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 in the land rental market. Our econometric approach accounts for the effects of disaster-exposure both on the adjustments in the quantity of operated land (i.e. extensive margins) and agricultural income conditional on the land quantity adjustments (i.e. intensive margins). Using a household survey dataset from Bangladesh, we find that farmers were able to ameliorate their losses from exposure to disasters by optimizing their operational farm size through transactions in the land rental market. We also find that although larger farmers receive higher total benefits, rent-in transactions help especially the smallholder farmers to either overcome or reduce their losses. These results suggest that the land rental market may be an effective instrument in reducing disaster risks, and post-disaster policies should take into account this role more systematically. Finally, our results are robust to alternative definition of exposure, alternative estimation method, and alternative definitions of welfare measures.

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

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

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I. INTRODUCTION

Agricultural households from low-income countries are highly susceptible to exposure to climate-induced natural disasters such as floods and storms. Widespread poverty among rural households often 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 (Duflo 2003; Jensen 2000).[1] Common such immediate responses of rural households include selling agricultural land and seeking off-farm employment (Banerjee 2007; Mueller and Quisumbing 2011). However, since arable agricultural lands are scarce and the sales markets are often incomplete in rural areas, farmers might instead involve in land rental transactions in response to disaster exposure (Ward and Shively 2015). Through participation in the land rental market, some farmers facing exposure to disaster risks might choose to rent-in agricultural land, whereas some others might rent-out land. These land rental transactions enable farmers to adjust their operational farm size, and thus indirectly, agricultural production. While separate strands of related literature investigated agricultural land rental transactions as response to disaster exposure (e.g., Ward and Shively 2015) and revenue effects of land rental transactions (Chamberlin and Ricker-Gilbert 2016), literature has not yet addressed the revenue effects of this potential mechanism of farmers using the land rental market as a source of adaptation to natural disaster. 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 experiences recurring damaging disaster events: it experienced 89 floods, 172 storms and 71 other natural disasters during 1900-2015 (Table 1; EM-DAT 2017). Of them, 9 floods and 15 storms took place between 2011 and 2015 with aggregate reported losses of $264 million (Table 2; EM-DAT 2017). Most of these losses occur to agriculture, which employs around 44 percent of the labor force and accounts for 20 percent of gross domestic product (BBS 2010). In case of Bangladesh, Banerjee *et al.* (2015) found that climate change, such as sea level rise, resulted in a 1.23 percent reduction in agricultural GDP, while the reduction in overall GDP is only 0.11 percent. In addition to farmers' apparent motive of maximizing profit from agricultural production, low average farm size and high incidence of rural poverty in Bangladesh necessitate the optimal management and utilization of the available

[1] For example, selling of arable land is among the coping strategies adopted by Bangladeshi farmers in response to disaster exposure (BBS 2010).

land. Land rental transactions in can potentially serve this purpose by benefiting both the rent-in and rent-out farmers especially in the wake of a disaster.

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 extensive margin, i.e., revenue-effect of disaster-induced adjustments in the quantity of operated land, and intensive margin, i.e., direct revenue-effect of disaster-exposure (e.g., Lee 1990; Moore, Gollehon, and Carey 1994; Pfeiffer and Lin 2012 and 2014). We estimate the extensive margin by a random effect tobit regression model, in which the rental transactions (i.e., either rent-in or rent-out amounts) are augmented for farmers' participation choices (i.e., no transaction, rent-in or rent-out) in the rental market. On the other hand, we use a random 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 comes 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 (i.e., between 2011 and 2015), which allows us to examine the effects of disaster-exposure in inducing variations in crop profits (which indicates the direct effect of disaster on agriculture) and land rental transactions (which facilitates the indirect effect of disaster on agriculture).

Related literature on disaster and agriculture mainly focuses on the direct effects of natural disasters on agriculture (e.g., Deschenes and Greenstone 2007; Mendelsohn, Nordhaus, and Shaw 1994). In addition, literature on land rental market focuses on the welfare effects of rental transactions. For example, Chamberlin and Ricker-Gilbert (2016) investigated the welfare effects of land rental transactions in Zambia and Malawi to identify that while renting in results in positive economic returns, renting out results in either negative or negligible positive returns, both conditional on farming ability and landholding. Moreover, Ward and Shively (2015) investigated the effects of covariate village-level income shocks on land market participation to identify that Chinese households engage in land rentals as a response to covariate shocks. To our knowledge, this is the only previous study of 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 in 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 (Banerjee 2010b). 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. Assuming rent-in and rent-out farmers are two separate groups, we find that such mitigating effects of rental transactions are considerably greater for rent-in than rent-out transactions. However, although larger farmers receive higher total marginal benefits, smaller farmers can 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 (Sklenica *et al.* 2014; Deininger, Savastano, and Carletto 2012; Masterson 2007). In this paper, we show that access to a well-functioning land rental market might be a crucial part of the coping strategy that allows farmers to adjust their revenues, and thus improving and facilitating the functioning of such markets in rural areas should be an important component of government's post-disaster risk reduction strategies. Our results are consistent with related studies (e.g., Chamberlin and Ricker-Gilbert 2016; Ward and Shively 2015); and are robust to alternative definition of exposure, alternative estimation method, and alternative definitions of welfare measures (see Section VI for details). However, given different types of sharecropping and tenural arrangements and different profiles of disaster exposure in other low-income countries, generalizing our results and policy suggestions for other countries requires caution and further study in their specific contexts.

The content of the remainder of this paper is as follows. Section II discusses the background information on land rental market and natural disasters in Bangladesh. Section III describes data and identification. Section IV specifies the empirical model. Section V reports and discusses our main empirical results. Section VI provides some additional results and robustness checks. Finally, Section VII summarizes and concludes by discussing the key policy implications of the analysis.

II. BACKGROUND

II.A Land Rental Market in Rural Bangladesh

Rural households in Bangladesh predominantly depend on agriculture for their livelihood and employment. Agriculture employs around 44 percent of the labor force in Bangladesh and contributes around 20 percent of its gross domestic product (BBS 2010). 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 2015), 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 (BBS 2014), many farmers rely on the land rental market to better manage and utilize the available arable land.

A recent 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 decimal 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]

Common land rental categories in Bangladesh are (i) share-cropping arrangements, and (ii) cash-renting at a fixed predetermined rate. The Land Reform Act of 1984 fixed rents for sharecropping tenants at 33 percent of the harvest for the landlords (without input sharing) or 50 percent if inputs are shared at a 50 percent rate (GoB 1984; Rahman 2010). However, in absence of proper enforcement of existing laws, most of the agricultural land rental agreements take place without any documentation through informal land rental markets.

Although rental arrangements do not change the land ownership structure, the presence of 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 (BBS 2014).

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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.

II.B Land Rental Market and Natural Disasters in Bangladesh

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. As shown in Table 1, Bangladesh experienced 172 storms and 89 floods during 1900-2015 (EM-DAT 2017). 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.[4] 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 2010-15, i.e., the time between two rounds of the BIHS survey. Table 2 lists yearly number of different types of natural disasters that took place in Bangladesh during that period, alongside the associated numbers of deaths and affected people and economic damages. Altogether, Bangladesh experienced 9 floods and 15 storms during 2010-15 (Table 2). These natural disasters resulted in more than 800 reported deaths, whereas around 20 million people were affected.[5]

Common adaptation practices in response to disaster-exposure in Bangladesh include crop switching, migration, and increased labor supply (e.g., Moniruzzaman 2015; Penning-Rowsell, Sultana, and Thompson 2013; Banerjee 2007; Mueller and Quisumbing 2011). 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

4 Of them, two floods in June-July and July-September of 2007 covered 46 districts and affected around 13.3 million people including 6 million children. These back-to-back floods caused more than 1,200 deaths, in addition to 1.1 million damaged or destroyed homes and 2.2 acres of damaged croplands. Damages were estimated at US$ 100 million. Next, cyclone Sidr struck the coastal regions of Bangladesh on November 15, 2007. The 240 km per hour winds destroyed 30 districts in Barisal and Khulna divisions, resulting in more than four thousand deaths and 55 thousand injuries in addition to 1.5 million damaged or destroyed homes and 2.5 acres of damaged croplands. Economic damages were estimated at US$ 2,300 million. Finally, cyclone Aila struck 14 districts on the south-west coast of Bangladesh on May 25, 2009. Aila affected around 4 million people and caused 190 deaths, in addition to an estimated US$ 270 million worth damages in infrastructures and livelihoods.

5 Note that the damage figures for many relatively smaller disasters are not reported in Table 2, implying that the actual economic damages are likely to be even higher.

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).[6]

However, since operational farm size is necessarily proportional to agricultural labor employment, our idea of using land rental market to adjust operational farm size is synonymous to increased 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 in to the role of rental transactions becomes relevant.

III. DATA AND IDENTIFICATION

III.A BIHS Data

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 (Figure 1), with a sample size of 5,503 rural households from 325 primary sampling units. The second round of the survey was collected from January to June in 2015, which was administered on the same sample of households surveyed in the baseline creating a two-round panel, when 5,260 households from the baseline survey were re-interviewed. However, 5,133 of those households have properly reported their agricultural revenues and rental transactions; and

6 "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 2017). 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).

therefore, forming our valid sample of rural agricultural households. Tables 3 and 4 describe and summarize 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, both affecting 3% of the surveyed households in between BIHS rounds 1 and 2 (Table 3). 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. Although 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 is a highly restrictive definition to identify the number of affected people, and therefore, undermines the potential effects of disaster exposure at the household level.

The BIHS dataset contains information on farm and non-farm incomes in addition to detail 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 Dollar in PPP terms at the rates 26.61 and 21.87 Bangladeshi Taka for BIHS rounds 1 and 2, respectively. Table 3 reports that on average, crop profits are evaluated at $1,696 and $888 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 payments made for rented in land.

Table 3 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 and 22 percent farmers, respectively, participate in the land rental market in order to, on average, rent-in 0.13 ha and rent-out 0.08 ha of agricultural land. 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 increases from 0.13 ha to 0.25 ha through these rental transactions.

However, such rental transactions are conditional on a number of socioeconomic factors such as household-, farm- and regional-level attributes. Table 4 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. First, the BIHS data includes information on household characteristics such as family size and employment status, age and education of the household head and other members. On average, household size is 4.26 and household heads are 45 years old, whereas 87 percent of them are males. Highest educated member in the family has 6.6 years of schooling on average. Next, BIHS also contains data on farm-level characteristics such as the ownership of important farming assets (e.g., tractor or plough-yoke and irrigation pump) and access to agricultural facilities (e.g., agricultural extension services and agricultural subsidy). Table 4 shows that 13 percent farmers own tractors or plough-yokes which is an important technology for cultivation in rural Bangladesh. On the other hand, 7 and 10 percent of farmers, respectively, benefit from agricultural extension services and agricultural input subsidy. Finally, the BIHS contains information on the availability of local level infrastructure such as markets. Common survey proxies of such infrastructural access include distances of nearest market and paved road from the homestead. Table 4 reports that on average, 62 percent households are located within 1 kilometer of a bus stop, main road or train station; whereas 26 percent are located within 2 kilometers of a bank or a source microcredit.

III.B Empirical Strategy

Since farmers are the primary victims of natural disasters in rural areas, investigation into the ways of agricultural adaptation to disaster exposure is important. For example, 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 closely follows Deininger and Jin (2008) and Deschenes and Greenstone (2007).[7] For simplicity, we assume that the land rental market always clears

[7] In case of US agriculture, Deschenes 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

irrespective of whether or not a disaster takes place. However, this simplifying 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, representative farmers' optimal rent-in and rent-out amounts, respectively, are:

$$(1) \qquad \begin{aligned} l^I &= l^I(\tau; \varpi^I) \\ l^O &= l^O(\tau; \varpi^O)' \end{aligned}$$

whereas ϖ^I and ϖ^O are the observed attributes associated to rent-in and rent-out households, respectively. $\tau = 1$ represents exposure to a natural disaster, and $\tau = 0$ indicates no such exposure. We suppress time and household subscripts for notational simplicity.

The representative farmer produces a given mix of crops using its given endowment of land l. It also earns from non-farm economic activities at an exogenously determined wage rate; however, farmers normally supply non-farm labor during lean seasons (Deininger and Jin 2008), and often experience credit constraint in doing so (Bryan, Chowdhury, and Mobarak 2014).[8] Therefore, rural farm labor supply can be treated as inelastic in farm wage due to lack of labor mobility between sectors and locations. Considering these facts, we express the output and cost functions, therefore profit function, as functions of operational land only. Therefore, capturing the effects of operational farm size adjustments on crop profits requires maximizing the following profit function:

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

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 $l + l^I - l^O \; \forall l^I, l^O \geq 0$. $\alpha \geq 0$ 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.

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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.

8 However, we investigate how farmers' total incomes, which include non-farm incomes, are affected by disaster and disaster-induced rental transactions. Section VI.D reports this investigation as a robustness check.

Although sharecroppers may have lower yield on rent-in land (Shaban 1987), we assume that the rent is pre-fixed by the government, which is independent of the occurrence of a disaster. 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 by model environment (e.g., Deininger and Jin 2008). Moreover, we focus on total agricultural revenue instead of per-acre yield, and since farmers maximize their farming profits, pre-fixed 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 that 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 the fact 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 autarkic farmers

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

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

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

where for rent-in farmers, $\Delta q^i = (1-\alpha)q(l + l_1^I) - q(l + l_0^I)$; $\Delta c^I = c(l + l_1^I) - c(l + l_0^I)$; *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. $(r + T^I)$ refers to the per-unit cost for rented in land, i.e., the cash and kind payments made for the use of rented-in lands. On the other hand, for rent-out farmers, $\Delta q^O = (1-\alpha)q(l - l_1^O) -$

$q(l - l_0^O)$; $\Delta c^O = c(l - l_1^O) + c(l + l_0^O)$; and $\Delta l^O = l_1^O - l_0^O$. Similar to the case for rent-in farmers, $\alpha \geq 0$ governs the direct effect of disaster exposure; whereas l_1^O and l_0^O govern the indirect effect of disaster for rent-out farmers. $(r - T^O)$ refers to the per-unit cash and kind receipts from rented out lands. In addition, we must have $\Delta l^I > 0 \; and \; \Delta l^O = 0$ for rent-in, $\Delta l^O > 0 \; and \; \Delta l^I = 0$ for rent-out and $\Delta l^I = \Delta l^O = 0$ for autarkic farmers.

Therefore, based on equations (3) and (4), the difference-in-differences, DD, of disaster-induced rental transactions on the dependent variable of interest π is

$$(5) \qquad DD = \frac{[(\bar{\pi}_1|I = 1) - (\bar{\pi}_0|I = 1)] - [(\bar{\pi}_1|I = 0) - (\bar{\pi}_0|I = 0)]}{[(\bar{\pi}_1|O = 1) - (\bar{\pi}_0|O = 1)] - [(\bar{\pi}_1|O = 0) - (\bar{\pi}_0|O = 0)]},$$

where $I = 1 \; or \; O = 1$ if the treatment is given, and $\bar{\pi}$ is the mean of crop profits (Greene 2012). The first bracketed term gives the change in mean of crop profits for treatment groups (i.e., rent-in or rent-out farmers) due to disaster-exposure (i.e., $\tau = 0 \; or \; 1$). The second bracketed term gives the analogous measure for the control group (i.e., autarkic farmers). The differences between the bracketed terms indicate the effect of the treatments relative to the control.

Table 3 summarizes our outcome and land management variables, whereas Table 5 shows the difference-in-differences in outcome variables and rental transactions by flood and storm exposure. Overall, disaster-affected farmers have lower crop profits, and higher participation and transactions in the agricultural land rental market than the unaffected farmers. However, any conclusion drawn on these unconditional and separate difference-in-differences results may not be meaningful since two different groups of farmers are involved in rent-in and rent-out transactions. Moreover, these rental market participating roles are endogenous in disaster exposure (as shown in equation 4), and their corresponding transactions have indirect effects on crop profits. Therefore, it is important to identify the sources of changes in agricultural outcomes to understand whether the affected farmers were able to use the land rental market at least to lessen the losses from disaster exposure.

Such 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., $\varpi^I \neq \varpi^O$, 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. Table

4 reports the control variables that we include in our econometric specifications in the following section.

IV. 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 use of land plots.

We estimate the effects of disaster exposure on land quantity adjustment through the rental market. However, as Figure 2 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. Thus, the participating samples are nonrandom, and are drawn from a wider population of farmers.

Since land rental transactions follow a sequential decision (Teklu and Lemi 2004; Rahman 2010), we employ a random effect tobit model which suits best for the censored observations since it uses all the observations (i.e., data for both the participants and non-participants) while augmenting for the censored observations through capturing the latent level intensity of potential farmers who decide not to participate in the land rental transactions (McDonald and Moffit 1980; Teklu and Lemi 2004; Rahman 2010). Alternative methodology can be a variant of Heckman selection model which, as outlined in Section VI.B as a robustness check, uses only the censored observations representing only the participants.

Although the same group of farmers can be involved in both rent in and rent out transactions (Rahman 2010),[9] 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, Zegara, and Lavadenz 2003; Teklu and Lemi 2004; Deininger and Jin 2005; Vranken and Swinnen 2006; Masterson 2007; Holden, Deininger, and

9 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.

Hosaena 2007). Therefore, assuming that rent-in and rent-out are two independent decisions, our econometric investigation involves separate probit regressions to estimate the probabilities of renting-in and renting-out, and separate tobit regressions that estimate the volumes of rented in and rented out agricultural land.

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 as outlined in equations (6) and (7). First, a farmer i participates in the land rental market in time t according to following probit regressions:

$$(6) \qquad \begin{matrix} I_{it} = f(x_i, z_{it}, \varepsilon_{I,it}) \\ O_{it} = f(x_i, z_{it}, \varepsilon_{O,it}) \end{matrix},$$

where $\varepsilon_{I,it} \sim (0, \sigma_I^2)$ and $\varepsilon_{O,it} \sim (0, \sigma_O^2)$. 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. Vectors x_i and z_{it}, respectively, contain the conventional controls and the measures of disaster-exposure.

Vector z_{it} includes our variables of interest defining disaster exposure of a household. We run separate regressions for flood and storm exposures, where the binary measure of exposure takes a value equal to 1 if the household was exposed to any flood or storm in last five years and 0 if it was not exposed.[10] In addition, since the amount of landholding influences the renting decisions in general (e.g., Rahman 2010), we interact our exposure variables with landholding.[11]

Our empirical approach to estimating (6) 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, Zegara, and Lavadenz 2003; Teklu and Lemi 2004; Deininger and Jin 2005; Rahman 2010). A household is defined to include the number of people that dine-in together from the same pot. Household characteristics include the age and gender of the household head (defined as 1 if male and 0 if female), years of schooling of the highest educated family member and household size. Farm-level characteristics

10 For the purpose of comparison, we also consider exposure to idiosyncratic shocks as a third measure (Section VI.C).

11 Note that, we also consider long-term variations in monsoon rainfall as a continuous measure of shock exposure (Section VI.A).

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).[12,13]

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 temporarily or permanently migrate to unaffected or urban areas.

However, the main purpose of the random effect probit regressions in equations (6) is to look into the probabilities of participating in the land rental market. We next investigate actual rental transactions using random effect tobit regression models, for which we define the latent variables:

$$(7) \qquad \begin{aligned} LI_{it}^{*} &= g\left(x_i, z_{it}, \xi_{I,it}\right) \\ LO_{it}^{*} &= g\left(x_i, z_{it}, \xi_{O,it}\right) \end{aligned}$$

where $\xi_{I,it} \sim (0, \sigma_I^2)$ and $\xi_{O,it} \sim (0, \sigma_O^2)$. Vectors, x_i and z_{it}, are as described for equation (6). We observe the dependent variables LI_{it}^{*} and LO_{it}^{*}, both left-censored at zero, according to:

12 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.

13 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.

$$LI_{it} = \begin{cases} LI_{it}^* & if\ LI_{it}^* > 0 \\ 0 & if\ LI_{it}^* \leq 0 \end{cases}$$

$$LO_{it} = \begin{cases} LO_{it}^* & if\ LO_{it}^* > 0 \\ 0 & if\ LO_{it}^* \leq 0 \end{cases}$$

where LI_{it}^* and LO_{it}^*, respectively, denote the optimal rent-in and rent-out amounts. We empirically define the outcome variables LI_{it}^* and LO_{it}^* as the hectares of agricultural land rented in and rented out by farmer i in time t.

Effects of disasters on crop profits are conditional on rent-in and rent-out amounts, which are determined by equation (7), according to farmers' corresponding participating roles in the rental market. We employ following random 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):

$$(8) \qquad \begin{aligned} Y_{I,it} &= h_I\left(\widehat{LI}_{it}^*, z_{it}, \epsilon_{it}\right) \\ Y_{O,it} &= h_O\left(\widehat{LO}_{it}^*, z_{it}, \epsilon_{it}\right)' \end{aligned}$$

where $\widehat{LI}_{it}^*$ and $\widehat{LO}_{it}^*$ are predicted rental transactions amounts from equation (7). 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 (8) where we use total crop profits as our outcome variable instead of land value in order 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 (Deschenes and Greenstone 2007).

Predicted rent-in and rent-out amounts in equation (8) connect the coefficients of the components of z_i in (7) with the outcome variable in (8) and, therefore, yield the indirect effects or extensive margins of disaster-exposure through land rental transactions. On the other hand, coefficients of the components of z_i in (8) 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:

$$(9) \qquad \begin{aligned} \frac{dY_I}{dz} &= \frac{\partial h_I}{\partial z} + \frac{\partial h_I}{\partial \widehat{LI}^*} \times \frac{\partial \widehat{LI}^*}{\partial z} \\ \frac{dY_O}{dz} &= \frac{\partial h_O}{\partial z} + \frac{\partial h_O}{\partial \widehat{LO}^*} \times \frac{\partial \widehat{LO}^{*\prime}}{\partial z} \end{aligned}$$

where $\frac{\partial h_I}{\partial z}$ and $\frac{\partial h_O}{\partial z}$ are the intensive margins for disaster exposure of the farmers renting in and renting out agricultural lands, respectively; whereas the corresponding extensive margins for rent in and rent out transactions are $\frac{\partial h_I}{\partial \widehat{LI}^*} \times \frac{\partial \widehat{LI}^*}{\partial z}$ and $\frac{\partial h_O}{\partial \widehat{LO}^*} \times \frac{\partial \widehat{LO}^*}{\partial z}$.

V. RESULTS AND ANALYSIS

V.A Land Rental Market Participation and Transactions

Table 6 reports the determination of farmers' land rental market participation decisions. Participation choices, i.e., rent-in and rent-out, are estimated using random effect probit models according to specification (6), 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). Statistically significant χ^2 values justify our models.

We find that both flood and storm exposures increase the probability of rent-in and decrease the probability of rent-out; whereas, disaster-affected farmers with higher landholding are less likely to rent-in and more likely to rent-out than unaffected smaller farmers. Together, we can infer that while the probabilities of renting in and renting out are similar by exposure to different types of natural disasters, they vary by the volume of landholding. In addition, most of the other determinants of land rental market participation are statistically significant and exhibit same directions and similar magnitudes for both flood and storm.

Next, Table 6 also reports the determination of land rental market transactions using random effect tobit regression models according to equation (7). Outcome variables are hectares of rent-in and rent-out land, as described in Sections III and IV. As expected, estimated directions of relationships for rental transactions corroborate those in Table 6 from random effect probit regressions for rental market participations.

We find that disaster-exposure increases the rent-in amount by 0.27 ha and decreases the rent-out amount by 0.30 ha. Also, disaster-affected farmers with 1 ha higher landholding have lower rent in by 0.18 ha and higher rent out by 0.71 ha. Apart from confirming that disaster-exposure stimulates the land rental transactions, these 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.

In addition, a number of socio-economic factors significantly affect farmers' participation in the land rental market but these work mostly in opposite directions regarding decisions to rent-in or rent-out land.

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; however, they may also become less active at a relatively older age. Our results quite fittingly identify a statistically significant concave relationship between age and rent-in amounts: rent-in amounts increase with age but only at a decreasing rate. Besides, rent-out amounts are not affected by farmer's age. These results are consistent with literature (Kung 2002; Vranken and Swinnen 2006; Deininger and Jin 2005). Kung (2002) and Vranken and Swinnen (2006) found positive influence of age on renting-in land, whereas Deininger and Jin (2005) reported a negative influence.

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 concave relationship between family size and rent-in amounts (i.e., larger families rent-in more but the rent-in amounts increase at a decreasing rate) and a statistically significant convex relationship between family size and rent-out amounts (i.e., larger families rent-out less but the rent-out amounts decrease at an increasing rate). That is, higher subsistence pressure increases operational farm size, and, therefore, results in increased dependency on agriculture. These results are consistent with the findings of Rahman (2010) and Teklu and Lemi (2004) that smaller families are more likely to rent-out, and the findings of Kung (2002) that higher dependency ratio increases the likeliness to rent-in.

Quite unsurprisingly, we find that male-headed households rent-in more and rent-out less. In rural Bangladesh, female headship normally implies that the regular male head is either absent or deceased. In either of these situations, female-headed families have lower ability to operate agricultural lands themselves and, therefore, male-headed households have higher rent-in and lower rent-out than the female-headed households.

We find that the households with better education level, measured by the years of education of the highest educated household member, rent-in less and rent-out more. Since schooling is an indicator of household's likeliness to have a non-agricultural source of income, and since education increases the opportunity cost of agricultural income (e.g., Teklu and Lemi 2004), better-educated households may rent-out land in order to substitute their time away from agricultural production (Deininger, Zegara, and Lavadenz 2003; Teklu and Lemi 2004; Rahman 2010). This result is therefore consistent with the findings of Kung (2002) that Chinese households with active participation in the off-farm labor market rent-in less.

Among the farm-level characteristics, ownership of tractor or plough-yoke significantly increases both rent-in and rent-out volumes. Two opposing pictures can emerge from these estimates. First, owners of tractor might experience higher opportunity cost of farming activities and rather find it more beneficial to rent more lands out so as to be able to commercially use their tractors to cultivate other farmer's land. On the other hand, those who own plough-yoke are less likely to use their means of cultivation commercially, and therefore will have lower opportunity cost of cultivating their own land. Since we assume that rent-in and rent-out farmers are two different groups of people, these competing explanations can be true at the same time.

Access to agricultural extension services significantly increases rent-in amounts. Since getting in touch with extension services providers involves transactions costs such as time and transportation cost, farmers who want to expand their operation normally have higher likeliness to avail them. Similar directions of relationship with the access to agricultural input subsidy, together, imply that the farmers with access to technological information and knowledge rent-in more to optimize their operational farm size.

Finally, both the proximities to public transportation and the sources of public financing lower rental transactions – both the rent-in and rent-out amounts. Normally, better access to such infrastructural facilities lowers the dependency on agriculture, and also increases the possibility of commercial use of agricultural land. Therefore, our results are consistent with Kung (2002) who found that Chinese households with active participation in off-farm labor markets have rented less lands in.

V.B 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. Tables 7 reports the results from employing random effect panel regressions for different rental market participating roles according to equation (8).

Table 7 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, but opposite for different participating roles. For rent-in farmers, coefficients of both flood and storm exposures are negative, and that of the interactions between exposure and landholding are positive. In particular, flood and storm exposures lower crop profits by $793 and $485, respectively, for rent-in farmers; whereas, 1 ha additional landholding is associated with additional $2,530 and $3,421 profits for flood- and storm-affected rent-in farmers. That is, larger farmers involved in rent-in transactions may not experience any direct revenue effects of disaster exposure – losses due to exposure can be compensated by gains from greater landholding. On the other hand, for rent-out farmers, both the coefficients of exposure and the interactions between exposure and landholding are positive. That is, not only that the rent-out farmers do not experience the adversities of disaster, they can receive further gains due to their larger landholding.

The coefficients of estimated rental transactions, which connect the rental effects of disaster-exposure on crop profits along the extensive margins, confirm that both the rent-in and rent-out transactions can have mitigating effects. In particular, 1 ha additional rented-in land significantly increases crop profits by $2,825 and $2,835 for flood and storm affected rent-in farmers, respectively; whereas 1 ha additional rented-out land significantly increases crop profits by $895 and $850 for flood and storm affected rent-out farmers, respectively. 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.

V.C 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 (9) as the sum of intensive and extensive margins. All the calculations are based on the coefficients of rent-in and rent-out amounts, disaster exposure and the interaction between landholding and disaster exposure, as reported in Tables 6 and 7 according to equations (7) and (8). Table 8 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 7 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 (9) according to:

$$(10)\qquad \frac{\partial h_{\tau}}{\partial z} = \hat{\beta}_{disaster} + \hat{\beta}_{disaster\times landholding} \times Landholding\ \forall\tau = I, O,$$

where $\hat{\beta}_{disaster}$ and $\hat{\beta}_{disaster\times landholding}$ are the estimated coefficients of disaster exposure and its interaction with landholding from Table 7 according equation (8) that determines the direct effects of disaster exposure on crop profits.

Table 8 reports intensive margins associated to rent-in and rent-out farmers for both flood and storm exposures. Rent-in farmers experience direct effects on crop profits in the range [-$793, $16,010] and [-$485, $22,240] due to flood- and storm exposures, respectively, depending on their landholding. On the other hand, irrespective of their landholding, flood- or storm-exposure do not directly create adverse effects on crop profits of the rent-out farmers. Their corresponding intensive margins remain within a positive range: [$625, $9,234] for flood and [$523, $7,805] for disaster exposure. These estimates of intensive margins are consistent with IPCC results, which show that losses from natural disasters amounted to 0.3, 1.0 and 0.1 percent of GDP for lower-income, medium-income and higher-income countries during 2001-2006 (IPCC 2012).

Based on the stylized fact that smaller farmers rent-in and larger farmers rent-out agricultural lands, our estimated results on the direct effects disaster exposure imply that while disasters cause direct harms to agriculture, the severity is higher for the smaller farmers, and either lower or non-existent for the larger farmers. Especially the smallholder rent-in farmers with landholdings less than 0.31 ha and 0.14 ha, respectively, experience the direct adversities from flood and storm exposures. Therefore, flood affects the agricultural outcomes of a wider group of rent-in farmers than storm, and the mitigating effects of farm size are greater in the case of storm-exposure.

Next, following equation (9), we multiply the estimated effects of disaster-exposure on land rental transactions from Table 6 with the estimated effects of rent-in and rent-out land on crop profits from Table 7 to calculate the corresponding extensive margins. Total extensive margin for rent-in and rent-out transactions are calculated as:

$$(11)\qquad \begin{array}{l} \frac{\partial h_I}{\partial \widehat{LI}^*} \times \frac{\partial \widehat{LI}^*}{\partial z} = \hat{\beta}_{\widehat{LI}^*} \times \left[\hat{\beta}_{I,disaster} + \hat{\beta}_{I,(disaster\times landholding)} \times Landholding\right] \\ \frac{\partial h_O}{\partial \widehat{LO}^*} \times \frac{\partial \widehat{LO}^*}{\partial z} = \hat{\beta}_{\widehat{LO}^*} \times \left[\hat{\beta}_{O,disaster} + \hat{\beta}_{O,(disaster\times landholding)} \times Landholding\right] \end{array},$$

where $\hat{\beta}_{\widehat{LI}^*}$ and $\hat{\beta}_{\widehat{LO}^*}$ are the coefficients of rent-in and rent-out amounts from Table 7 according to equation (8), and $\hat{\beta}_{disaster}$ and $\hat{\beta}_{disaster\times landholding}$ are the estimated coefficients of disaster exposure and its interaction with landholding from Table 6 according equation (7) that determines land rental transactions.

The estimated extensive margins can be positive or negative for rental transactions (extensive margins are zero for autarkic farmers), conditional on farmer's landholding. Calculated results in Table 8 show that the indirect effects of disaster exposure along the extensive margins for rent-in transactions are [-$2,578, $764] and [-$10,090, $487] for flood and storm affected rent-in farmers, respectively. On the other hand, renting out, which works as a channel of risk avoidance, is associated with extensive margins of [-$265, $3,972] and [-$284, $4,504] 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 equations (9)–(11). The calculated total margins are [-$29, $13,430] and [$3, $12,150] for flood and storm exposures for rent-in farmers, respectively; and [$361, $13,210] and [$239, $12,310] for rent-out farmers. Although some rent-in farmers have negative total margins from flood exposure, a comparison between intensive and total margins reveals that all the rent-in farmers were able to at least reduce their losses from disaster exposure through land rental transactions. Overall, positive, or less negative, ranges of total margins then suggest that both the rent-in and rent-out transactions convey sufficient indirect benefits for the participating farmers so as to overcome the losses from exposure to floods and storms.

We identify that farmers were able to overcome or reduce their direct losses from storm and flood exposures through participation in the land rental transactions either by increasing their operational farm size through renting in or by outsourcing risks through renting out. In both cases, farmers who transacted in the land rental market to optimize their operational farm size are better-off than non-participants. More precisely, evaluated at the mean values of landholdings for rent-in farmers, flood-exposure results in $253 direct decrease in crop profits (average intensive margins), which is then compensated by $656 indirect increase in profits through rent-in transactions (average extensive margins). Altogether, we find a $404 net increase in crop profits of the flood-exposed rent-in farmers. In addition, for average-sized rent-in farmers' storm exposure, we find that the average intensive margins of $246 is further supplemented by $147 in average extensive margins. On the other hand, average-sized rent-out farmers have positive intensive margins and negative extensive margins: flood-exposure results in $902, -$128 and $$773 in intensive, extensive and total margins for rent-out farmers with average landholding; whereas the corresponding figures for storm exposure are $757, $131 and $627, respectively.

Overall, our estimates of average marginal effects of disaster-exposure 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. As Figures 5 and 6 demonstrate, our results suggest that the land rental market could enable farmers to more than overcome any income losses from disaster exposure. These figures also show that higher total margins for larger farmers are mostly due to their intensive margins, suggesting that rental transactions in response to disaster-exposure are more beneficial for the smaller farmers.

Our results may reinforce the notion of "creative destruction" since land rental transactions enable the farmers to more than overcome the losses from disaster exposure. In related literature, for example, Banerjee (2010) found that while severe flooding may lower agricultural yield in disaster months, they may also provide open-access irrigational input that lead to significant increases in post-flood productivity. However, empirical investigation of the notion of "creative destruction" is beyond the scope of this paper, especially since recurrent events of natural disasters in Bangladesh makes it difficult to identify the long-run impacts on yield of any single extreme event.

V.D Landholding, Rental Volumes and Marginal Effects

Both intensive and extensive margins are conditional on landholding: direct losses are higher for smaller farmers and lower for larger farmers; whereas the indirect benefits from rental transactions also vary by landholding and participating role in the land rental market. Table 13 and Figures 5 and 6 provide further details on the links between landholding, rental transactions and margins. Table 13 shows that rent-in intensive margins are negative for 77 and 65 percent farmers for flood and storm exposures, respectively. However, the extensive margins are negative for only 2 and 22 percent rent-in farmers, respectively. That is, 98 and 78 percent flood and storm affected rent-in farmers can either overcome or at least reduce their direct losses in crop profits from disaster-exposure.

Figure 5 plots rent-in and rent-out margins by landholding for a better understanding of how farm size affects the benefits of disaster induced rental transactions. Panel A shows that rent-in intensive margins are increasing in landholding, and rent-in extensive margins are decreasing in landholding. That is, while the smaller farmers experience greater severity from disaster exposure, they can also benefit more from rent-in transactions to optimize their operational farm size and agricultural productions. Therefore, especially the smaller farmers can use rent-in transactions in order to overcome or reduce their direct losses from disaster-exposure. On the other hand, for larger farmers, however, total margins are always higher but the gap between intensive and total margins widens, in favor of intensive margins, with landholding. One possible explanation is they might lose technical efficiency by renting-in more land although already holding more than average amount of land.

A comparison between the margins for flood and storm exposures reveals that while the direct losses from flood-exposure have a wider range than that for storm-exposure, smaller farmers can actually benefit considerably higher through extensive margins in case of flood-exposure than storm-exposure. Moreover, only very small farmers can benefit through renting-in in case of storm-exposure in comparison to the case of flood-exposure as evident from the observation that the gap between intensive and total margins by landholding is wider for storm than flood.

Panel B in Figure 5 shows that both the rent-out intensive and extensive margins are increasing in landholding. That is, renting out farmers, who either hold larger amount of land or have alternative sources of income, can potentially outsource risks associated to their agricultural operations by renting out. Moreover, smaller farmers do not benefit from rent-out transactions since they may rather experience negative extensive margins. However, this observation from Figure 5 is reasonable since smallholders normally do not rent-out, rather rent-in to expand their farming operations. Together, we can infer that rent-in transactions are more (less) beneficial for smaller (larger) farmers; whereas only the larger farmers can benefit from rent-out transactions.

Next, Figure 6 plots rent-in margins by rent-in amounts in Panel A and rent-out margins by rent-out amounts in Panel B. Although we plot intensive and total margins as well for comparison purpose, only the extensive margins from Figure 6 are relevant for our analysis.

We find that rent-in extensive margins are concave in rent-in amounts. That is, although rent-in transactions are beneficial for smaller farmers, very high rent-in amounts can eventually lower their technical efficiency due to very high operational farm size. On the other hand, rent-out transactions do not affect technical efficiency of rent-out farmers since they only involve receiving rents, and therefore, rent-out extensive margins linearly increase by rent-out amounts.

VI. ADDITIONAL RESULTS AND ROBUSTNESS CHECKS

VI.A Rainfall variations as continuous treatment

Since our use of self-reported disaster exposure can be a weak proxy for actual exposure, our first robustness check involves using rainfall anomalies as a continuous measure of disaster exposure. Guiteras, Jina, and Mobarak (2015) further identified that even rainfall data can also lack strong correlation especially with flood exposure. However, we follow the mainstream literature on the short- and long-run welfare effects of rainfall, temperature and disaster (e.g., Schlenker and Roberts 2009; Maccini and Yang 2009; Deschênes and Greenstone 2011; Zivin and Neidell 2013; Dell, Jones, and Olken 2014; Zhang, Zhang, and Chen 2017), and use long-term rainfall variation as an alternative measure.

For rainfall variations in the regressions investigating participation and transaction, 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. Besides, for rainfall variations in the regressions investigating profits, we take the difference between the average rainfall over the monsoon months of June-September for 2010 and 1980-2010 for BIHS round 1, and 2013 and 1980-2010 for BIHS round 2.

Table 9 reports the effects of rainfall variation on land rental participation and transactions and crop profits, which are mostly consistent with our main results in Tables 6 and 7. We identify that higher last year monsoon rainfall than the 30 year average monsoon rainfall increases rent-in and decreases rent-out participation and transactions; and that these effects are further strengthened for larger farmers. Next, higher 5 year average rainfall than 30-years' average increases both crop profits for both rent-in and rent-out farmers, which are then decreasing in landholding. Finally, marginal effects of disaster-exposure are consistent when we use long-term variations in monsoon rainfall as a continuous measure of disaster exposure.

VI.B Alternative Method: Amemiya's Two-step Estimator

In addition to the random effect tobit model (Section V.B), we additionally apply a modified version of Heckman selection model: Amemiya's two-step estimator, to the analysis of limited-dependent variables in this paper. Once again, we do not consider simultaneity between rent-in and rent-out decisions. We may perceive that 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 and, therefore, the participating samples are nonrandom, and are drawn from a wider population of farmers. Both the rent-in and rent-out choices must be modeled to avoid sample selection bias.

We use Lee's generalization of Amemiya's two-step estimator (Lee 1990; Pfeiffer and Lin 2014), which is asymptotically more efficient than Heckman's selection model (Heckman 1978). 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 as outlined in equations (6) and (10). First, a farmer i participates in the land rental market in time t according to equation (6). Employing the random effect probit models, we estimate the inverse mills ratios IMR_1 and IMR_2, which are then included as explanatory variables when estimating the optimal land quantity adjustment to correct the sample of land rental market participants. Optimal rent-in and rent-out amounts for a participating farmer i are determined according to:

$$(12) \qquad \begin{matrix} I_{it}^* = f\left(x_i, z_{it}, IMR_I, \xi_{I,it}\right) \\ O_{it}^* = f\left(x_i, z_{it}, IMR_O, \xi_{O,it}\right) \end{matrix},$$

where I_{it}^* and O_{it}^*, respectively, denote the optimal rent-in and rent-out amounts, which are observed when $I_{it} > 0$ and $O_{it} > 0$, respectively. We empirically define the outcome variables I_{it}^* and O_{it}^* as hectares of rent-in and rent-out land by farmer i in time t.

Main distinction between the Tobit and Selection models is the exogenous variables explaining the participation and transaction decisions. While the same set of exogenous variables explain both the decisions in the Tobit model, the set of exogenous variables ideally varies across decisions in the Selection model. Selection models are identified by functional form assumptions without a plausible exclusion restriction, and parameters in selection models are estimated with more precision if some regressors in the selection equation can be excluded from the outcome equation (Wooldridge 2010). However, since we only use the Selection model as a robustness check for our main results obtained from the Tobit model, we use the same set of exogenous variables in the Heckman model to keep our estimated coefficients more comparable.

Table 10 reports the determinants of land rental transactions using random effects regression estimates on selectivity-corrected samples of rental market participants. Results from this alternative specification are consistent with our main results on participation and transactions in rental market in Table 6, which further validate our main findings and their implications. In particular, for both flood and storm exposures, we identify that disaster exposure increases rent-in participation and transactions, which then decreases in landholding; whereas disaster exposure decreases rent-out participation and transactions, which then increases in landholding.

We also find that disaster exposure results in direct losses in crop profits for rent-in farmers, but those losses decrease in landholding; whereas rent-out farmers do not experience direct losses. Finally, since the coefficients of estimate land transaction amounts are positive, we infer that those rental transactions can facilitate farmers' recovery from the losses directly coming from disaster-exposure.

VI.C Effects of Idiosyncratic Shocks

Ward and Shively (2015) investigated the effects of covariate village-level income shocks on land market participation using a pooled cross-section instrumental variables probit and 3SLS estimates. They identified that Chinese households engage in land rentals as a response to covariate shocks, but not in response to idiosyncratic shocks. We compare our main results with the effects of idiosyncratic shocks that affect more than 36 percent of the estimating sample.

Table 11 reports our estimates of the effects of idiosyncratic shocks, which are mostly consistent with our main results reported in Tables 7 and 8. For disaster exposure and its interaction with landholding, estimated directions of relationships are same in participation, transactions and profit estimates for rent-in farmer; but the profit estimates differ for rent-out farmers. Similar to our main parameters of interest, control variables exhibit opposite directions regarding rent-in and rent-out decisions and transactions.

Unlike our main results, we rather find that idiosyncratic shocks directly lower crop profits for both rent-in and rent-out farmers, which then increase in landholding. That is, both the groups of farmers with lower landholding experience the direct effects of idiosyncratic shocks.

We further identify that rent-in farmers may be able to overcome or reduce their losses through rent-in transactions as the coefficient of predicted rent-in transactions is significant and high. However, rent-out farmers may not be able to overcome their losses from idiosyncratic shocks through rent-out transactions, as shown by statistically insignificant and low coefficient of predicted rent-out transactions.

In related literature, Günther and Harttgen (2009) identified that rural households experience higher impact of covariate shocks than idiosyncratic shocks, whereas the situation is exactly opposite for urban households. However, coefficient estimates for idiosyncratic shocks are larger and statistically more significant than those estimated for flood and storm. Therefore, while the directions of responses can be similar, households are more directly affected by idiosyncratic shocks that in case of natural disasters.

VI.D Effects on Total and Non-farm Incomes

We also investigate the role of land rental transactions in mitigating the effects of disaster on total income (Table 12), employing the econometric specifications (6)–(9). Total income is the sum of farm and non-farm incomes.

We find that the rent-in farmers are subject to the direct effects of disaster, with those harms being lower for larger farmers. Consistent with our estimates of total marginal effects for crop profits, rent-in transactions then facilitate their indirect adaptation to the losses in total household incomes along the extensive margins. Similarly, results for rent-out farmers are also consistent with our main results in Tables 6 and 7.

VII. 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 Lee (1990), 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 identify that while disaster exposure directly harms especially the smallholder farmers, farmers exposed to disasters appear to have successfully overcome those losses by adjusting their operational farm size through rent-in and rent-out decisions in the agricultural land rental market. Although larger farmers receive higher benefits from these indirect sources, rent-in transactions and resulting benefits are important for smallholder farmers who otherwise could not overcome their losses. These results are robust when we use long-term rainfall variation as a continuous measure of exposure (Section VI.A) and Amemiya's two-step estimator as an alternative method (Section VI.B). Results are also consistent with those for idiosyncratic shocks and total household incomes (Sections VI.C and VI.D).

Accounting for the effects of disaster exposure on the adjustments in the quantity of operated land and their impact on crop profits is important since disaster-exposure results in losses in income (IPCC 2012). Such a relationship may be especially relevant when farmers actively participate in land rental markets. Our results have important implications for Bangladesh and other low-income countries in terms of land management, economic welfare and disaster risk reduction. In general, low-income countries have high degrees of land fragmentation, severe incidences of 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; Sklenica *et al.* 2014). 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 on agriculture from natural disasters. Such a mechamism may become increasingly important as an adaptation response to climate change: since farmers appear to employ the land rental market to adjust the quantity of operational land to adapt to the losses of past disasters and to mitigate the potential losses of future disasters, the land rental market provides a useful mode of climate change adaptation relevant for any low-income agricultural country with recurrent disaster exposure. However, since other low-income countries may have different sharecropping and tenural arrangements and different disaster profiles, generalizing our results and policy suggestions for other countries requires caution and further study in their specific contexts.

As this paper suggests that access to a well-functioning land rental market might be a crucial part of the coping strategy that allows farmers to adjust their crop profits, 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 low-income 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.

One important direction of future research is to address the effects of land quantity adjustment on the sustainability of land and soil resources in addition to the agricultural revenue effect explored in this paper. However, since adaptation increases food productivity (Di Falco, Veronesi, and Yesuf 2011), it may imply that farmers actually adapt to food scarcity and not to climatic extremes. This argument justifies the short-term nature of responses to disaster exposure such as adjusting operational land quantity as outlined in this paper. However, since weather extremes are noticed much earlier than changes in mean climate (Katz and Brown 1992), adaptation practices need to be incorporated in short-term investment decisions as well (Fankhauser, Smith, and Tol 1999). Therefore, although the debate will remain whether land quantity adjustments as adaptation to disasters are good for environmental sustainability, farmers' adoption of this channel of adaptation helps them at least to overcome the immediate harms of a disaster.

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. Future research on this topic may also considering further extension to incorporate flood-induced increased soil fertility effect as well.

FIGURES

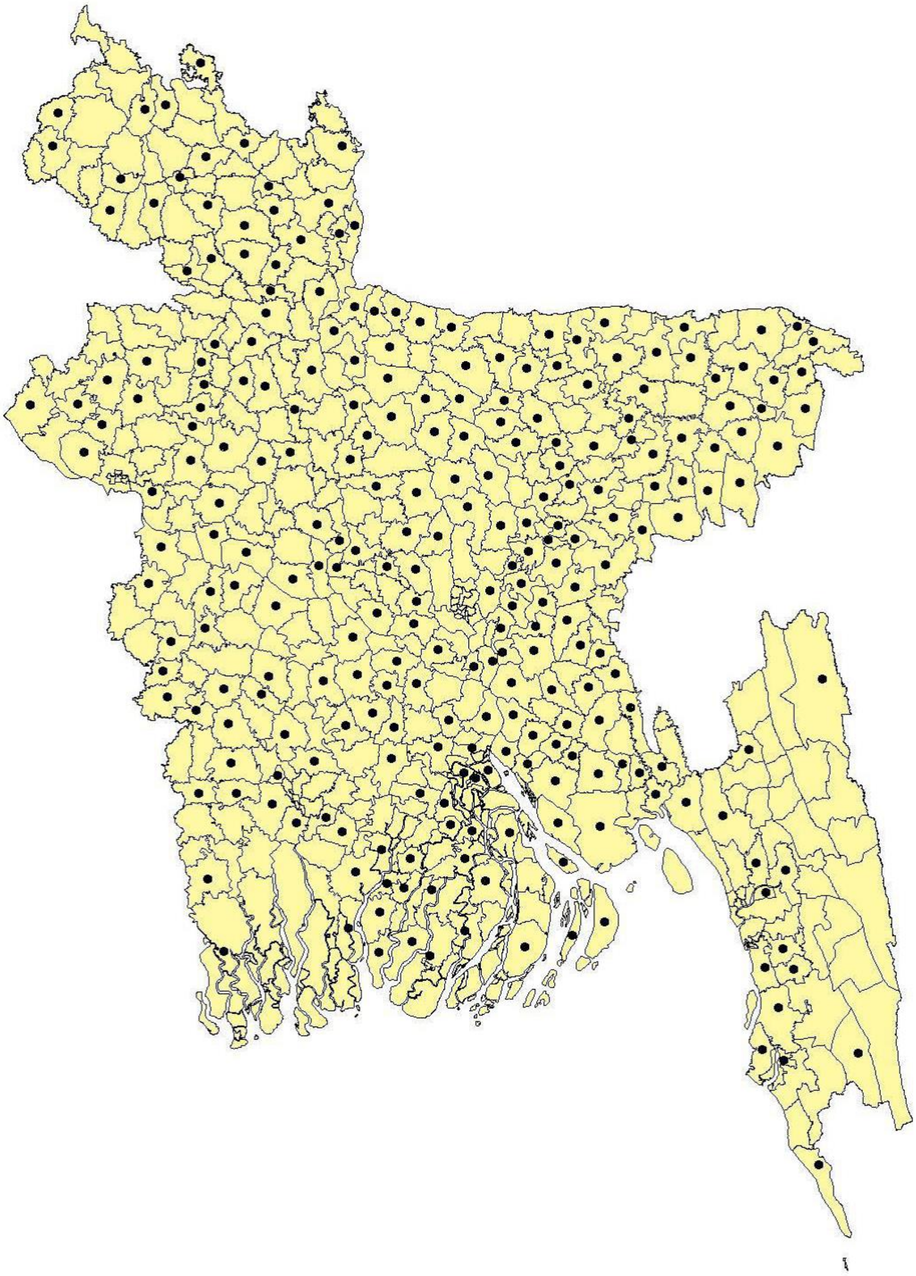

Figure 1 – Map of Bangladesh showing the BIHS survey upazilas

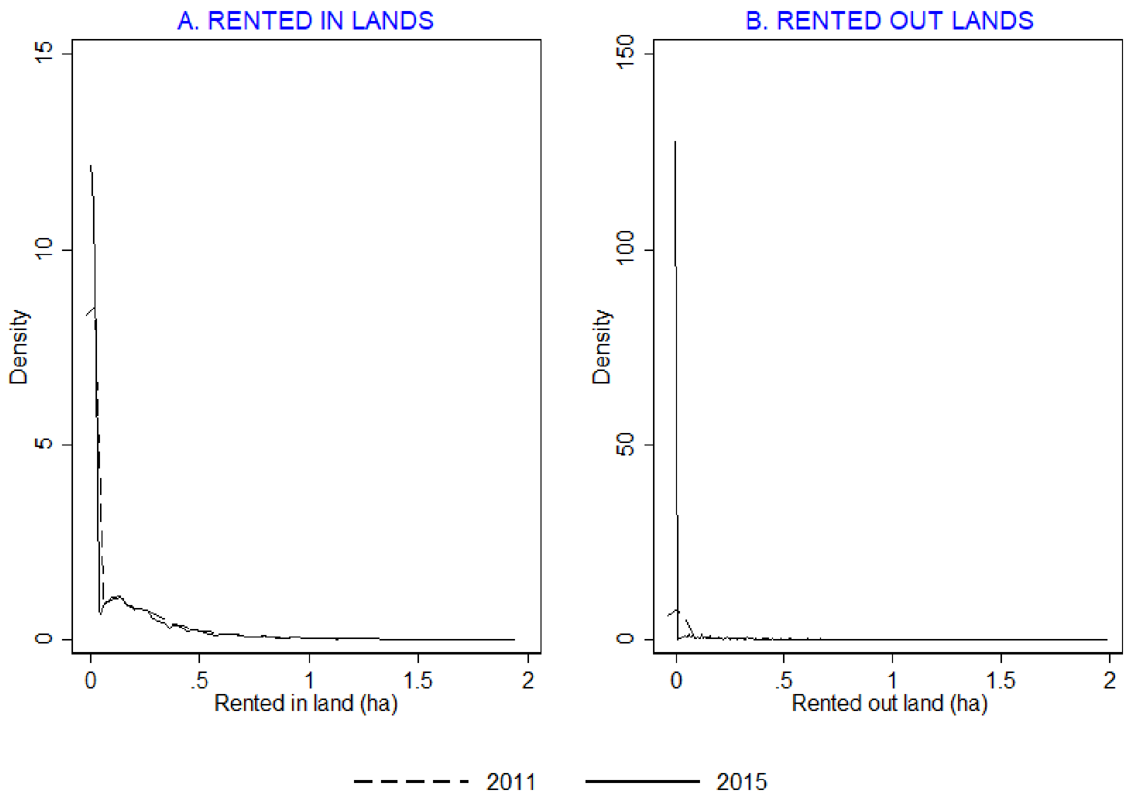

Figure 2 - Land rental transaction distributions

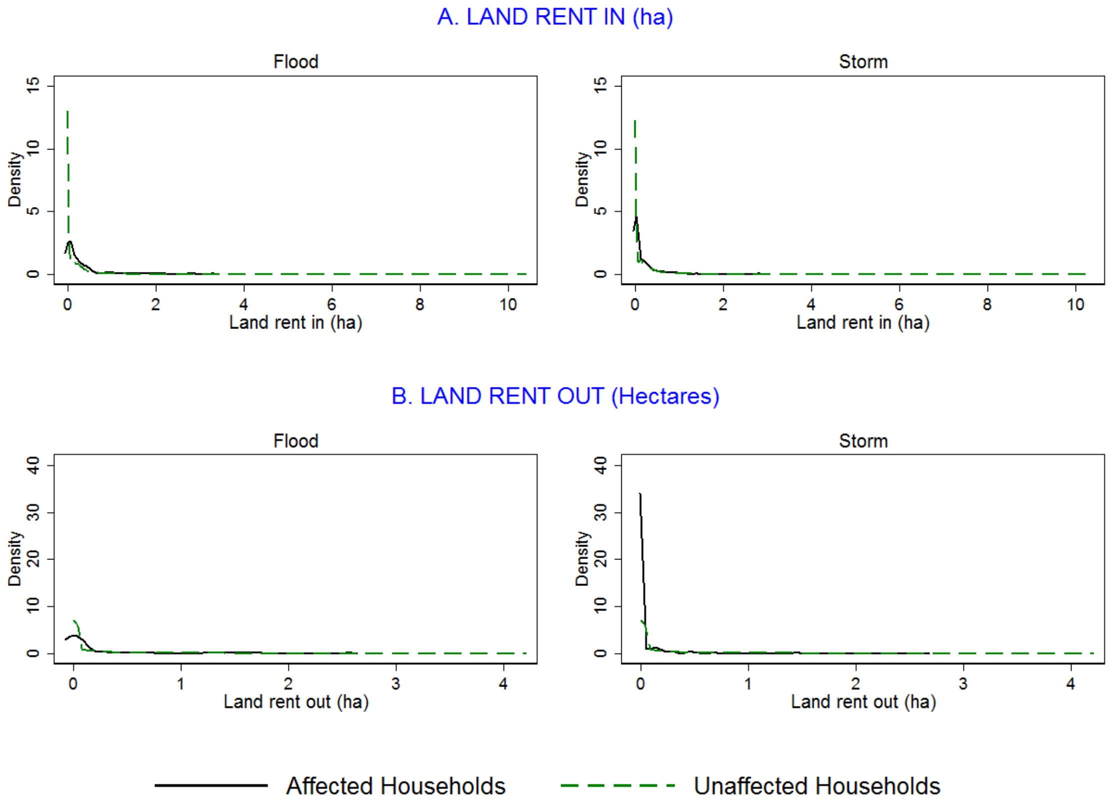

Figure 3 - Land rental transaction distributions by disaster-exposure

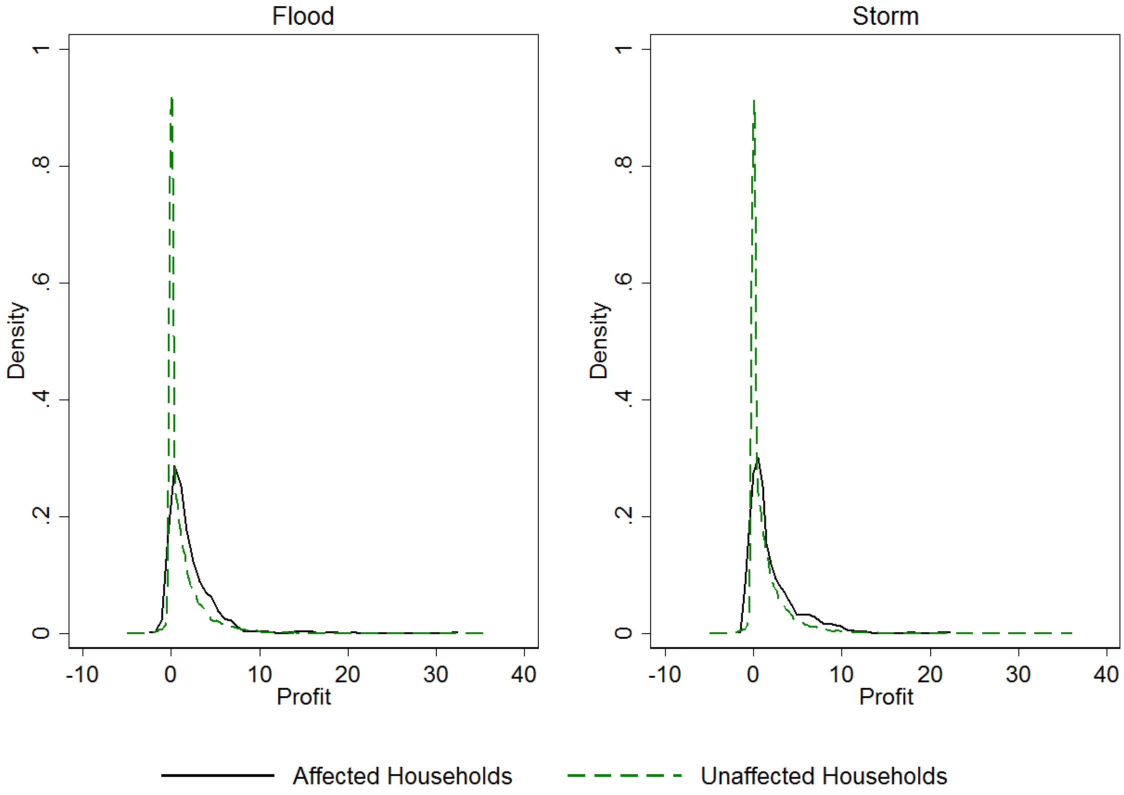

Figure 4 – Crop Profit Distributions by Flood and Storm Exposure

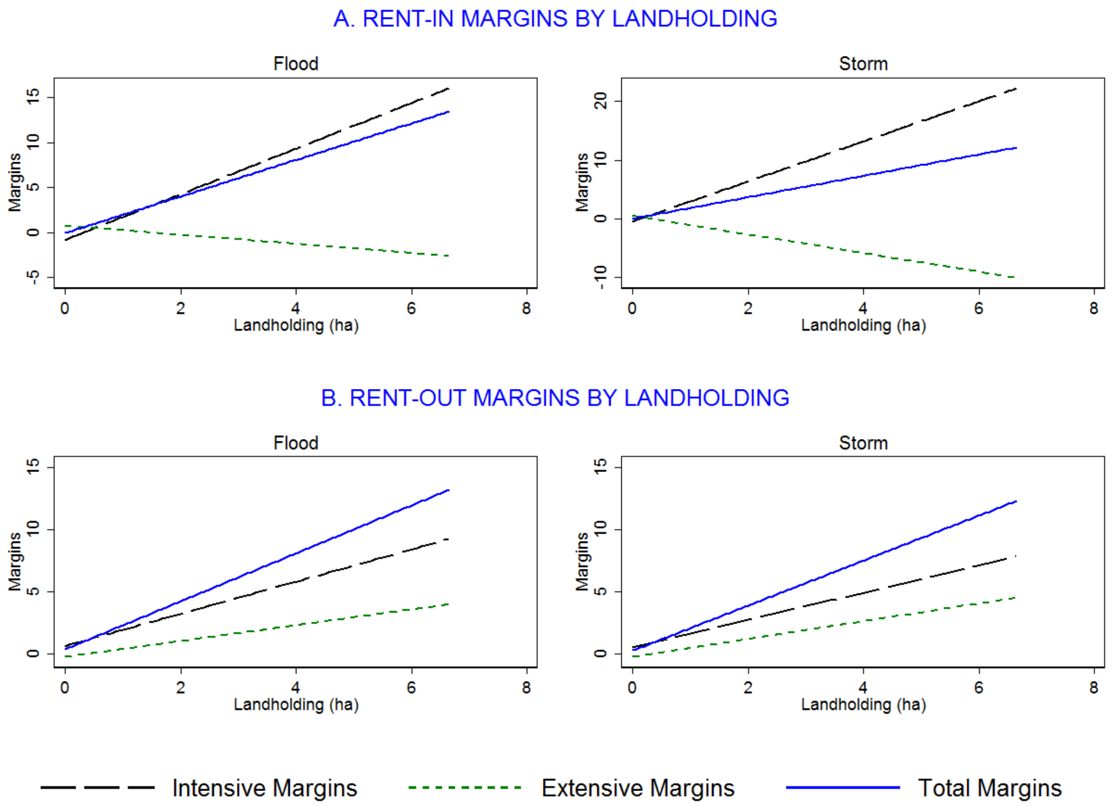

Figure 5 – Rent-in and rent-out margins of disaster exposure by landholding

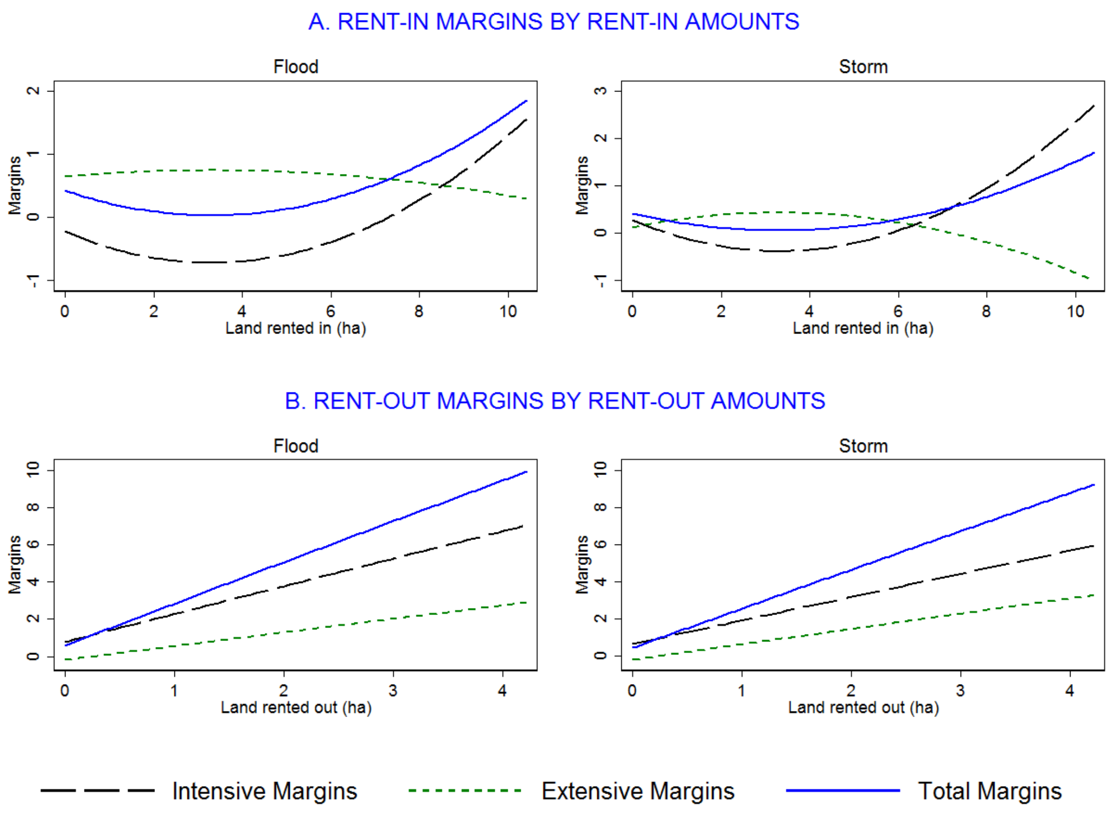

Figure 6 – Rent-in and rent-out margins of disaster exposure by rental amounts

TABLES

TABLE 1 – NUMBER OF DISASTERS BY TYPES IN BANGLADESH, 1900-2015

Disaster type	Occurrence	Total deaths	Total affected	Total damage ('000 US$)
Drought	7	1,900,018	25,002,000	
Earthquake	8	40	19,325	500,000
Epidemic	30	403,188	3,042,429	
Extreme temperature	22	2,440	414,200	
Flood	89	52,331	322,243,064	12,238,400
Landslide	4	103	56,283	
Storm	172	634,663	81,492,115	5,696,380

Notes: Total affected includes the number of deaths, injured, otherwise affected and homelessness due to disaster exposure.
Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium (Created on: October 2, 2017)

TABLE 2 – NATURAL DISASTERS IN BANGLADESH, 2010-2015

Year	Disaster type	Occurrence	Total deaths	Total affected	Total damage ('000 US$)
2010	Flood	2	15	575,000	
2010	Landslide	1	66	55,230	
2010	Storm	3	26	257,160	
2011	Extreme temperature	2	62	102,000	
2011	Flood	1	10	1,570,559	
2011	Landslide	1	17		
2011	Storm	1	13	121	
2012	Extreme temperature	1	72	75,000	
2012	Flood	2	139	5,398,475	
2012	Storm	2	133	184,679	
2013	Storm	3	50	1,532,207	20,000
2014	Flood	2	59	3,200,447	160,000
2014	Storm	2	20	5,262	
2015	Earthquake	1	4	200	
2015	Flood	2	31	1,411,901	40,000
2015	Landslide	1	7	1,003	
2015	Storm	4	117	2,660,250	44,000

Notes: Total affected includes the number of deaths, injured, otherwise affected and homelessness due to disaster exposure.
Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium (Created on: October 2, 2017)

TABLE 3 – SUMMARY STATISTICS OF KEY VARIABLES BY BIHS ROUNDS

Variables	Description of the variable	BIHS 2011	BIHS 2015
SHOCKS			
Idiosyncratic shock	1 if the household experienced any idiosyncratic shock between BIHS 1 and 2; 0 if not		0.363
Flood	1 if the household was exposed to flood between BIHS 1 and 2; 0 if not		0.0323
Storm	1 if the household was exposed to storm between BIHS 1 and 2; 0 if not		0.0333
WELFARE			
Profit	Total farm profits from cultivation, adjusted for rental transactions and costs of production	1.696	0.888
		(2.735)	(1.924)
Non-farm income	Total non-agricultural income	2.012	2.522
		(3.213)	(3.888)
Total income	Total income: sum of farm and non-farm incomes	3.259	3.882
		(3.842)	(4.430)
LAND MANAGEMENT			
Land own	Total area of own and operated arable land (ha)	0.132	0.128
		(0.305)	(0.322)
Rent in land	Total area of rented in and operated arable land (ha)	0.130	0.124
		(0.268)	(0.301)
Rent out land	Total area of rented out arable land (ha)	0.0769	0.0905
		(0.260)	(0.275)
Operated land	Total area of operated arable land (ha)	0.262	0.252
		(0.409)	(0.442)
Landholding	Total area of owned arable land (ha)	0.209	0.218
		(0.428)	(0.451)
Tenants	1 if participates in rent in transactions; 0 if otherwise	0.399	0.366
		(0.490)	(0.482)
Landlords	1 if participates in rent out transactions; 0 if otherwise	0.220	0.256
		(0.414)	(0.437)

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 1 decimals = 0.00405 hectares.

TABLE 4 – BASELINE SUMMARY STATISTICS OF CONTROL VARIABLES

Variables	Description of the variable	Mean	Standard Deviation	Minimum	Maximum
Age	Age of the household head (completed years)	44.99	13.68	17	95
Family size	Number of family members in the household	4.246	1.561	1	15
Gender	Gender of the household head: 1 if Male; 0 if Female	0.847	0.360	0	1
Education	Years of education of the highest educated family member	6.613	3.656	0	16
Extension	1 if the household was in contact with agricultural extension services in the last 12 months; 0 if otherwise	0.0729	0.260	0	1
Subsidy	1 if the household holds an agricultural subsidy card; 0 if otherwise	0.105	0.307	0	1
Transportation	1 if the household is located within 1 kilometer of a bus stop, main road or train station; 0 if otherwise	0.620	0.485	0	1
Finance	1 if the household is located within 2 kilometers of a Bank or a microfinance NGO; 0 if otherwise	0.264	0.441	0	1
Tractor	1 if the household owns a tractor or plough-yoke; 0 if otherwise	0.131	0.337	0	1

Notes. All data comes from the Bangladesh Integrated Household Survey (BIHS) dataset round 1. All monetary values are expressed in US$PPP at the rates of 26.61 and 21.87 Bangladeshi Taka for BIHS rounds 1 and 2, respectively.

TABLE 5 – DIFFERENCE-IN-DIFFERENCES IN OUTCOME VARIABLES BY DISATERS

Change in Variables	FLOOD			STORM		
	0	1	DD	0	1	DD
Crop profits	-0.795	-1.207	0.121**	-0.785	-1.471	0.213***
	(2.018)	(2.735)		(2.025)	(2.501)	
Rent in land	-0.00801	0.0628	-0.138***	-0.00657	0.0189	-0.071
	(0.271)	(0.435)		(0.279)	(0.226)	
Rent out land	0.0127	0.0423	-0.108**	0.0125	0.0480	-0.123***
	(0.173)	(0.214)		(0.173)	(0.229)	

Notes. Standard deviations are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. 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. We calculated DD as the standardized difference in differences, calculated as the ratio of differences in mean of the outcome variables for treatment and control groups to the square root of squared sum of their corresponding standard deviations.

TABLE 6 – LAND RENTAL MARKET PARTICIPATION AND TRANSACTIONS

	PARTICIPATION: RE PROBIT MODELS				TRANSACTIONS: RE TOBIT MODELS			
	FLOOD		STORM		FLOOD		STORM	
VARIABLES	Pr(in)	Pr(out)	Pr(in)	Pr(out)	Rent in	Rent out	Rent in	Rent out
Disasters	1.456***	-0.825***	0.801***	-0.904***	0.270***	-0.296***	0.172***	-0.335***
	(0.196)	(0.270)	(0.191)	(0.274)	(0.046)	(0.078)	(0.049)	(0.079)
Disasters × Landholding	-1.388***	2.305***	-2.085***	2.942***	-0.178**	0.713***	-0.562***	0.848***
	(0.320)	(0.469)	(0.407)	(0.522)	(0.082)	(0.092)	(0.112)	(0.097)
Age	0.062***	0.021	0.065***	0.019	0.017***	0.001	0.017***	0.001
	(0.014)	(0.016)	(0.014)	(0.016)	(0.004)	(0.005)	(0.004)	(0.005)
Squared Age	-0.001***	0.000	-0.001***	0.000	-0.000***	0.000	-0.000***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Family size	0.310***	-0.337***	0.303***	-0.339***	0.083***	-0.117***	0.082***	-0.115***
	(0.075)	(0.083)	(0.075)	(0.083)	(0.020)	(0.025)	(0.020)	(0.025)
Squared Family size	-0.021***	0.020**	-0.020***	0.020***	-0.004**	0.008***	-0.004**	0.008***
	(0.007)	(0.008)	(0.007)	(0.008)	(0.002)	(0.002)	(0.002)	(0.002)
Gender	1.629***	-0.911***	1.635***	-0.911***	0.437***	-0.246***	0.437***	-0.247***
	(0.106)	(0.104)	(0.106)	(0.104)	(0.029)	(0.031)	(0.029)	(0.031)
Education	-0.073***	0.217***	-0.074***	0.216***	-0.017***	0.067***	-0.017***	0.067***
	(0.008)	(0.012)	(0.009)	(0.012)	(0.002)	(0.003)	(0.002)	(0.003)
Extension	0.452***	0.110	0.473***	0.045	0.119***	0.062	0.123***	0.037
	(0.112)	(0.137)	(0.113)	(0.138)	(0.030)	(0.041)	(0.030)	(0.041)
Subsidy	0.576***	0.278**	0.624***	0.252**	0.167***	0.062*	0.180***	0.051
	(0.096)	(0.117)	(0.097)	(0.117)	(0.025)	(0.035)	(0.025)	(0.035)
Transportation	-0.060	-0.026	-0.088	-0.029	-0.021	-0.038*	-0.028*	-0.040*
	(0.059)	(0.074)	(0.059)	(0.074)	(0.016)	(0.022)	(0.016)	(0.022)
Finance	-0.152**	-0.170**	-0.157**	-0.175**	-0.036**	-0.053**	-0.038**	-0.056**
	(0.066)	(0.082)	(0.066)	(0.082)	(0.018)	(0.025)	(0.018)	(0.025)
Tractor	0.554***	0.234**	0.581***	0.269**	0.199***	0.086**	0.208***	0.092***
	(0.093)	(0.114)	(0.093)	(0.113)	(0.024)	(0.034)	(0.024)	(0.034)
Constant	-3.634***	-2.239***	-3.653***	-2.175***	-1.103***	-0.598***	-1.104***	-0.577***
	(0.347)	(0.402)	(0.348)	(0.401)	(0.095)	(0.121)	(0.095)	(0.121)
Observations	10,266	10,266	10,266	10,266	10,266	10,266	10,266	10,266
Number of households	5,133	5,133	5,133	5,133	5,133	5,133	5,133	5,133
Chi^2	1105	1143	1122	1139				

Notes: Standard errors are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. Results for participation choices come from random effect probit regressions according to the specification (6); whereas the results for rental transactions come from random effect tobit regressions according to (7). Outcome variables follow the definitions in Table 4; whereas the explanatory variables are described in Table 6. 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 1 decimals = 0.00405 hectares.

TABLE 7 – WELFARE EFFECTS BY DISASTER EXPOSURE AND LAND RENTALS

	RENT-IN		RENT-OUT	
Variables	FLOOD	STORM	FLOOD	STORM
Land rent in	2.825***	2.835***		
	(0.120)	(0.118)		
Land rent out			0.895***	0.850***
			(0.104)	(0.105)
Disasters	-0.793***	-0.485***	0.625***	0.523***
	(0.188)	(0.184)	(0.193)	(0.195)
Disasters × Landholding	2.530***	3.421***	1.296***	1.096***
	(0.299)	(0.308)	(0.322)	(0.334)
Constant	1.936***	1.919***	1.728***	1.708***
	(0.040)	(0.039)	(0.062)	(0.062)
Observations	10,266	10,266	10,266	10,266
Number of households	5,133	5,133	5,133	5,133
Overall R^2	0.0898	0.0889	0.0256	0.0201

Notes: Standard errors are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. The random effect regressions follow the specification (8). Outcome variables follow the definitions in Table 4. 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 1 decimals = 0.00405 hectares.

TABLE 8 – RENT-IN AND RENT-OUT MARGINS OF DISASTER EXPOSURE

	RENT-IN MARGINS				RENT-OUT MARGINS			
Variables	Mean	SD	Min	Max	Mean	SD	Min	Max
FLOOD								
Intensive Margin	-0.253	1.112	-0.793	16.01	0.902	0.570	0.625	9.234
Extensive Margin	0.656	0.221	-2.578	0.764	-0.128	0.280	-0.265	3.972
Total Margin	0.404	0.891	-0.0289	13.43	0.773	0.850	0.361	13.21
STORM								
Intensive Margin	0.246	1.503	-0.485	22.24	0.757	0.482	0.523	7.805
Extensive Margin	0.147	0.700	-10.09	0.487	-0.131	0.317	-0.284	4.504
Total Margin	0.393	0.803	0.00270	12.15	0.627	0.799	0.239	12.31

Notes: rent-in and rent-out margins are calculated according to equations (6) – (8).

TABLE 9 – RAINFALL ANOMALIES AND LAND RENTAL MARKET

	PARTICIPATION		TRANSACTIONS		PROFIT	
VARIABLES	Pr(in)	Pr(out)	Rent in	Rent out	Rent in	Rent out
Land rent in					2.776***	
					(0.113)	
Land rent out						0.653***
						(0.098)
Rainfall variation	0.002	-0.004**	0.000	-0.001	0.004***	0.003***
	(0.001)	(0.002)	(0.000)	(0.000)	(0.001)	(0.001)
Rainfall variation × Landholding	0.006**	-0.009***	0.001*	-0.003***	-0.022***	-0.019***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
Age	0.064***	0.021	0.017***	0.001		
	(0.014)	(0.016)	(0.004)	(0.005)		
Squared Age	-0.001***	0.000	-0.000***	0.000		
	(0.000)	(0.000)	(0.000)	(0.000)		
Family size	0.307***	-0.349***	0.083***	-0.119***		
	(0.076)	(0.085)	(0.020)	(0.025)		
Squared Family size	-0.020***	0.020**	-0.004**	0.008***		
	(0.007)	(0.008)	(0.002)	(0.002)		
Gender	1.649***	-0.933***	0.439***	-0.250***		
	(0.107)	(0.107)	(0.029)	(0.031)		
Education	-0.077***	0.223***	-0.017***	0.069***		
	(0.009)	(0.012)	(0.002)	(0.003)		
Extension	0.434***	0.124	0.113***	0.067		
	(0.113)	(0.139)	(0.030)	(0.042)		
Subsidy	0.614***	0.282**	0.178***	0.060*		
	(0.097)	(0.119)	(0.025)	(0.036)		
Transportation	-0.093	-0.022	-0.028*	-0.038*		
	(0.060)	(0.075)	(0.016)	(0.023)		
Finance	-0.162**	-0.175**	-0.039**	-0.055**		
	(0.067)	(0.084)	(0.018)	(0.025)		
Tractor	0.588***	0.253**	0.208***	0.089**		
	(0.094)	(0.116)	(0.024)	(0.035)		
Constant	-3.616***	-2.305***	-1.095***	-0.613***	1.904***	1.624***
	(0.350)	(0.411)	(0.095)	(0.122)	(0.041)	(0.062)
Observations	10,266	10,266	10,266	10,266	10,266	10,266
Number of households	5,133	5,133	5,133	5,133	5,133	5,133
Chi2	1140	1176				
Overall R^2					0.134	0.0770

Notes: Standard errors are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. Results for participation, transaction and welfare follow specifications (6), (7) and (8), respectively. For rainfall variations in the regressions investigating participation and transaction, 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. Besides, for rainfall variations in the regressions investigating welfare, we take the difference between the average rainfall over the monsoon months of June-September for 2010 and 1980-2010 for BIHS round 1, and 2013 and 1980-2010 for BIHS round 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 1 decimals = 0.00405 hectares.

TABLE 10 – LAND RENTAL TRNSACTIONS: AMEMIYA'S TWO-STEP ESTIMATOR

	TRNSACTIONS				PROFIT			
	FLOOD		STORM		RENT-IN		RENT-OUT	
VARIABLES	Rent in	Rent out	Rent in	Rent out	Flood	Storm	Flood	Storm
Land rent in					8.334***	8.062***		
					(0.597)	(0.579)		
Land rent out							2.498***	1.919***
							(0.691)	(0.688)
Disasters	-0.139	-0.252***	0.097	-0.404***	-0.508**	-0.355	1.023*	0.567
	(0.085)	(0.080)	(0.079)	(0.076)	(0.243)	(0.278)	(0.535)	(0.559)
Disasters × Landholding	0.356***	0.414***	-0.408*	0.708***	1.588***	6.338***	0.613	0.585
	(0.111)	(0.105)	(0.235)	(0.105)	(0.522)	(0.755)	(0.562)	(0.658)
Age	-0.005	-0.009*	0.011	-0.007				
	(0.006)	(0.005)	(0.008)	(0.005)				
Squared Age	0.000	0.000***	-0.000	0.000***				
	(0.000)	(0.000)	(0.000)	(0.000)				
Family size	-0.026	-0.053	0.047	-0.082***				
	(0.029)	(0.034)	(0.036)	(0.031)				
Squared Family size	0.004*	0.005*	-0.001	0.006***				
	(0.002)	(0.003)	(0.003)	(0.002)				
Gender	-0.201	-0.044	0.256	-0.139**				
	(0.141)	(0.076)	(0.197)	(0.068)				
Education	0.012**	0.023	-0.006	0.044***				
	(0.006)	(0.017)	(0.008)	(0.015)				
Extension	-0.027	0.079**	0.073	0.066*				
	(0.037)	(0.037)	(0.048)	(0.037)				
Subsidy	-0.002	-0.029	0.126**	-0.011				
	(0.040)	(0.037)	(0.058)	(0.035)				
Transportation	0.003	-0.062***	-0.016	-0.070***				
	(0.014)	(0.021)	(0.016)	(0.021)				
Finance	0.018	-0.012	-0.019	-0.033				
	(0.018)	(0.027)	(0.021)	(0.026)				
Tractor	0.063	0.060*	0.190***	0.083**				
	(0.040)	(0.036)	(0.055)	(0.035)				
Inverse Mills Ratio	-0.172*	0.021	0.173	0.149*				
	(0.104)	(0.098)	(0.146)	(0.086)				
Constant	0.691*	0.420	-0.539	0.108	-0.524***	0.376	-0.472**	0.575**
	(0.380)	(0.278)	(0.528)	(0.246)	(0.199)	(0.234)	(0.195)	(0.233)
Observations	3,927	2,445	3,927	2,445	3,927	2,445	3,927	2,445
Number of households	2,532	1,623	2,532	1,623	2,532	1,623	2,532	1,623
Overall R^2					0.0802	0.0305	0.0736	0.0189

Notes: Standard errors are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. Results for rental transactions come from random effect regressions according to the specification (12); whereas the results for profits come from random effect regressions according to (8). 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 1 decimals = 0.00405 hectares.

TABLE 11 – EFFECTS OF IDIOSYNCRATIC SHOCKS

VARIABLES	PARTICIPATION Pr(in)	PARTICIPATION Pr(out)	TRANSACTIONS Rent in	TRANSACTIONS Rent out	PROFIT Rent in	PROFIT Rent out
Land rent in					2.803***	
					(0.112)	
Land rent out						0.200
						(0.124)
Disasters	0.127**	-0.477***	0.028	-0.203***	-0.526***	-0.397***
	(0.065)	(0.084)	(0.018)	(0.022)	(0.059)	(0.068)
Disasters × Landholding	-1.221***	1.927***	-0.339***	0.677***	2.566***	1.610***
	(0.143)	(0.143)	(0.038)	(0.026)	(0.093)	(0.133)
Age	0.064***	0.022	0.017***	0.001		
	(0.014)	(0.016)	(0.004)	(0.004)		
Squared Age	-0.001***	0.000	-0.000***	0.000		
	(0.000)	(0.000)	(0.000)	(0.000)		
Family size	0.281***	-0.298***	0.075***	-0.086***		
	(0.076)	(0.086)	(0.020)	(0.023)		
Squared Family size	-0.018**	0.015*	-0.004*	0.005**		
	(0.007)	(0.008)	(0.002)	(0.002)		
Gender	1.642***	-0.924***	0.437***	-0.230***		
	(0.106)	(0.106)	(0.029)	(0.028)		
Education	-0.066***	0.203***	-0.014***	0.056***		
	(0.009)	(0.012)	(0.002)	(0.003)		
Extension	0.521***	-0.004	0.132***	0.005		
	(0.114)	(0.140)	(0.030)	(0.037)		
Subsidy	0.673***	0.161	0.191***	0.009		
	(0.097)	(0.119)	(0.025)	(0.032)		
Transportation	-0.101*	-0.007	-0.031*	-0.026		
	(0.060)	(0.075)	(0.016)	(0.020)		
Finance	-0.178***	-0.144*	-0.044**	-0.034		
	(0.066)	(0.083)	(0.018)	(0.023)		
Tractor	0.679***	0.054	0.231***	-0.002		
	(0.095)	(0.117)	(0.024)	(0.031)		
Constant	-3.636***	-2.188***	-1.093***	-0.508***	1.926***	1.405***
	(0.349)	(0.408)	(0.094)	(0.109)	(0.042)	(0.067)
Observations	10,266	10,266	10,266	10,266	10,266	10,266
Number of households	5,133	5,133	5,133	5,133	5,133	5,133
Chi²	1105	1115				
Overall R^2					0.138	0.0600

Notes: Standard errors are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. Results for participation, transaction and welfare follow specifications (6), (7) and (8), respectively. 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 1 decimals = 0.00405 hectares.

TABLE 12 – EFFECTS OF DISASTERS ON NON-FARM AND TOTAL INCOMES

	RENT-IN FARMERS		RENT-OUT FARMERS	
VARIABLES	FLOOD	STORM	FLOOD	STORM
Land rent in	4.320***	4.215***		
	(0.209)	(0.205)		
Land rent out			0.783***	0.751***
			(0.180)	(0.182)
Disasters	-2.290***	-0.972***	-0.371	0.306
	(0.328)	(0.321)	(0.337)	(0.338)
Disasters × Landholding	3.244***	3.572***	2.003***	0.698
	(0.527)	(0.541)	(0.567)	(0.585)
Constant	4.587***	4.517***	3.963***	3.935***
	(0.070)	(0.069)	(0.107)	(0.108)
Observations	9,926	9,926	9,926	9,926
Number of households	5,133	5,133	5,133	5,133
Overall R^2	0.0616	0.0593	0.00533	0.00386

Notes: Standard errors are shown in parentheses. ***,** and * represent statistical significance at 1, 5 and 10 percent levels, respectively. The random effect regressions follow the specification (8). 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 1 decimals = 0.00405 hectares.

TABLE 13 – LANDHOLDING BY MARGINS

	RENT-IN MARGINS				RENT-OUT MARGINS			
	IM		EM		IM		EM	
Variables	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
<u>FLOOD</u>								
Landholding	0.055	0.805	2.395	0.171		0.218	0.073	0.939
	(0.086)	(0.682)	(1.124)	(0.277)		(0.451)	(0.111)	(0.727)
% of Households	77	23	2	98	0	100	83	17
<u>STORM</u>								
Landholding	0.020	0.579	0.798	0.054		0.218	0.068	0.903
	(0.038)	(0.606)	(0.679)	(0.084)		(0.451)	(0.104)	(0.714)
% of Households	65	35	22	78	0	100	82	18

Notes. Standard deviations are shown in parentheses. All land measures are expressed in hectares, where 1 decimals = 0.00405 hectares.

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