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Are remittances a source of finance for private adaptation strategy? Evidence from a natural experiment in the Cyclone Sidr hit regions of southern Bangladesh

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Abstract

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Keywords

Remittances, private adaptive expenditure, endogenous risk, storm protection behavior, Cyclone Sidr, Cyclone Roanu, climate change, Bangladesh.

JEL Classification

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1. Introduction

Coastal communities are most vulnerable to tsunamis, hurricanes, and other large storms (IPCC, 2014; World Bank, 2010). The frequency and severity of such natural disasters are expected to rise as a result of global climate change. In 2017 alone, we observed powerful and catastrophic Hurricanes Harvey, Irma, and Maria, inflicting significant human, health, and economic losses on Southern coastal areas and Eastern inland states of USA and Puerto Rico, the Caribbean Islands, the eastern and northeastern coastal parts of North America, the coastal communities of Cape Verde and the Yucatan Peninsula of Mexico (NHC-NOAA, 2017). For USA alone, total economic losses from Hurricane Harvey is estimated to be between US$45 billion and US$75 billion (Grant, 2017); whereas, estimated insurance losses from Hurricane Irma turned out to be US$100 billion for Florida and US$150 billion for Texas (Berr, 2017). Given such climate change-induced developments, communities that are vulnerable to increasing frequency and severity of major storms are in need of public programs and private initiatives that can mitigate damages and assist the communities to cope with post-shocks of the major storm events (Bevan and Cook, 2016; Kunreuther et al. 2016).[1] This form of public programs and private initiatives that can shape a community's resiliency against major storms is more desirable for poorer coastal communities who may not have access to resources similar to richer coastal communities (Mendelsohn et al. 2006; Heltberg et al. 2009; Moser and Satterthwhite, 2010; Mahmud and Barbier, 2016). Although governments, development agencies, and civil society organizations made significant investments to improve coastal communities' ability to mitigate and adapt against major storm events, research reveals that majority of such investments are uncoordinated, and often fail to incorporate private indigenous adaptive capacities of the coastal communities (Ford et al. 2015; Cinner et al. 2018). As a result, the intended outcome to minimize risks of individuals and households from storm induced damages to health, property, agricultural livelihoods, etc. may not be achieved (Brugnach et al. 2016; Cinner et al. 2018). Such outcome is further evident in poor coastal communities of developing countries due to lack of information and understanding of their adaptive capacities in

[1] Hurricanes, cyclones, and typhoons are all the same weather phenomenon; we just use different names for these storms in different places. In the Atlantic and Northeast Pacific, the term "hurricane" is used. The same type of disturbance in the Northwest Pacific is called a "typhoon" and "cyclones" occur in the South Pacific and Indian Ocean. Retrieved from https://oceanservice.noaa.gov/facts/cyclone.html (October 16, 2017)

the form of private defensive strategies to reduce storm-inflicted risks (Moser & Satterthwaite, 2008; Gibbs, 2015). Studies also reveal that private defensive strategies to avert and mitigate storm-inflicted damages might be influenced by communities' access to the public programs (Botzen & van den Bergh, 2008; Shughart, 2011; Bubeck et al. 2012; Mahmud and Barbier, 2016) and remittances from abroad (Mohapatra et al. 2009; Le De et al. 2013). Taking all relationships into account, our paper focuses on the economic behavior of the poor coastal communities in terms of private investments in storm protection to avert and reduce severity of storm-inflicted damages if they have access to publicly financed storm mitigation programs, such as, embankments, cyclone shelters, etc. and access to remittances.

Evidence abound that global climate change-induced developments may significantly increase the intensity of severe cyclones and associated storm surges in future because of sea level rise and increases in sea surface temperatures (IPCC, 2014; Weisse et al. 2014; Tasnim et al. 2015; Walsh et al. 2016). Although governments, development agencies, and civil society organizations made significant investments to improve coastal communities' ability to mitigate and adapt against major storm events, research reveals that majority of such investments are uncoordinated, and often fail to incorporate private indigenous adaptive capacities of the coastal communities (Ford et al. 2015; Cinner et al. 2018). As a result, the intended outcome to minimize risks of individuals and households from storm induced damages to health, property, agricultural livelihoods, etc. may not be achieved (Brugnach et al. 2016; Cinner et al. 2018). Such outcome is further evident in poor coastal communities of developing countries due to lack of information and understanding of their adaptive capacities in the form of private defensive strategies to reduce storm-inflicted risks (Moser & Satterthwaite, 2008; Gibbs, 2015). Although the households have no control over the exogenous storm event, their investments in private storm protection strategies allow them to exercise some control over either reducing the likelihood and severity of losses to property from a major storm event (Botzen and Van Den Bergh, 2009; Poussin et al. 2015; Mahmud and Barbier, 2016). Since private investments to implement storm protection actions have the potential to reduce the probability and severity of storm-inflicted damages, the risks associated with the storm event becomes endogenous (Shogren, 1991; Crocker and Shogren, 2003; Mahmud and Barbier, 2016; Berry and Finnoff, 2016).

Furthermore in risk analysis and behavioral economics literature, studies reveal that investment and insurance purchase decisions against natural disaster risks are influenced by perceived social norms rather than perceived risks of an individual or a household (Peacock et al. 2005; Adeola, 2009; Lo, 2013). One possible explanation of this behavioral anomaly is households' treatment of the future natural disaster risk to be low on the probability scale but high on the consequence scale, which is also known as low-probability/ High-consequence (LP-HC) events or tail events (Kahneman and Tversky, 1979; Kunretuther et al. 2013; Botzen et al. 2015). Studies also show that individuals are less likely to insure themselves against natural disaster risks when they believe help will be available from outside sources, either via public-sponsored programs or private charities (Browne and Hoyt, 2000; Kunreuther and Pauly, 2006). Although there has been no prior research investigating possible influence of remittances on households' private defensive strategies against major storm events, it is expected that households access to remittances could be treated equivalent of having access to market insurance. Evidences, in fact, indicate that there is increasing flow of remittances after occurrence of a natural disaster event (Pelling et al. 2002; Clarke and Wallsten, 2003; Mohapatra et al. 2012; Le De et al. 2013). Such increasing flow of remittances is more prevalent among poor coastal communities that are frequently exposed to major storm events (Yang and Choi, 2007; Yang, 2005; Wisner, 2003). Hence, a household's incentive to increase private storm protection activities to reduce the storm surge damage risk might be influenced by whether it has access to public programs, remittances, or both.

Surprisingly, given the importance of the issues discussed, there has never been a comprehensive study on the effect of disaster-related transfers on private economic actions to reduce disaster risk. Recently Mahapatra, Joseph and Ratha (2012) have shown that remittances do affect ex-post disaster response behavior using field data from developing countries. However, they do not provide a theory or a framework of how this mechanism works. We endeavor to fill in this gap by developing an original model of household private investment in storm protection given public transfer and remittances by addressing two important issues in this paper. They are (1) whether public storm protection programs, such as embankments, cyclone shelters, etc. lead to less private investment in storm protection by coastal households; and, (2) whether access to domestic and foreign remittances also results in less defensive expenditures against a future storm event by coastal households.

We explore these issues by developing a household model of private investment in storm protection under an endogenous risk framework following Mahmud and Barbier (2016), where the representative household chooses the level of its private defensive expenditures to protect themselves from damages from a major storm event.[2] These damages are in terms of death and injury in the family, loss of assets, and loss in domesticated animals, crops, and trees. To keep our exposition simple, we consider all private storm protection actions into one category. Examples of private investments in storm protection actions in a poor coastal community in Bangladesh could be identified as converting a mud-built house to brick-built house, raising the height of the homestead, increase in number of floors, repair of walls, installation of tube well for water, modernization of toilet, improvement of domestic animal sheds, ponds, and boundary of the house, raising the plinths, etc. All these private storm protection actions could also be categorized as adaptation after a major storm or cyclone from the perspective of Bangladesh coastal communities. By applying the endogenous risk framework to the problem of defensive expenditures to mitigate storm damages by poor coastal households given their access to public programs and private transfers, our paper makes two distinct contributions to the literature. First, for the endogenous risk literature (Ehrlich and Becker, 1972; Shogren and Crocker, 1991; Quiggin, 1992; Archer et al., 2006), we pioneer the introduction of private transfers through remittances from migrant family members that are allocated exclusively to reduce severity of damages from a storm event in a household model of private investment in storm protection. Second, for the remittances literature (Chami et al., 2008; Page and Plaza, 2006; Rao and Hassan, 2011, 2012; Rapport and Docquier, 2005), our paper is the first to introduce an endogenous risk framework to understand possible influences of remittances on private investment in storm-protection. In particular, we make use of the comparative analyses from our model to predict whether domestic and foreign remittances are substitutes or complements to private investment in storm protection. That is, whether remittances "fully" or "partially" crowd out or crowd in household decision to invest in adaptation strategies to reduce the likelihood and severity from a major storm-inflicted damages.

[2] Many previous studies have used the household production function framework to study the impact of adverse environmental conditions (e.g., Agee and Crocker, 1996; Berger et al., 1987; Shogren and Crocker, 1991; Freeman, 2003).

The rest of the paper is organized as follows. Section 2 explains the household model of private investment on storm protection. Section 3 introduces the results from the theoretical model. Section 4 concludes.

2. The Household Model of Private Investment in Storm Protection

Assume that a representative rural household lives in a coastal area exposed to the threat of a severe cyclone-induced storm surge event that could inflict property loss. This storm surge risk has two characteristics: (1) the range of possible adverse consequences, and (2) the probability distribution across consequences. In this paper, we measure the adverse effects as monetary losses to property in terms of the damages to houses, trees, livestock and poultry, and agricultural crops. To keep the exposition simple, we assume that there is one adverse storm event. Since we are interested in the household's defensive actions when it is fully exposed to a storm surge event, we do not consider non-storm states. Considering the adverse storm event to be an exogenous event, the rural coastal household in our theoretical model faces two states of nature: state 1, the probability of experiencing damages, $\pi(.)$; and state 2, the probability of experiencing no damages, $1-\pi(.)$. We assume that a household's private spending on storm protection can influence its probability as well as the severity or magnitude of any damages from an adverse storm event.

The probability of damages for representative household *i* located in village *j* fully exposed to an adverse storm event is

$$\pi_{ij} = \pi_{ij}\left(S_{ij}; G_{ij}\right) \qquad (1)$$

where S_{ij} is the level of private storm protection actions (or, expenditures) that decrease the probability of facing ex-post damages;[3] and, G_{ij} is the household's access to publicly financed storm mitigation programs, such as dams, embankments, cyclone shelters, etc.

When exposed to a storm, each household faces monetary losses. We can state this prospect as

$$L_{ij} = L_{ij}\left(S_{ij}; R_{ij}, G_{ij}\right) \qquad (2)$$

[3] We assume that private storm protection actions of the household have no positive or negative externality impact on other households. This suggests that the household cannot transfer the consequences of its storm protection actions to others.

where S_{ij} is the level of private storm protection actions (or, expenditures) that involve actions to reduce the severity of ex-post damages to properties in terms of assets, domestic animals, crops, trees, and, R_{ij} is the flow of remittances from migrant household members where significant portion is expended to reduce magnitude of damages to properties from a major storm event. We expect the property losses to decrease if the household invests in private storm protection actions, enjoys accessibility to publicly financed storm mitigation programs and expects to receive more remittances once a major storm event occurs.

The household is assumed to maximize a *von Neumann-Morgenstern utility index* over wealth. Considering the two possible states of nature, let $U_{ij}^{L}(.) \equiv U_{ij}\left(W_{1}\right)$ denote the household utility when the household faces storm-inflicted monetary losses to properties (state 1) and, $W_{1} = I_{ij} - S_{ij} - L_{ij}\left(S_{ij}; R_{ij}, G_{ij}\right)$, is the net wealth considering the property loss. In W_{1}, a household's full income is represented by I_{ij}, and its level of private storm protection expenditures by S_{ij}. On the other hand, let $U_{ij}^{NL}(.) \equiv U_{ij}(W_{2})$ denote the household utility when it faces no storm damages (state 2) and $W_{2} \equiv (I_{ij} - S_{ij})$ is the net wealth. Since we are dealing with two possible states of nature as a result of full exposure to a major storm, we suggest that a household faces more disutility when it experiences storm-inflicted damages. This could be interpreted as, $U_{ij}^{L}(.) < U_{ij}^{NL}(.)$. Furthermore, we assume that the utility functions are strictly increasing, concave, and twice continuously differentiable over S_{ij}. Given these assumptions, the utility functions under the two states of nature are

$$\begin{aligned} U_{ij}^{L} &\equiv U_{ij}\left(W_{1}\right) \equiv U_{ij}\left(I_{ij} - S_{ij} - L_{ij}(S_{ij}; R_{ij}, G_{ij}\right) \\ U_{ij}^{NL} &\equiv U_{ij}\left(W_{2}\right) \equiv U_{ij}\left(I_{ij} - S_{ij}\right) \end{aligned} \tag{3}$$

Given (1)-(3), the household maximization problem is[4]

$$\underset{S}{Max}\ EU = \pi\left(S;G\right).U\left(I - S - L\left(S;R,G\right)\right) + \left(1 - \pi\left(S;G\right)\right) \cdot U\left(I - S\right)$$

$$\Rightarrow \left[\pi\left(S;G\right) \cdot U(W_{1}) + (1 - \pi(S;G)) \cdot U(W_{2})\right] \tag{4}$$

[4] For ease of exposition, we omit the household index i and the village index j in the following steps.

Expression (4) says that expected utility, which is to be maximized, is the sum of the utilities of facing damages and no damages, weighted by their respective probabilities.

The first-order conditions with respect to the level of private storm protection actions lead to

$$\pi_S(.)\cdot\left[U\left(W_1\right)-U\left(W_2\right)\right] \quad =\pi(.)\cdot\left(1+L_S\right)\cdot U^{'}(W_1)+\left[(1-\pi(.))\right]\cdot U^{'}\left(W_2\right) \qquad (5)$$

where $U^{'}(W_1)$ and $U^{'}(W_2)$ are the marginal utilities of income with respect to private storm protection actions. Assuming, $\left|L_S\right|>1$, the sign of $(1+L_S)$ becomes negative since more private investment for storm protection actions should reduce households' exposure to severity of storm damages, i.e. $L_S=\dfrac{\partial L}{\partial S}<0$.

Expression (5) reveals that a household could employ private storm protection actions to reduce the severity of storm surge damages up to the point where the *expected marginal benefits of private storm protection,* EMB_S , as defined by the decreased chance of storm damages weighted by the utility difference between the two states, equals *expected marginal costs of private storm protection,* EMC_S. For the second-order sufficiency conditions, the sign of the cross-partial derivatives with respect to private storm protection actions cannot be determined even if the household is considered to be averse to storm risks. We show later how imposing additional restrictions in determining the signs of these cross-partial derivatives plays a significant role in determining some key comparative static results.

Behavioral Economics of Private Storm-protection

To find the impact of remittances on private storm protection actions, we applied the *implicit function rule*. Our mathematical exposition reveals,

$$\frac{dS}{dR} = -\frac{F_R}{F_S} = -\frac{\left(\frac{\partial EU}{\partial R}\right)}{\left(\frac{\partial EU}{\partial S}\right)}$$

$$= -\frac{\pi \cdot (-L_R) \cdot U_R}{\pi_S \left[U(W_1) - U(W_2)\right] - \left[\pi \cdot (1+L_S) \cdot U_S(W_1) + (1-\pi) \cdot U_S(W_2)\right]} \tag{6}$$

$$= \frac{\overset{'+'}{\pi} \cdot \overset{'-'}{L_R} \cdot \overset{'+'}{U_R}}{\overset{'-'}{\pi_S} \cdot \overbrace{\left[U(W_1) - U(W_2)\right]}^{'-'} - \left[\overset{'+'}{\pi} \cdot \overbrace{(1+L_S)}^{'?'} \cdot \overbrace{U_S(W_1)}^{'+'} + \overbrace{(1-\pi)}^{'+'} \cdot \overbrace{U_S(W_2)}^{'+'}\right]}$$

Applying the concepts of marginal analysis and behavioral economics from the perspective of a risk averse household, Equation (6) reveals two possible outcomes.

Outcome 1: For a risk-averse coastal household, increasing flow of remittances leads to higher private investment in storm protection (increasing private storm protection actions), i.e. $\frac{dS}{dR} > 0$, if and only if expected marginal benefits of private investment in storm protection, $\pi_S \left[U(W_1) - U(W_2)\right]$, is *lower* than expected marginal costs of private investment in storm protection, $\left[\pi \cdot (1+L_S) \cdot U_S(W_1) + (1-\pi) \cdot U_S(W_2)\right]$.

Outcome 2: For a risk-averse coastal household, increasing flow of remittances leads to lower private defensive expenditures (or, decreasing private storm protection actions), i.e. $\frac{dS}{dR} < 0$, if and only if expected marginal benefits of private defensive expenditures, $\pi_S \left[U(W_1) - U(W_2)\right]$, is *higher* than expected marginal costs of private defensive expenditures, $\left[\pi \cdot (1+L_S) \cdot U_S(W_1) + (1-\pi) \cdot U_S(W_2)\right]$.

Applying the *marginal analysis* concept, Outcome 1 represents the households that are currently making small contributions toward private storm protection actions since their expected marginal costs exceeds expected marginal benefits on such investments. Consequently, these households are willing to invest additional remittance money to increase their level of expenditures on private storm protection actions. They are less likely to invest additional remittance money on assets and savings accumulation.

Conversely, Outcome 2 shows the possibility of identifying households who are already making significant investments on private storm protection actions due to their expected marginal benefits being greater than expected marginal costs of private defensive expenditures. For this type of households, they are more likely to invest additional remittance money on resources (or, on savings accumulation) other than adding more towards their existing level of private defensive expenditures. That is, increasing flow of remittances encourage these households to reallocate resources for assets and savings accumulation (or, both) but at the expense of private defensive expenditures.

Basically, Outcomes 1 and 2 capture the very essence of behavioral economics of private storm protection actions where households' choice to allocate increasing remittance money for private defensive expenditures against major storm-inflicted damages is influenced by their respective *marginal analysis* of private storm protection actions. This is not surprising since an individual or a household's preconceived notions of applying private storm protection actions could be shaped by past experiences, socio-economic condition, social norms, individual beliefs, information access, community networks, etc. In fact, studies under behavioral economics reveal that individuals adapt their behavior in response to positive or negative outcomes of an event by forming simple *heuristics* or by applying *ecological rationality* in their decision-making process (Goldstein and Gigerenzer, 2002; Kahneman, 2003; Thaler, 2015; Todd and Gigerenzer, 2007).[5]

From an individual household perspective, the relationship between foreign remittances and private storm protection investments could be illustrated using a U-shaped curve, initially increasing, $\frac{dS}{dR} > 0$; and, then, decreasing, $\frac{dS}{dR} < 0$. The shape of $\frac{dS}{dR}$ reaches maximum, i.e. with

[5] *Heuristics* are commonly defined as cognitive shortcuts or rules of thumb that simplify decisions. They represent a process of substituting a difficult question with an easier one and can also lead to cognitive biases (Kahneman, 2003). Goldstein & Gigerenzer (2002) defined application of heuristics as an "ecologically rational" strategy that makes best use of the limited information available to individuals.

the slope of $\frac{dS}{dR} = 0$, when the expected marginal benefits of investing in private storm protection actions, EMB_S , is equal to expected marginal costs of investing in private storm protection actions, EMC_S . Considering the expected marginal costs of a household being a fixed amount to consider a mix of private storm protections, i.e. converting mud built to brick built house combined with increasing the number of floors, etc., the households are anticipated to face increasing expected marginal benefits when taken into consideration the aggregate benefits of investing in a mix of private storm protection actions.

Furthermore, as part of our comparative static application to capture the behavioral economics behind private storm protection actions (or, private defensive strategies), we also considered possible influence of households' access to publicly financed storm mitigation programs on choice of private storm protection actions (or, choice of determining the level of private defensive expenditures). Applying implicit function rule on equation (4), we get the following,

$$\begin{aligned}
\frac{dS}{dG} &= -\frac{F_R}{F_S} = -\frac{\left(\frac{\partial EU}{\partial G}\right)}{\left(\frac{\partial EU}{\partial S}\right)} \\
&= -\frac{\pi_G \cdot \left[U(W_1) - U(W_2)\right] + \pi \cdot U_G \cdot (-L_G)}{\pi_S \left[U(W_1) - U(W_2)\right] - \left[\pi \cdot (1+L_S) \cdot U_S(W_1) + (1-\pi) \cdot U_S(W_2)\right]} \\
&= \frac{\overbrace{-\pi_G}^{'-'} \cdot \overbrace{\left[U(W_1) - U(W_2)\right]}^{'+'} + \overbrace{\left[\overbrace{\pi}^{'+'} \cdot \overbrace{U_G}^{'+'} \cdot \overbrace{L_G}^{'-'}\right]}^{'-'}}{\overbrace{\pi_S}^{'-'} \cdot \overbrace{\left[U(W_1) - U(W_2)\right]}^{'+'} - \left[\overbrace{\pi}^{'+'} \cdot \overbrace{(1+L_S)}^{'?'} \cdot \overbrace{U_S(W_1)}^{'+'} + \overbrace{(1-\pi)}^{'+'} \cdot \overbrace{U_S(W_2)}^{'+'}\right]}
\end{aligned} \quad (7)$$

According to equation (7), the directional relationship between the publicly financed storm mitigation programs on private defensive expenditures gives rise to the following outcomes,

Outcome 3: For a risk-averse coastal household, increasing access to publicly financed storm mitigation programs leads to increase in private defensive expenditures against a major storm event, i.e. $\frac{dS}{dG} > 0$, if and only if expected marginal benefits of private defensive expenditures,

$\pi_S\left[U(W_1)-U(W_2)\right]$, is *higher* than the expected marginal costs of private defensive expenditures, $\left[\pi\cdot(1+L_S)\cdot U_S(W_1)+(1-\pi)\cdot U_S(W_2)\right]$.

Outcome 4: For a risk-averse coastal household, increasing access to publicly financed storm mitigation programs leads to decrease in private investment in storm protection, i.e. $\frac{dS}{dG}<0$, if and only if expected marginal benefits of private investment in storm protection, $\pi_S\left[U(W_1)-U(W_2)\right]$, is *lower* than the expected marginal costs of private investment in storm protection, $\left[\pi\cdot(1+L_S)\cdot U_S(W_1)+(1-\pi)\cdot U_S(W_2)\right]$.

Using the concept of marginal analysis, Outcome 3 reveals that if a household is significantly contributing towards private defensive expenditures due to its expected marginal benefits being higher than expected marginal costs of private defensive expenditures, then, the household will be encouraged to allocate more towards private storm protection with access to publicly financed storm mitigation programs. That is, living close or having access to publicly sponsored dams, embankments, cyclone shelters, etc. create greater incentives for households to pursue private storm protection actions.

Outcome 4, on the other hand, demonstrates that if the households are not contributing much towards private defensive expenditures due to their expected marginal benefits being lower than expected marginal costs of private defensive expenditures, then, they will reduce their allocation towards private storm protection with more access to publicly financed storm mitigation programs. Since this type of households do not value the benefits of taking private storm protection actions, they feel somewhat vindicated to reduce their allocation for private defensive expenditures once they are assured that storm protection services are available through public programs.

Although literature on the relationship between public and private investment evidence reveals similar *crowding-out* and *crowding-in* effects (Ramirez, 2000; Mitra, 2006; Gjini and Kukeli, 2012), there not much research to explore the relationship between public and private investment in natural disaster mitigation (Mahmud and Barbier, 2016). Outcomes 3 and 4 suggest that such relationship are a possibility. To verify whether this is the case, we will examine empirically later in the paper whether publicly finances storm mitigation programs, *G*, causes crowding-out or crowding-in of defensive expenditures by households in relation to hazardous coastal storm events.

Our theoretical model allows us to determine the relationship between publicly financed storm mitigation programs and remittances.

$$\begin{aligned}
\frac{dR}{dG} &= -\frac{F_G}{F_R} = -\frac{\left(\dfrac{\partial EU}{\partial G}\right)}{\left(\dfrac{\partial EU}{\partial R}\right)} \\
&= -\frac{\pi(.)\cdot L_R \cdot U_R}{\pi_G\left[U\left(W_1\right)-U\left(W_2\right)\right]+\pi\cdot U_G\cdot L_G} \qquad (8)\\
&= \frac{\overset{'+'}{\pi}\cdot \overset{'-'}{L_R}\cdot \overset{'+'}{U_R}}{\underset{'-'}{\pi_S}\cdot\overbrace{\left[U\left(W_1\right)-U\left(W_2\right)\right]}^{'+'}+\overset{'+'}{\pi}\cdot\overset{'+'}{U_G}\cdot\overset{'-'}{L_G}}
\end{aligned}$$

Equation (8) demonstrates that public assistance storm mitigation programs are *complements* to private remittances. This findings is not surprising as evidence abound that remittances provide necessary funds that allow households' to access public services in many developing countries (Adida & Girod, 2011; Tusalem, 2018). From a developing country perspective, it will be interesting to empirically test whether such relationship could be established between private remittances and publicly financed storm mitigation programs for poor coastal households that are frequently exposed to major storm events.

Table 1 summarizes the behavioral outcomes of household investment in private storm protections through remittances (both domestic and foreign) and publicly funded storm mitigation programs based on our theoretical model framework.

3. Research Hypotheses

Taking into account the outcomes of the comparative static analysis based on our proposed household model of private investment in storm protection, we formulated two hypotheses to be tested empirically:

Hypothesis 1. A household receiving either foreign remittances in the aftermath of a crisis from the migrant member(s) invests more in private storm protection activities to reduce the severity of future storm-inflicted damages.

Hypothesis 2. A household's access to publicly financed storm mitigation programs, such as, cyclone shelters, embankments, dams, etc. lead to less investment in private storm protection actions.

Since majority of the coastal households in our study area in Bangladesh have low-income and asset poor, we suggest **Hypothesis 1**. Based on the marginal analysis concept, this is akin to Outcome 1 under our comparative static analysis. However, for **Hypothesis 2**, we think the same households will be willing to invest in private storm protection if they have access or live close to government sponsored storm mitigation programs, such as embankments, cyclone shelters, etc. That is, a crowding out effect is most likely to occur which is similar to Outcome 4 of our comparative statics analysis.

4. Case Study Area, Sampling Method, and Survey

Bangladesh coastal areas are susceptible to frequent and severe storms due to their unique geographical and geomorphological characteristics (IPCC, 2014; Karim and Mimura, 2008, Dasgupta et al. 2009). Given the limited capacities of public programs, poor coastal households that are vulnerable to major storm events might pursue their own private initiatives to reduce storm-inflicted damages to their properties and agricultural land. (Mahmud and Barbier, 2016). Major focus of our study is to examine the households' choices regarding their participation in private storm-protection actions against major storm events in southeast coastal areas of

Bangladesh given their access to public programs and remittances. In addition, our designated study area is one of the major remittances recipients of the world (World Bank, 2011).

According to recent Bangladesh Disaster Related Statistics (BBS, 2015) 78.31% the coastal households have been affected by the tropical cyclones during 2009-2014 period.[6] For our study area, we considered Bhola, Barguna, and Patuakhali districts of the Barisal division.[7] The Disaster Management Bureau (DMB) of Bangladesh identified these districts to be the most affected zones from frequent cyclones. From each district, we selected an upazilla. Our selected upazillas are Monpura from Bhola, Amtoli from Barguna and Kapara from Patuakhali. After selection of the Upazillas, we, then, selected two affected unions from each upazilla based on the available data from the DMB on number of affected households from their exposure to most recent severe storm events, Cyclone Sidr, which made landfall in 15th November 2007, and Cyclone Roanu, which made landfall in 23rd May 2016. Figure 1 and 2 shows the study area along with the track of Cyclone Sidr.

For our next step, we applied the *Two Stage Sampling methods* based on the Kish Grid/Allocation formula.[8] For the first stage, we performed simple random sampling (SRS) to pick two (2) villages from each union for the household survey. Under the second stage, we applied a systematic random sampling to pick fifty (50) households from each village. Since we have twelve (12) villages from three (3) districts for our household survey, our household survey covered around 600 households (50 households*12 Villages). We employed structured questionnaires to conduct interviews as part of our household survey. There were six (6) data collectors for three districts with two (2) for each

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[6] According to the Hurricane Research Division of the National Oceanic and Atmospheric Administration (NOAA), a tropical cyclone is generally referred to as a hurricane in the Atlantic and the northeastern Pacific oceans; whereas, in the Indian and south Pacific oceans it is called a cyclone, and in the northwestern Pacific it is called a typhoon (Source: Hurricane Research Division, 2018, http://www.aoml.noaa.gov/hrd/).

[7] Administratively, Bangladesh has 6 divisions, 64 districts or zilas, 508 upazilas and 4466 unions (Source: *Statistical Pocketbook of Bangladesh*, 2009). The term 'union' refers to the lowest administrative unit in the rural areas of Bangladesh. Under the Village Chaukidari Act of 1870, villages were grouped into unions to provide for a system of watches and wards in each village.

[8] We have determined our sample size according to the following formula: $Sample\ Size = n_{initial} = \frac{N^2 + Z^2 + S^2}{MOE^2}$; Where, **N** = Total number of beneficiary households= 818,137; **Z =** Critical value from Normal Probability Distribution = 1.96; **S=** Standard deviation of the distribution of beneficiary data = 0. (Assume that since beneficiary data is not available) and, Margin of error (MOE) to be +/- 5% with 95% confidence interval. Sample size for random sampling is determined at 400 for household population size of 818,137. Considering the two stage sampling procedure, the design effect (DE) has been fixed at 1.5. This allows the sample size to be determined at 600 (=400*1.5) households.

Upazilla. On average, each data collector interviewed five (5) household respondents per day. A Field Coordinator was assigned to ensure the quality of the household survey. Prior to the main household survey, a pilot survey was conducted to improve the final version of the questionnaire. For successful completion of the fieldwork, enumerators with graduate level degrees in social science subjects were selected. A day long orientation was conducted involving the enumerators whose main job was to collect qualitative and quantitative data from the targeted villages. The training included a detail discussion of each question on the questionnaire as well as how to record the questionnaire data for each household survey. Since the data collection method was mobile app based with inclusion of recording the global positioning system (GPS) of each household, importance of maintaining highest level of consistency in data collection was communicated during the training program.

To ensure quality information collection, a booklet on purposive non-probability sampling guidelines were provided to the data enumerators. At the end of the training program, all the data collection instruments were practiced through field-based demonstrations. In addition, a separate training was conducted for the Field Coordinator to ensure constant monitoring of questionnaire fill-up activities by the data enumerators. As part of the required tasks, the Field Coordinator was directed to randomly cross check the completed questionnaire through telephone calls, spot or physical cross checking, and backward checking with the respondents. Any information gap that could be identified through these cross checking methods was corrected accordingly. Table 2 summarizes the distribution of the sample households.

Our survey questionnaire contains basic questions about household characteristics, education level, age, gender, number of children, and their socioeconomic status. To address our research objectives, specific questions are directed that capture household access to public sponsored programs, number of migrant members in the family, amount of remittances received from migrant members, structure of the houses before-and after two major storm events spanning 9 years, i.e. between 2007 and 2016, and disaster related questions. There are also specific questions on household's location from nearest cyclone shelter, embankments, vehicular road, primary school, and the forest. Our structured questionnaire also includes some specific migration related questions.

Table 3 reveals the general demographic and socioeconomic characteristics of the 610 households in the study area. Majority of the respondents are male (66.39%), have primary (42.13%) and no education (30.49%), and involved with timber business (23.72%), farming (15.82%), and salaried (14.16%) jobs. Among the surveyed households, 44.14% have no access to latrine. Those have access, 21.66% have water-sealed sanitary latrine and, only 18.62% have high-commode latrine. For drinking water, around 37% of the households use filters for water purification, 31% use tube well, and 27.8% use tap water. Dungs and leaves (70%) turned out to be major sources of cooking followed by fuelwood (17%) and cylinder gas (13%). Less than 1% of the surveyed households have electricity connection. Solar power is the major sources of energy. 95.41% of the households use it to meet their energy demand. Only 19.02% of households access to telephone connection and 7.70% to television.

Table 3 also shows that 41.80% of the households have domestic migrants; whereas, only 17.21% of the households have family migrants in the family. Regarding home location, 33.45% live in lowland, 31.15% within polder, and 11.94% near forest. Rest of the households, 23.35%, are located on embankment. Table 4 reveals damages during the two major cyclone events, and post-cyclone adaptation strategies pursued by the households in the study area. For adaptation against major storm events, majority of the households increased the number of floors (25%), put new tube wells for water (24%), and improved their pond areas (12%) after Cyclone Sidr. Same adaptation strategies were applied post Cyclone Roanu. Survey results show that income, savings, and donations were major sources of funds for adaptation after these two major storm events however, close to 20% of the households were forced to sell their lands and assets to protect their homes and other properties from future storm events. On public perceptions of public adaptation measures, around 22% of the households think building embankments with stone and cement blocks is the most effective strategy. Next most effective strategy is raising height of the embankment (16.46%). This is followed by building new cyclone shelters or expanding the existing ones (14%), raising floors or heights of the house (13.44%) and, raising plinths (11.55%). Interestingly, other public adaptation measures, such as building clay embankment (9.15%) and afforestation (7.86%), did not get much approval from the survey respondents. Our survey data tells that 93.44% of the households experienced flooding or water logging affecting their houses.

Tables 5 and 6 summarizes the results.

5. Econometric Strategy, Results and Discussion

For empirical analysis, our econometric estimations are based on households' response to private storm protection actions on home improvement Post-Cyclone Sidr, one of the major storm event that made landfall at our study area on 15 November of 2007. We also collected data on Post-Cyclone Roanu, another major storm event that made landfall at our study area on May 21 of 2016, and used it as an identification strategy to make causal inference on remittances receipts and private adaptive expenditures. Our survey questions allowed us to capture the strategies that households' privately adopted to avert the likelihood and reduce the severity of storm-inflicted damages to properties covering almost a 10-year timeframe. We identified households of two (2) types : (Type 1) Households that have migrant family member(s) and hence, have access to monthly or yearly remittances; and, (Type 2) Households that have no migrant family member and hence, do not have access to remittances.

Our baseline model of analysis is:

$$y_{ij} = \alpha_{ij} + \gamma \times R_{ij} + \boldsymbol{X}_{ij} \times \theta + u_{ij} \qquad (9)$$

Where y is the expenditure on home improvement Post-Cyclone Sidr for household i in village j, R is the receipt of foreign remittances, X is vector of household characteristics. To test our model's prediction, we are interested in the sign of γ which allows us to estimate a measure of the causal effect of remittances on household adaptive expenditure. Ideally, we start by estimating baseline equation (1) by applying Ordinary Least Squares (OLS), assuming that the error term of Eq. (1) uij term meet the standard properties of the classical linear regression. The fundamental assumption for consistency of the OLS estimators is that the error term is unrelated to the regressors. Because the variable we are interest in is the regressor R, it is essential that $E(u \mid R)=0$. Failing this condition in the estimation of Eq. (1) would imply that the OLS estimator can no longer be given a causal interpretations. We do not run any explicit test to check for the existence the endogeneity bias, but it makes sense to assume a-priori that $E(u \mid R) \neq 0$. The reason being that, it is natural to expect that natural disasters will set forth and accelerate the flow of emigration, which in turn can generate more remittances inflow. In fact, as an answer to a survey question related to the reasons that the household find that significantly affect their migration decision, a frequently chosen option was to avoid disaster damage from cyclones or flooding. Therefore the instrumental-variables (IV) estimator would be the choice of our preferred estimators. The efficacy of the IV estimator is, however, crucially dependent on a very strong assumption that valid instruments exists. That is, if we can find other variables Z correlated with remittances that satisfy the condition that $E(u \mid Z)=0$, also known as the exclusion criteria. There are also a number of different sources of bias that need to be accounted for. In order to gauge the causal effect of remittances, while we explicitly control for other observable household characteristics, such as age, education, etc. that we collected through the survey instrument represented in the vector X, we also need to do the same for the unobservable factors such as abilities, knowledge, customs etc. Therefore, we slightly modify the baseline regression in Eq. (1) to a different version, as follows:

$$y_{ij} = \alpha_{ij} + \gamma \times R_{ij} + \boldsymbol{X}_{ij} \times \theta + F_j + u_{ij} \quad (9)$$

Where Fj is the village fixed effects to control for the unobservable factors. This still leaves out the possibility of a non-zero correlation between remittances and the error term, which is why we rely on the previous strategy of estimating Eq. (2) with an IV estimator. We envisaged the problem of endogeneity bias a–priori during the formation period of our research before data collection. We therefore premeditated at the outset of our data collection on potential variables that would be suitable as instruments for remittances. Having reviewed the literature, we collected data on two variables that may serve our purpose as valid instruments for our estimation purpose. These two variables are: i) the distance of the household from the nearest vehicular road (Z_1) and ii) the distance of the household from the nearest primary school (Z_2). Mean distances to the nearest primary school and the vehicular road in kilometers, the two commons distance instruments in rural areas, are likely to be correlated with both foreign and domestic remittances. This is because a shorter distance to a primary school or a vehicular road generally associated with a lower travel cost, and as a result a higher ratio of emigrants to the total population, which for obvious reasons leads to higher remittances on average. We also found support of this argument to treat these two variables as valid instruments in migration and remittance literature that dealt with purely cross-sectional and household survey data (Hassan and Faria, 2015; Edwards and Ureta, 2003; Abdih et al. 2012; Adams and Page, 2005). [9]

The IV approach requires that instruments are sufficiently correlated with the endogenous variable (i.e. the coefficient of the *Z* variables in the first stage is nonzero) in addition to the exclusion restriction condition Cov(u, Z)=0. The initial estimation of the Eq. (2) using an IV-2SLS led us to find that the instruments were not sufficiently strong, i.e. the estimated coefficients on Z_1 and Z_2 were not sufficiently correlated with remittances because the first stage F-test statistic on the excluded instruments was not big enough compared to the rule of thumb as suggested by (Staiger & Stock, 1997), implying a weak instruments problem. In practice, however, there is no clear critical value for the F statistic to test for instrument relevance because it depends on many factors (Cameron & Trivedi, 2005, 2009). Nonetheless, with the presence of weak instruments, the precision of the 2SLS estimator can be reduced (Hayashi, 2000). Therefore, we used the limited information maximum likelihood (LIML) estimator as an alternative which has a better finite-sample properties when instruments are weak (Murray, 2006).

However, to effectively isolate the impact of the variable remittances, so that a causal inference can be made, one needs to identify a random exogenous shock at source that generate the variation in the endogenous variable to a treatment group vs. a non-treatment group. We attain this objective by harnessing a random assignment of treatment of remittances by exploiting the naturally occurring shock in our data set wherein some households suffered damage from a second Cyclone Roanu in the same area just prior to the survey period in 2016. The shock represents a randomization of remittances because the development literature report evidences for a surge in remittances inflow in the aftermath of a natural disaster. Since the occurrence of the landfall of Cyclone-Roanu is a random event, the associated remittances flows stemming from such a shock can also be treated as random. Thus using natural experiment as an identification strategy, we estimate a remittances equation in the first stage by modifying our instruments: Interacting both

[9] The migration and remittance literature shows that the two instrumental variables are strong candidates of being correlated with remittance flows but not with the dependent variable, except through the included Regressors. Also, our purely cross-sectional household survey data enabled us to consider these two time-invariant geographic variables as instruments.

Z_1 and Z_2 with an indicator variable for whether the remittances recipient households' homes suffered damage by Cyclone Roanu (the treatment group) controlling for several control variables including village fixed effects. The resulting new instruments are labeled as Z_3 and Z_4 respectively. In the second stage regression, where the dependent variable is private adaptive expenditure undertaken after Cyclone Sidr, the coefficient on remittances measures the "average treatment effect" for the treatment group. The standard errors are conservatively clustered by village in the first and second stage regressions in addition to their being jointly estimated where the errors in the second stage take into account the estimation error in the first stage. Table 7 shows the summary statistics for the explanatory variables, including the control and treatment variables, used in our regression.

Using this identification method, we proceed with our IV estimation in Table 8. Firstly, note from Column (1) that the Z_3 instrument enters significantly in the first stage regression which is implying that a one kilometer closer distance to the nearest vehicular road increases foreign remittances by 4484 Tk. It is not an unreliable estimate because nearness to vehicular road enhances migration opportunities and subsequently increases the sending of remittances. Moreover, the land price tend be higher the near the residence is to the vehicular road which will only relatively wealthier households can afford where the potential migrant will have the greater capacity to undertake the cost of migration and thus will be on average more capable of sending more remittances. On the other hand, the instrument Z_4 is insignificant in the first stage implying that the distance from nearest primary school have no impact foreign remittances. The causal impact of remittances on private adaptive expenditure can be found in the second stage through the resulting estimated coefficient on remittances that measures the "average treatment effect" for the treatment group (remittances recipient household affected by Cyclone Roanu) which is reported in column (1) of Table 8 and shows that a 1000 Tk. increase in foreign remittances lead to an increase in private adaptive expenditures of 22.52 Tk. The effect of remittances is found to be significant at 1% level. The first stage F-statistic on excluded instrument is found to be 11.68 (with a Shea's partial R^2 of 0.42) which is greater than the rule-of-thumb value of 10 implying instruments are sufficiently strong. The exclusion restriction condition Cov(u, Z)=0, cannot be formally tested because the error term is not directly observed. However we do offer an intuitive explanation to the claim that the instruments affect the dependent variable only indirectly through their effects on remittances, and that they cannot effect the dependent variable directly. The reason is the dependent variable represents adaptive expenditures after Cyclone Sidr, but the instruments Z_3 and Z_4 represent whether or not damages sustained after Cyclone Ruanu. Two are different events separated by a significant time lag, and therefore the instrumental variables cannot directly affect the dependent variable. Finally, because we used two instruments for one endogenous variable we have an over-identified system. To check for if the overidentifying restrictions are valid we undertook the Basman F-statistic and report its p-value which equals 0.203 which means that the null hypothesis that identifying restrictions are valid may not be rejected.

To further check for the robustness of results we estimate Eq (2) with only Z_3 as being the instrument because the instrument Z_4 was found insignificant in the first stage. The first stage result shows (column 3) that an increase of one kilometer proximity to the nearest vehicular road tend to significantly increase remittances by 4133 Tk. Using this strategy, we report in column (4) of Table 8 that a 1000 Taka increase in foreign remittances lead to an increase in private adaptive expenditures of 19.03 Taka. Again, the estimated coefficient on remittances measures the "average treatment effect" for the treatment group (remittances recipient household affected by Cyclone Roanu) is significant at 1% level. The first-stage F-statistic is 17.94 (with a Shea's partial R^2 of 0.38), which is greater than 16.38, the critical value for 5% 2SLS relative bias. The justifications for the exclusion restriction conditions provided in the preceding paragraph also applies here. The use of a single instrument lead us to the exact identification of the equation.

We expect to meet the criteria for both internal and external validities in our research. [10] Our design of the natural experiment allows for the randomization of the effect of treatment, which is considered to have met the criterion of *internal validity*. On the other hand, the requirement for *external validity* is that the confounding variables or the pretreatment household observable characteristics of treatment group (all the control variable) and non-treatment group, should not differ significantly except for the treatment (remittances). Our IV results are generalizable because

[10] In experimental research, there are two criteria to judge the validity of a research. One is, *internal validity*, which reveals the effectiveness of the method to control for the effect of the treatment from other confounding factors in the natural experimental study. Randomizing the effect of treatment achieves internal validity, which we have obtained through our design of the natural experiment. The second criterion of validity of experimental research is established through *external validity*. This refers to the generalizability of the research.

the control and treatment groups do not differ in their pretreatment observable characteristics except for the treatment received. This is shown using a *t test* on these household characteristics where the null hypothesis of zero mean difference between two groups cannot be rejected at 5% significant level. In our case, we found all the household characteristics meet this criterion except for remittances (treatment variable), which is what we need to confirm the external validity of research. Table 9 summarizes the external validity tests.

Regarding the control variables, we included age, age squared, total members living in the house, total female members and workers in the house, total female students, total school going children below 7 years of age, family income, medical and education expenditures per month, areas of the homestead and agricultural land, different education levels (where the reference groups Masters and others) and farmers. Additional controls of public spending on storm protection, such as a household's distance from the embankment and the cyclone shelter, are also included along with the village fixed effects. In our regression specifications, the coefficient of having more female family members is significant but negative. However, the coefficients of female workers and female students in the family are positive and highly significant. This implies that private investment in storm protection will increase if a household has more educated and working female members. Interestingly, the coefficient of family income is significant but has negative sign indicating that a household invest less in private storm protection when its income goes up. A plausible explanation could that due to household's access to foreign remittances, it might be compelled to spend additional income on other resources.

The coefficients of ownership of homestead and agricultural land - proxies for the household's asset ownership – remain positive and significant. Although not highly significant, the coefficients for age and the square of age of the survey respondent display positive and negative signs, respectively, under both regression specifications. This suggest that a household investing in private storm protection has an inverted U-shaped relationship with age, initially increasing but then declining. Interestingly, the coefficient of household's total education expenditures is negative and significant at 1% level. This could be explained in terms of households that are allocating significant portion of remittances to support education expenditures of their members, have less money to allocate for private storm protections. Among the control variables of public spending on storm protection, the coefficient of a household's distance from the embankment bears positive sign although this effect is not statistically significant. On the other hand, the coefficient of a household's distance from the nearest cyclone shelter show positive sign although this effect is statistically significant. With regard to education we can we can see that the private storm protection spending is less by those having primary to university level education in comparison to those who have a master's degree. In terms of occupation, farmers spend more on private adaptive spending compared with rest of the other types of occupations.

Revisiting our hypotheses based on the comparative statics of our theoretical model, our empirical analysis reveal that both foreign and domestic remittances lead to increase in private investment in storm protection after a major storm event. That is, the empirical findings support Hypothesis 1 and Outcome 1 of our theoretical model. Since our empirical findings show that the influence of public sponsored storm mitigation programs, such as embankments and cyclone shelters, on private investment in storm protection actions are ambiguous, we cannot reach a conclusion of Hypothesis 2 and Outcome 4 of our theoretical model. Although the coefficient of distance from the nearest embankment has the expected negative sign representing the *crowding-out* effect on private investment in storm protection, the sign of the coefficient of distance from the nearest cyclone shelter has positive sign implying *crowding-in* effect on private investment in storm protection. Therefore, similar to Outcomes 3 and 4 of our comparative statics analysis, the empirical finding also lead to inconclusive results.

6. Conclusion

Considering the possibility of coastal households being exposed to increasing frequency and severity of major storm events, we examined two key important issues in our paper: (1) whether household's access to domestic and foreign remittances lead to increase in private investment in storm protection; and (2) whether household's access to public sponsored storm mitigation programs, such as embankments, dams, etc. create disincentives among households by reducing private investments in storm protection actions. At macro level, the latter could lead to the possibility of the entire coastal community experiencing the *crowding-out* effect. To examine these two issues, we explored the dynamics of the household storm protection behavior by proposing a theoretical model that could be empirically tested using household survey data.

For our theoretical model, we introduced a household production function under an endogenous risk framework where households choose the level of private defensive expenditures against a major storm event their access to publicly financed storm mitigation programs, such as, embankments, cyclone shelters, etc., and remittances received either domestic or foreign sources through migrant family members. Analysis of our theoretical model reveals some interesting results. For a risk averse household, increasing remittances lead to higher private defensive expenditures (or, higher private investment in storm protection) if expected marginal benefits is lower than expected marginal costs of private defensive expenditures. On the other hand, a risk averse household is expected to spend less on private defensive expenditures with increasing flow of remittances if its expected marginal benefits exceeds expected marginal costs of private defensive expenditures. That is, a household's decision to rely on remittances to reduce the likelihood and mitigate the severity of storm inflicted damages depends on household's marginal analysis of its private storm protection actions.

Regarding the influence of publicly financed storm mitigation programs on private defensive expenditures, findings from our theoretical model show that the directional relationship between the two variables can only be determined by introducing some additional assumptions. Hence, it is not straight forward to establish *crowding out* effect for a community that has access to both public storm mitigation programs and private remittances. In fact, our theoretical model demonstrates that it is possible that public assistance storm mitigation programs could act as *complements* to private remittances. Such finding is not surprising as evidence abound that remittances provide necessary funds that allow households' to access public services in many developing countries (Adida & Girod, 2011; Tusalem, 2018). From a developing country perspective, it will be interesting to empirically test whether such relationship could be established between private remittances and publicly financed storm mitigation programs for poor coastal households that are frequently exposed to major storm events.

For our empirical analysis, we use data collected from a household survey along the southwest coastal areas of Bangladesh that have been frequently exposed to cyclones during 2007-2015 period. From our empirical model, our goal is to analyze whether publicly sponsored storm mitigation programs and access to remittances influence the economic behavior of the coastal communities in terms of their investments in private storm-protection actions. Our household survey comprises 610 households among twelve (12) villages in the southwest coastal areas of Bangladesh. We applied *two stage sampling method* to first identify the villages by performing simple random sampling (SRS) on six (6) unions of the three (3) most affected upazillas exposed to frequent cyclones between 2007 and 2015 following observations of the Disaster Management Bureau (DMB) of Bangladesh. [11] For the second stage, we performed systematic random sampling to pick fifty (50) households from each village. With a team of enumerators and a supervisor, the survey was conducted between late October and mid-December of 2016.

Our empirical findings using different regression specifications reveal that coefficients of foreign remittances are positive and statistically significant. Hence, there is an indication of positive causality from remittance (both foreign and domestic) to household investments on storm protection. Results also show that household characteristics, such as family income, size of ownership of agricultural land, area of the homestead, family size, and number of foreign family migrants, influence household investment in private storm protection. Regarding the influence of household's access to public sponsored storm mitigation programs, such as cyclone shelters and embankments, on private defensive expenditures against a major cyclone event, only the coefficient of a household's distance from the embankment turned out to be statistically significant at 10% level with negative sign implying the possibility of experiencing crowding-out effect. On the other hand, the coefficient of distance from cyclone shelter has positive sign but not statistically significant in all regression specifications.

From policy perspectives, we think that our theoretical and empirical findings are relevant for poor coastal communities in developing countries in two areas. First, our findings will establish public-private partnerships involving government, non-governmental organizations, development agencies, and local indigenous communities to efficiently allocate resources for emergencies and humanitarian purposes to reduce the severity of future storm-inflicted damages to properties.

[11] Administratively, Bangladesh has 6 divisions, 64 districts or zilas, 508 upazilas and 4466 unions (Source: *Statistical Pocketbook of Bangladesh*, 2009). The term 'union' refers to the lowest administrative unit in the rural areas of Bangladesh. Under the Village Chaukidari Act of 1870, villages were grouped into unions to provide for a system of watches and wards in each village.

Second, our findings will also encourage key stakeholders to form public-private partnerships to create development funds that are specifically targeted to improve long-term adaptive capacities of the poor coastal communities to reduce their likelihood of facing extensive storm-inflicted damages in future. Such development funds should combine contributions from the government, development agencies, and civil society organizations with contributions from private indigenous communities on adaptive capacities to improve community resiliency against major storm and other natural disaster events.

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Figure 1: Explaining the Behavioral outcomes of Private Storm Protection Actions

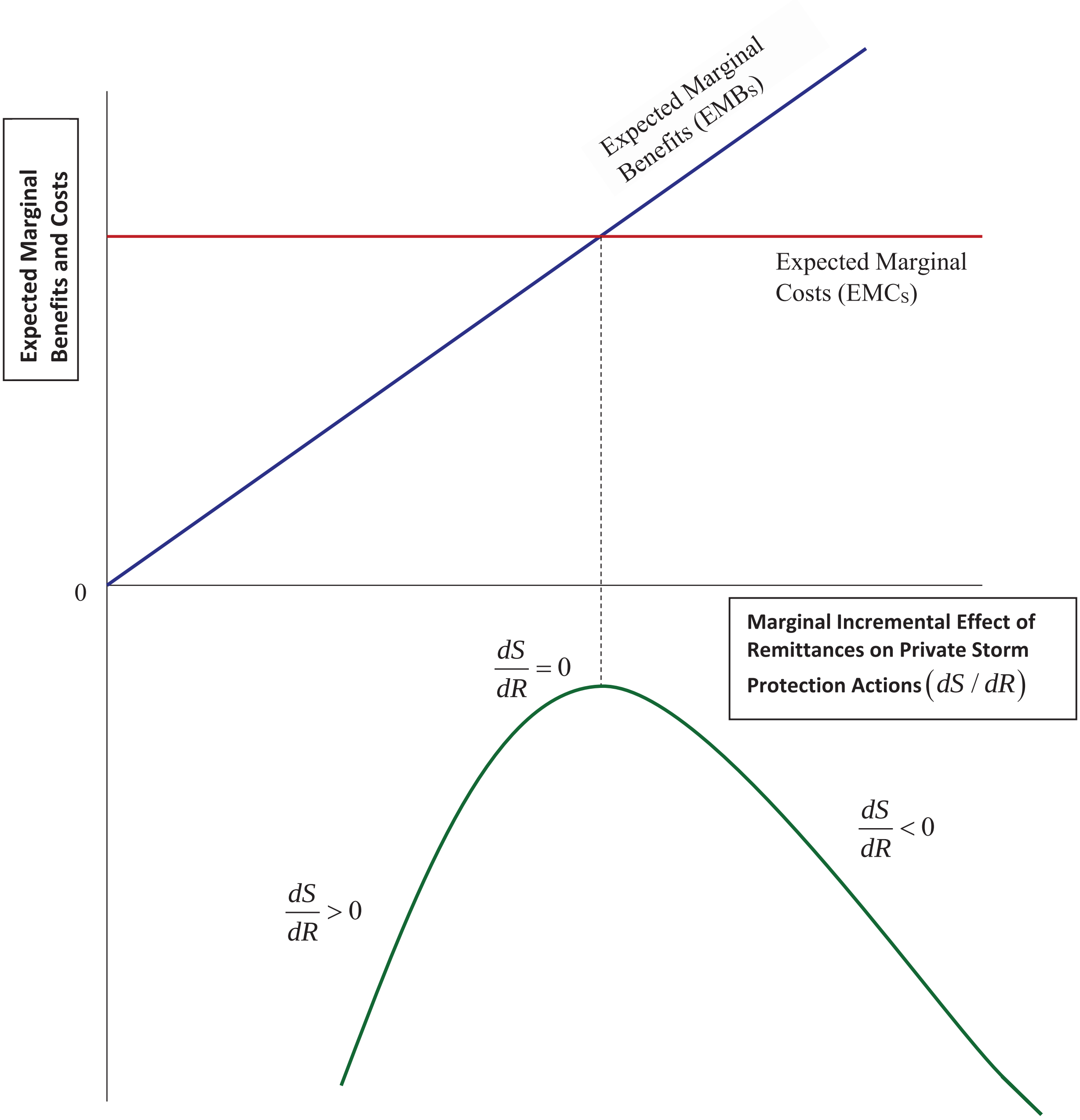

Figure 2: Study area showing the Geo-coded Household locations along with the track of Cyclone Sidr

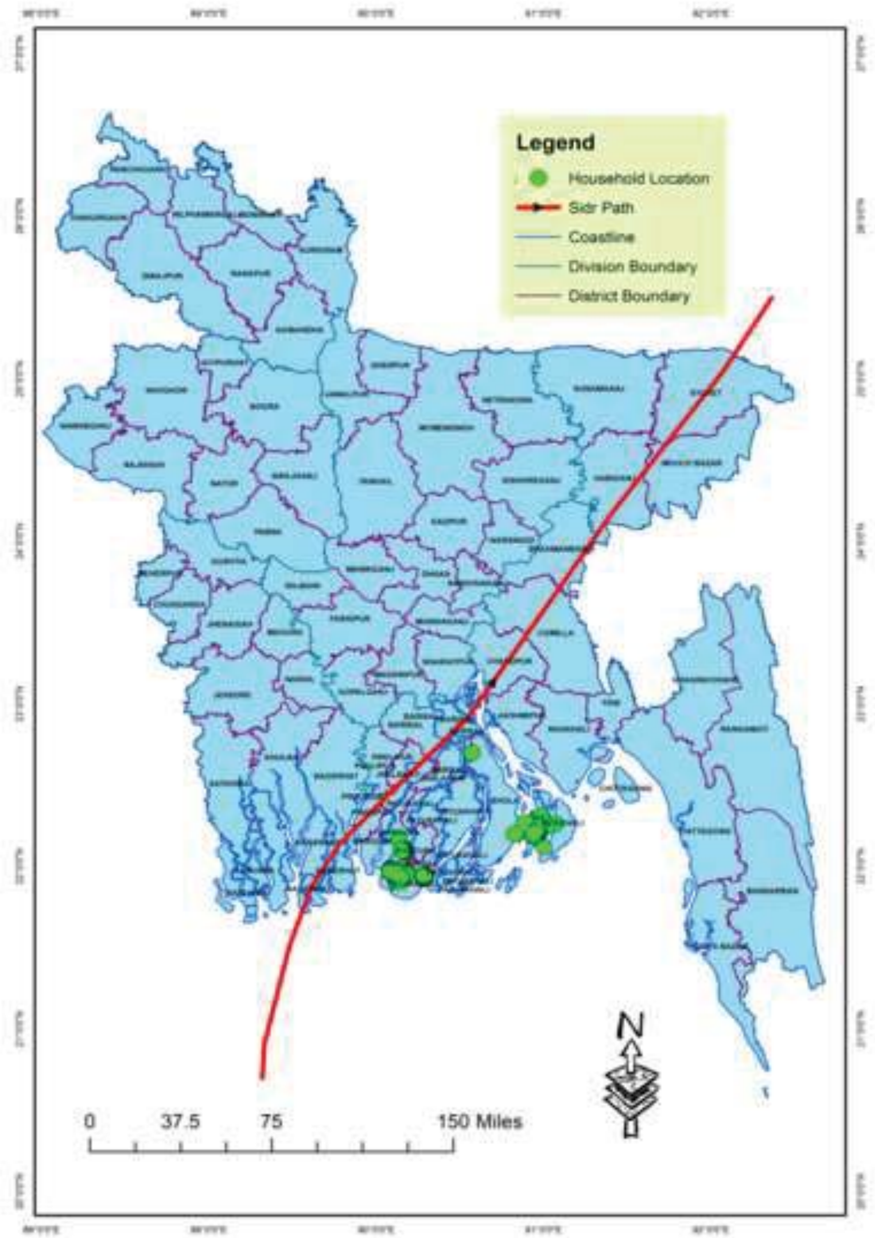

Figure 3: Enlarged study area showing geo-coded household location

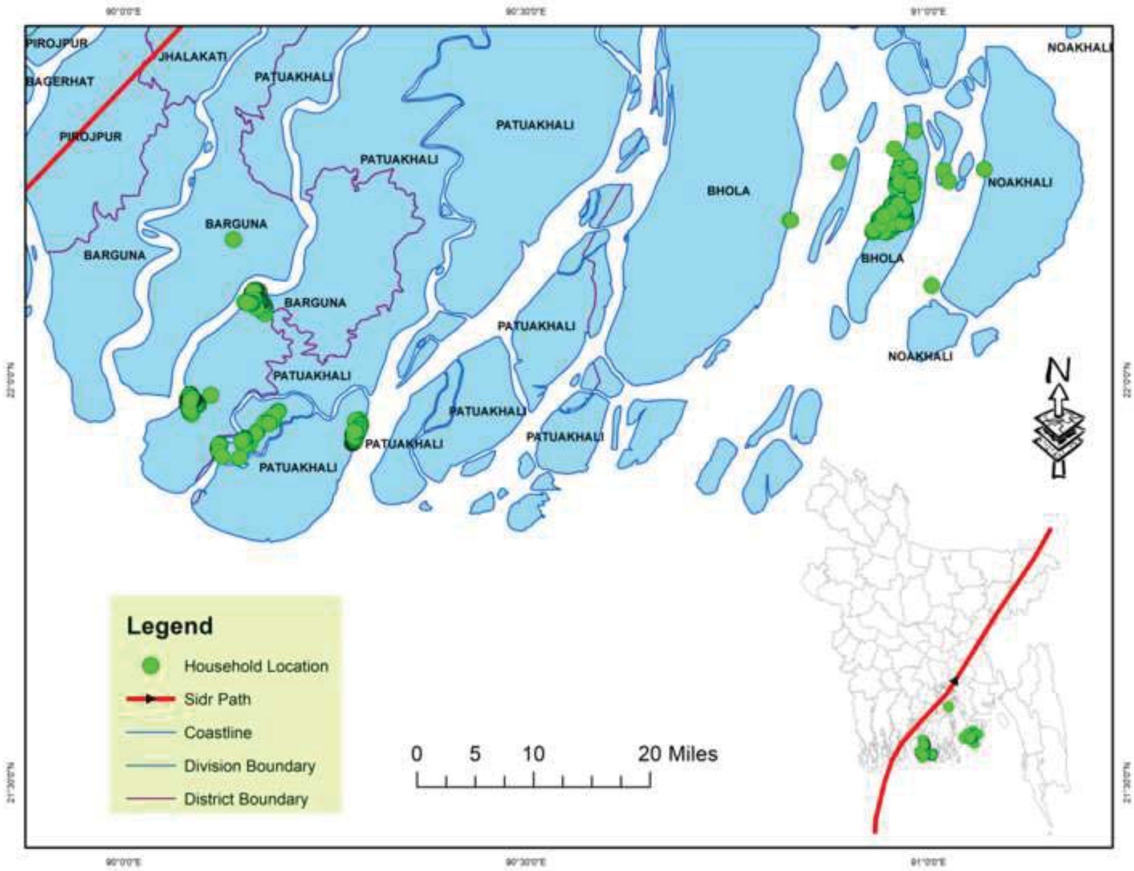

Figure 4: Foreign Remittances on Private Storm Protection *Post*-Cyclone Sidr

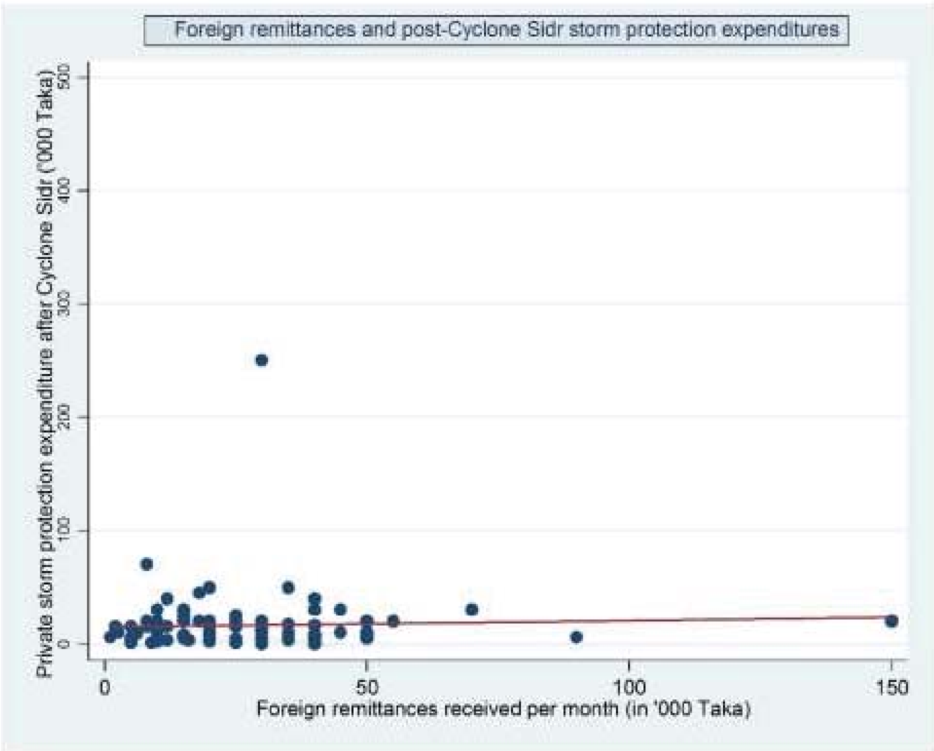

Figure 5: Foreign Remittances on Private Storm Protection *Post*-Cyclone Roanu

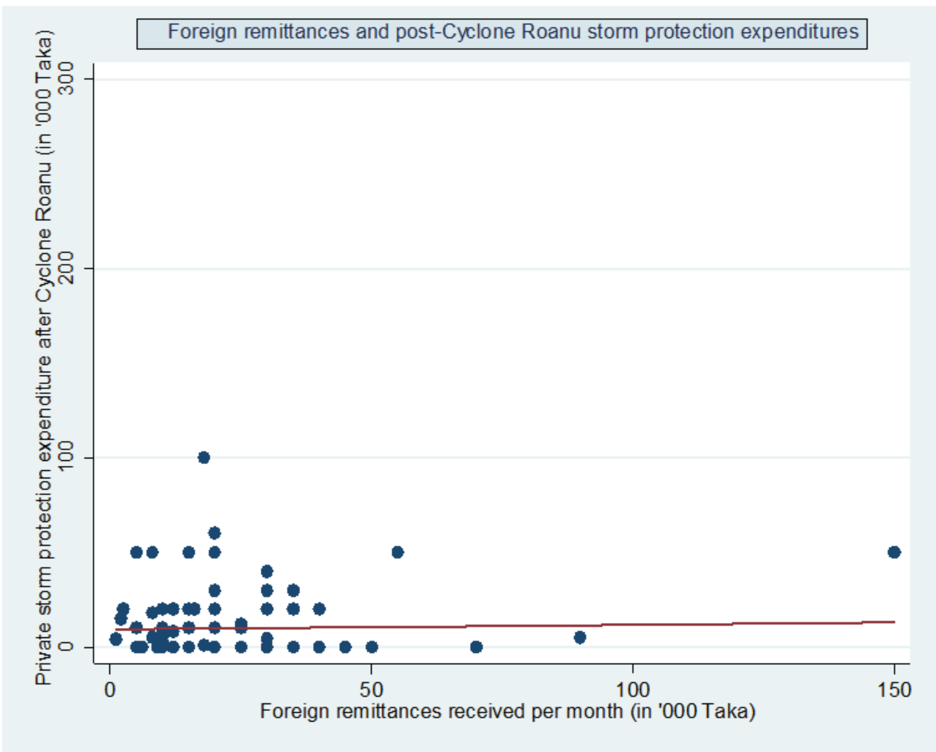

Table 1: Behavioral economics of influence of foreign and domestic remittances on private investments on storm protection

Variable	Marginal Analysis Condition	Behavioral Outcome
Increasing flow of remittances	$EMB_S > EMC_S$	$\frac{dS}{dR} < 0$
	$EMB_S < EMC_S$	$\frac{dS}{dR} > 0$
Access to publicly funded storm mitigation programs	$EMB_S > EMC_S$	$\frac{dS}{dG} > 0$
	$EMB_S < EMC_S$	$\frac{dS}{dG} < 0$

Table 2: Distribution of sample households

Districts	Upazilla	No. of selected Unions	No. of selected Villages	Total Number of Households
Bhola	Monpura	2	4	200
Borguna	Amtoli	2	4	200
Patuakhali	Kalapara	2	4	200
Sum Total		**6**	**12**	**600**

Table 3: Key Characteristics of Households based in the Survey area

Household Characteristics		Value
Respondent age (Mean)		41.49
Respondent gender (%)	Male	66.39
	Female	33.61
Respondent education (%)	No education	30.49
	Primary (Class 1-5)	42.13
	SSC	13.11
	HSC	5.74
	Diploma	0.33
	Undergraduate	0.98
	Masters	0.66
	Others	6.57
Respondent occupation (%)	Farmer	15.82
	Fisherman	9.82
	Timber Business	4.46
	Shrimp fry collector/ Shrimp fisher	23.72
	Business	7.91
	Salaried	14.16
	Professional	0.89
	Day laborer	2.68
	Others	7.02
	Housewife	9.18
	Student	4.34
Domestic migrants in family (%)		41.80
Foreign migrants in family (%)		17.21
Type of latrine (%)	Water-sealed sanitary latrine	21.66
	Sanitary latrine	7.17
	High commode latrine	18.62
	Non-sanitary latrine	8.41
	None	44.14
Sources of drinking water (%)	Tubewell	31.10
	Pondwater	4.68
	Filters for water purification	36.47
	Tap water	27.75
Sources of energy for cooking (%)	Cylinder gas	12.79
	Biogas	0.31
	Fuelwood	16.95
	Dung and leaves	69.95
Location of the house (%)	Within polder	31.15
	On embankment	23.45
	Lowland	33.45
	Near forest	11.94
Solar power (%)		95.41
Electricity connection (%)		0.82
Access to television (%)		7.70
Access to telephone connection (%)		19.02

Table 4: Damages and adaptation strategies: Cyclone Sidr (2007) and Cyclone Roanu (2016)

Variable name	Description	Percentages (%)
Damages during Cyclone Sidr (2007)	Death in the family (157)	7.28
	Injury in the family (8)	0.37
	Loss of assets (385)	17.85
	Loss in domestic animals (589)	27.31
	Loss in crops (569)	26.38
	Loss in trees (447)	20.72
	No loss (2)	0.09
	Total frequencies (2157)	**100**
Damages during Cyclone Roanu (2016)	Death in the family (20)	1.72
	Injury in the family (3)	0.26
	Loss of assets (114)	9.78
	Loss in domestic animals (358)	30.70
	Loss in crops (300)	25.73
	Loss in trees (203)	17.41
	No loss (168)	14.41
	Total frequencies (1166)	**100**
Adaptation post-Cyclone Sidr (2007)	Repair of walls (39)	1.85
	Increase in number of floors (519)	24.67
	Brick wall (163)	7.75
	Tube well for water (514)	24.43
	Modernization of toilet (48)	2.28
	Improvement of domestic animal sheds (45)	2.14
	Improvement of pond areas (247)	11.74
	Improvement of boundary of the house (211)	10.03
	Others	15.11
	Total frequencies (2104)	**100**
Adaptation post-Cyclone Roanu (2016)	Repair of walls (21)	2.93
	Increase in number of floors (104)	14.53
	Brick wall (36)	5.03
	Tube well for water (256)	35.75
	Modernization of toilet (7)	0.98
	Improvement of domestic animal sheds (6)	0.84
	Improvement of pond areas (92)	12.85
	Improvement of boundary of the house (52)	7.26
	Others (142)	19.83
	Total frequencies (716)	**100**

Table 5: Sources of funds for Adaptation

Event name	Sources of funds	Percentage (%)
For adaptation after Cyclone Sidr (2007)	Income / savings (470)	35.15
	Loan (214)	16.01
	Donation (388)	29.02
	Help from friends/ relatives (87)	6.51
	Sold land / asset (178)	13.31
	Total frequencies (1334)	**100**
For adaptation after Cyclone Roanu (2016)	Income/ savings (262)	46.70
	Loan (72)	12.83
	Donation (119)	21.21
	Help from friends/ relatives (4)	0.71
	Sold land/ asset	18.54
	Total frequencies (561)	**100**

Table 6: Households perception of facing flooding and water logging from major cyclone events

	Total 'Yes' responses	Percentages
Entire Study Area	570	93.44
Patuakhali	191	33.51
Borguna	206	36.14
Bhola	173	30.35

Table 7: Summary Statistics of the Key Variables used for Regression Analysis

Variable	Definition	No. of Observations	Mean	Standard Deviation
Dependent Variables				
PRIHOMECS	Household spending on home improvement after Cyclone Sidr (in Tk.)	610	114293.4	257082.0
PRIHOMECR	Household spending on home improvement after Cyclone Raono (in Tk.)	610	9321.166	18344.22
Independent Variables				
REMITFOR	Foreign remittance received per month (in Tk.)	105	25690.50	19285.60
REMITDOM	Domestic remittance received per month (in Tk.)	230	6187.39	4036.48
AGE	Age of the respondent (in years)	610	41.485	13.975
AGE2	Age squared of the respondent (in years)	610	1916.02	1246.36
MEMBER	Total members living in the house	610	5.761	2.289
FORMEM	Total members of the household living and working in foreign countries	105	1.133	0.369
DOMMEM	Total members of the household living outside home but working within Bangladesh	255	1.314	1.063
FEMMEM	Total female members living in the house	610	2.7777	1.4574
FEWMEM	Total female workers in the house	610	0.1639	0.4319
FSTU	Total female students in the house	610	0.6754	0.8041
CSCH	School going children below 7-years age	610	0.3377	0.5562
FAMINC	Family Income per month (in TK.)	610	16894.75	14656.47
MEDEXP	Medical expenditures per month (in Tk.)	610	1648.77	1318.40
EDUEXP	Education expenditures per month (in Tk.)	610	1922.95	2196.35
HOMEST	Area of the homestead (in Decimals)	610	34.41	80.23
AGLAND	Area of agricultural land (in Decimals)	323	187.675	317.596
DISEMB	Distance from nearest embankment (in km.)	610	0.696	0.736
DISCYSH	Distance from nearest cyclone shelter (in km.)	610	1.345	0.840
DISPS	Distance from nearest primary school (in km.)	610	1.149	0.837
DISVR	Distance from nearest vehicular road (in km.)	610	1.192	1.227

Table 8: Instrumental Variable Limited Information Maximum Likelihood (IV-LIML) Model to capture Foreign Remittance Influence on Private Storm Protection Expenditures after Cyclone Sidr

Regressand	Private spending on home improvement after Cyclone Sidr			
Instrumented	Foreign remittance received per month (in Tk).			
	(1) First Stage Result	**(2) DISVR*DMROANU DISPS*DMROANU (Z_3, Z_4)**	**(3) First Stage Result**	**(4) DISVR*DMROANU (Z_3)**
Z_3	4484.60 (939.90)***		4133.127 (975.65)***	
Z_4	-3537.39 (2416.20)			
REMITFOR		22.52 (6.307)***		19.03 (2.94)***
AGE		15426.18 (4235.646)***		13235.99 (4229.14)***
AGE^2		-251.57 (62.716)***		-212.79 (47.54)***
MEMBER		6460.72 (26962.74)		3258.12 (24722.6)
FEMMEM		-65330.51 (31128.59)**		-57545.49 (30215)*
FEWMEM		200667.4 (69071.15)***		171540.60 (45721.2)***
FSTU		90522.77 (47035.94)*		82638.94 (45425.26)*
CSCH		35450.29 (48462.25)		39941.47 (42490.28)
FORMEM		162201.1 (155938.2)		132052.80 (121703.2)
MEDEXP		62.54 (24.74)**		56.38 (18.14)***
EDUEXP		-34.35 (19.02)*		-34.30 (16.50)**
FAMINC		-17.92 (7.05)**		-14.94 (4.02)***
HOMEST		1935.11 (1903.68)		1709.95 (1506.09)
DISEMB		-43101.32 (30020.03)		-34822.89 (27218)
DISCYSH		20672 (28888.87)		29073.50 (25884.19)
AGLAND		254.90 (100.12)**		230.14 (78.97)***
PRIMARY		-182272.5 (76469)**		-166131.70 (55681.79)***
SECONDARY		-210296 (82095)***		-180843.50 (52945.8)***
HIGHER SECONDARY		-289171.2 (111205.3)***		-245362.90 (58783.47)***
UNDERGRAD		-415035.1 (165986.4)**		-356119.40 (97233.83)***
FARMER		95318.61 (49376.01)*		85665.54 (45023.1)*
CONSTANT		94214.11 (183231.2)		85212.62 (155960.9)
No. of observations		50		50
Wald χ^2		376.27		434.83
Prob. > χ^2		0.000		0.000
R-squared		0.504		0.600
1st stage F-statistics	11.689		17.945	
Shea's Partial R^2	0.426		0.384	
P value Basmann F test	0.203			

Table 9: Results of external validity test

Treatment Group (Group 1): *Remittance recipient affected by Cyclone Roanu* **Non-treatment Group** (Group 0): *Remittance recipients not affected by Cyclone Roanu*			
Confounding Variables	**Mean difference**	**t-test**	**p-value** *(Mean differences being zero)*
REMIFOR***	-23089.29	-3.0574	0.0034
AGE	1.464	0.1580	0.8750
AGE SQAURED	140.083	0.1779	0.8594
MEMBER**	2.577	1.9308	0.059
FEMMEM	1.024	1.321	0.1919
FEWMEM	0.3393	1.062	0.2925
FSTU	0.1548	0.3803	0.7051
CSCH	0.4286	1.474	0.1459
FORMEM	0.1250	0.6435	0.5225
MEDEXP	-625.00	-0.5519	0.5832
FAMINC**	-22821.43	-2.3739	0.0210
HOMEST	13.506	0.5994	0.5513
AGLAND	117.439	0.5535	0.5825
DISEMB	0.5	0.8956	0.3796
DISCY	0.4125	0.9173	0.3628
FARMER	-0.2262	-0.4722	0.2452
PRIMARY	0.1488	0.4953	0.6223
SECONDARY	-0.4345	-1.696	0.0953
HIGHER SECONDARY	0.1250	0.6435	0.5225
UNDERGRAD	0.0357	0.3276	0.7444
Degrees of Freedom	**57**		