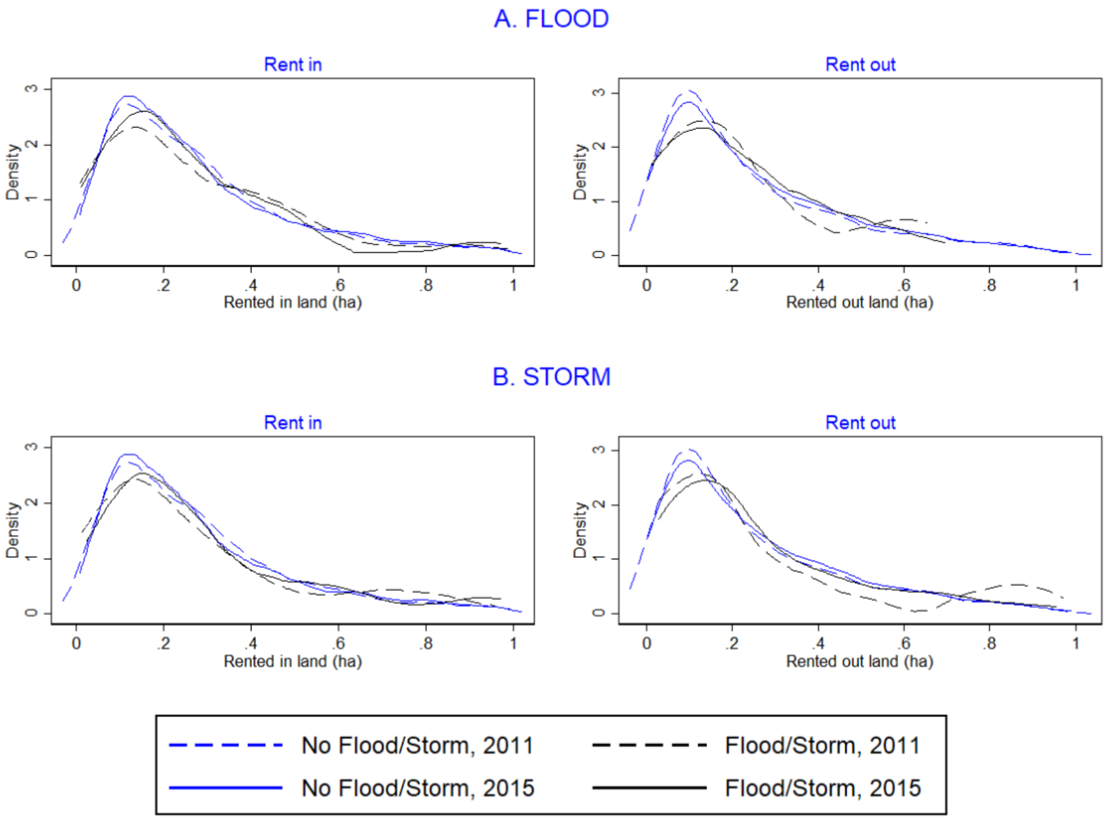


**Figure 2 – Land rental transactions by year and disaster**

[1] “The Great Bhola Cyclone of 1970” struck the coastal regions of Bangladesh November 12, 1970 with peak winds of 115 miles per hour. Considered as the deadliest tropical cyclone and one of the deadliest natural disasters in modern times, it resulted in widespread loss of life and property. It severely affected the coastal regions of Noakhali and Barisal, resulting in total mortality of more than 300,000 people and estimated total damage equivalent to $450 million in 2006 USD (EM-DAT 2021). The mean mortality rate throughout the affected regions was 16.5 percent, and over 0.15 million people relied upon aid for half of their food for over three months (Sommer and Mosley 1972).

[2] Under a program of the Government of Bangladesh with funding support “Access to Land Programme” of the European Union (EU), Manusher Jonno Foundation (MJF) conducted a first-of-its-kind survey on Land Market Situation in Bangladesh to investigate the rural land sales and rental markets dynamics in Bangladesh. The survey was carried out by Human Development Resources Centre (HDRC). The preliminary survey findings were disseminated on December 3, 2014.

[3] Decimals and acres are widely used units of land size in Bangladesh, alongside traditional measures. The conversion rates are 1 acre = 100 decimals = 0.405 hectares.

[4] Allowing for heterogeneous transaction costs for rented in and rented out lands and exogenous wage rate, Deininger and Jin (2008) use data from Vietnam to identify rental market is more important, than sales market, for the poor to access land that becomes available as the non-farm economy develops. In the case of US agriculture, Deschênes and Greenstone (2007) exploited the random year-to-year variation in temperature and precipitation to estimate whether agricultural profits are higher or lower in years that are warmer and wetter. Specifically, they estimated the impacts of temperature and precipitation on agricultural profits and then multiply them by the predicted change in climate to infer the economic impact of climate change in this sector. We differ by exploiting disaster-induced variations, other than continuous measures of climatic changes.

[5] We follow the notion that relative land scarcity makes cultivation based on hired labor undesirable and implies that additional labor is largely through informal exchange or to break seasonal bottlenecks (Binswanger, Deininger, and Feder 1995). Therefore, Households can allocate their labor endowment between farming their own land and off-farm employment at an exogenous wage (Deininger and Jin 2008).

[6] In fact, according to the BIHS rounds 1 and 2 data, only 6 percent members from surveyed households migrated in 2011, whereas it was lower than 2 percent in 2015. Migrations for employments are even lower. Detailed results are reported in Table A1.

[7] Rahman (2010) adopted a multivariate tobit structure to identify the joint determinants of simultaneously made rent-in and rent-out decisions by rural farmers from two Bangladeshi districts.

[8] Bandyopadhyay and Skoufias (2015) identified ex ante occupational diversification, together with policy interventions such as access to market, credit and safety net, as an autonomous and proactive adaptation strategy in Bangladesh.

[9] Taslim and Ahmed (1992) found that farm size, number of workers or income earning members in the family and access to agricultural assets such as ownership of bullocks are important determinants of land rental market transactions in Bangladesh. Skoufias (1995) also identified similar factors affecting the leasing market in India.