Consequences of Public Programs and Private Transfers on Household's Investment in Storm Protection

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Abstract: Due to rising incidences of natural calamities, governments are lacking capacity to properly protect households living in areas which are prone to disasters like cyclones and associated storm surges. To protect the property damages of the disaster victims, private storm protection activities need to be better understood within a systematic framework. We develop a theory of household private investment in storm protection, where the storm surge risk is endogenous and analyse how the behavioural responses – ex-ante self-protection expenditures and ex-post self-insurance expenditures – of the households are affected by both government transfers and remittances. The interior solutions of the model show that for a risk-averse household, ex-ante government spending on public programs leads to crowding-in of self-protection, but crowding-out of self-insurance. Whereas, self-protection declines (i.e., becomes a substitute) but self-insurance increases (i.e., becomes a complement) if households have more access to ex-post public-assisted disaster relief and rehabilitation programs. For a risk-neutral household, self-protection declines (i.e., becomes a substitute) but self-insurance increases (i.e., becomes a complement) if households have more access to private inward remittances.

Key words: Endogenous risk, storm protection behaviour, disaster response, government relief, remittances.

JEL Classification: O12; D03; Q54.

1. Introduction

Coastal communities are most vulnerable to tsunamis, hurricanes, and other large storms (IPCC, 2007; World Bank, 2010). Climate changes 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, 2007; UNDP, 2007; Dasgupta et al., 2009). Considering the climate change induced developments and their possible impacts on the vulnerable coastal population especially from low-income countries, governments are recognizing the prospect of not having enough funds to support public programs to properly protect their coastal communities from major storm events (IPCC, 2007; World Bank, 2010). As a result, coastal communities face considerable challenges regarding how to manage their responses to actual and anticipated damage from future storm events (World Bank, 2010). Evidence reveals that a significant portion of private inward remittances is allocated by coastal households to cope with and recover from major natural disaster shocks, such as hurricanes and floods, especially in low-and middle-income countries (Yang, 2005; Raschky, 2007; Yang, 2007; Mahapatra et al., 2009). Given the coastal households' access to public sponsored programs and private remittances against major storm events, this paper endeavours to develop a theoretical framework of private investment behaviour of poor coastal households to insulate themselves from the risk of storm damages to their property.

While the risk of the event causing natural disaster is exogenous, evidence suggest that individuals do try to influence the likelihood or the severity of an undesirable event (Crocker and Shogren, 2003). Stallen and Thomas (1984) concluded in their seminal paper that individuals are not only highly concerned in estimating the uncertainty involved in their exposure to a threatening event but also the ways to influence or control their exposure to that uncertain event. Considering the higher risks entailed in facing extensive storm-inflicted damages to property, households that have had previous encounters with damaging storm events might subsequently invest a portion of their time and money to insulate themselves against such risks. 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 averting expected storm-inflicted damages from occurring and reducing losses to property in the event of the damages. 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 event becomes endogenous (Shogren, 1991; Shogren and Crocker, 1999; Crocker and Shogren, 1999, 2003; Sandsmark and Vennemo, 2007).

However, human behavioural studies show that one of the main inhibiting factors when it comes to investing in natural disaster risk reduction strategies is the lack of concern among households about impending natural disasters (Brechin, 2003; Nisbet and Myers, 2007; Norgaard, 2009). 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 (Kahneman and Tversky, 1979; Magat et al., 1987; Camerer and Kunreuther, 1989; Kahneman et al., 2001). Moreover, studies reveal 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 study investigating households' private investment behaviour to insure themselves against natural disasters when they have migrant family members sending remittances, Clarke and Wallsten (2004) found inward remittances to act like insurance and it increases after occurrence of a natural disaster event. While studies by Yang and Choi (2007) and Yang (2005) reveal that the poorer countries, which are exposed to increased risk of being hit by hurricane, are associated with greater remittances flows. These findings vindicate Wisner (2003) study that migration flows increase in the aftermath of disasters such as Hurricane Gilbert, in Jamaica, and Hurricane Mitch, in Central America. 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 protection programs, private inward 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 (forthcoming) have shown that remittances do affect ex-post disaster response behaviour using field data from developing countries. However, they do not provide a theory or a framework of how this mechanism works. We endeavour 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 protection programs, such as ex-post public disaster relief and rehabilitation programs and ex-ante publicly constructed barriers, dams, and embankments, lead to less private defensive expenditures by coastal households; and, (2) whether expectation of receiving increased flow of remittances to reduce losses from a future major storm event also results in less defensive expenditures 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 (2011), where the representative household chooses the level of its private defensive expenditures to protect themselves from damages to property from a major storm event.[1] We classify a household's private defensive expenditures into two categories: (1) *self-protection expenditures*, a form of ex-ante prevention, are private investments that reduce expected storm-inflicted damages from occurring; and, (2*) self-insurance expenditures*, a form of ex-post adaptation, are private investments in human, physical, and social capital by the households to reduce their losses in the event of storm-inflicted damages. Examples of self-protection include converting a mud-built house to brick, raising the height of the homestead, moving the house inside an embankment, taking refuge in a neighbour's house, and locating further away from the shoreline to a safer place. Examples of self-insurance include income source diversification, crop and plot diversification, reciprocal gift exchanges, and inter-and intra-household income transfers based on insurance motives (or informal risk sharing). All these possibilities are directly or indirectly resulting from household private investments in human, physical, and social capital to reduce the severity or magnitude of damages to property as a result of a major storm event. .

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 property damages from a storm event in a two-choice variables model of private defensive strategies of self-protection and self-insurance, for a risk-averse household. Second, for the

[1] 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).

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 inward remittances on private storm-protection strategies. In particular, we make use of the comparative analyses from our model to predict whether post-disaster remittances transfers are substitutes or complements to self-protection and self-insurance (i.e., whether inward remittances "fully" or "partially" crowd out or crowd in private self- protection and self-insurance expenditures).

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. Figure 1 illustrates the probability tree that depicts how the sequence of events that takes place when a household is fully exposed to a storm surge.

Under a simple discrete formulation, Figure 1 shows that the probability tree starts with the adverse storm event, which is exogenous. At this point, the household faces two states of nature: state 1, the probability of experiencing property damages, $\pi(.)$; and state 2, the probability of experiencing no damages to property, $1-\pi(.)$. We assume that a household's private spending on storm protection can influence its probability of experiencing property damage through self-protection, whereas the severity of any damages resulting from the storm surge is reduced through self-insurance. For the sake of simplicity, the model does not consider any health-related impacts, such as injury and loss of life as a result of the storm event.

The probability of damages to property fully exposed to a storm for representative household *i* located in village *j* is

$$\pi_{ij}(.) \equiv \pi_{ij}\left(Z_{ij}; G_{ij}, C_{ij}\right) \tag{1}$$

where Z_{ij} is the level of self-protection expenditures including migration that decrease the probability of facing ex-post property damages;[2] G_{ij} is the household's access to ex-ante public protection programs, such as disaster preparedness programs and publicly constructed embankments or dams that reduce the probability that the household incurs flooding damages; and, lastly, C_{ij} is a vector of characteristics of a severe cyclone-induced storm surge, such as storm surge height and wind velocity, direction and distance of the cyclone path from the household location, etc.

When exposed to a storm, each household faces monetary losses. We can state this ex-post damage to property as

$$L_{ij} = L_{ij}(A_{ij}; N_{ij}, R_{ij}) \tag{2}$$

where A_{ij} is the level of self-insurance expenditures that involve actions to reduce the severity of ex-post property damage; N_{ij} is the expectation of receiving increased flow of remittances from migrant household members specifically allocated for the reduction damages to property from a major storm; and, R_{ij} is the household's access to ex-post public sponsored disaster relief and rehabilitation programs. We expect the property losses to decrease if the household invests in self-insurance expenditures and enjoys accessibility to public-assistance programs and expects to receive more private inward remittances.

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 property (state 1) and $W_1 \equiv (I_{ij} - A_{ij} - Z_{ij} - L_{ij}(.))$ is the net wealth considering the property loss. In W_1, a household's full income is represented by I_{ij}, its level of self-protection expenditures by Z_{ij},

[2] We assume that the self-protection or self-insurance 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 self-protection or self-insurance actions to others.

and its level of self-insurance expenditures by A_{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 $W_2 \equiv (I_{ij} - A_{ij} - Z_{ij})$ 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 self-protection $\left(Z_{ij}\right)$ and self-insurance $\left(A_{ij}\right)$ expenditures. Given these assumptions, the utility functions under the two states of nature are

$$\begin{aligned} U_{ij}^{L} &\equiv U_{ij}\left(W_1\right) \equiv U_{ij}\left(I_{ij} - Z_{ij} - A_{ij} - L_{ij}(A_{ij}; N_{ij}, R_{ij}\right) \\ U_{ij}^{NL} &\equiv U_{ij}\left(W_2\right) \equiv U_{ij}\left(I_{ij} - Z_{ij} - A_{ij}\right) \end{aligned} \tag{3}$$

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

$$\underset{Z,A}{Max}\, E(U) = \begin{bmatrix} \pi(Z;G,C)\cdot U((I-A-Z-L(A;N,R)) \\ +(1-\pi(Z;G,C))\cdot U((I-A-Z) \end{bmatrix}$$

$$\Rightarrow \left[\pi\left(Z;G,C\right)\cdot U(W_1) + (1-\pi(Z;G,C))\cdot U(W_2)\right] \tag{4}$$

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 self-insurance and self-protection lead to

$$-\pi(.)\cdot U^{'}(W_1)\left[1+\frac{\partial L}{\partial A}\right] \quad = U^{'}(W_2)\cdot\left[(1-\pi(.))\right] \tag{5}$$

$$-\frac{\partial \pi(.)}{\partial Z}\cdot\left[U(W_1) - U(W_2)\right] \quad = \pi(.)\cdot U^{'}(W_1) + (1-\pi(.))\cdot U^{'}(W_2) \tag{6}$$

where $U^{'}(W_1)$ and $U^{'}(W_2)$ are the marginal utilities of income with respect to self-insurance and self-protection respectively. Expression (5) reveals that a household could employ self-insurance to reduce the severity of storm surge damages up to the point where the expected marginal benefits of self-insurance, as defined by the net reduction in loss, equal expected

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

marginal costs. Expression (6) indicates that a household could employ self-protection up to the point where the expected marginal benefits of self-protection, as defined by the decreased chance of storm damages weighted by the utility difference between the two states, equal expected marginal costs.

For the second-order sufficiency conditions associated with (4), the sign of the cross-partial derivatives with respect to self-protection and self-insurance expenditures cannot be determined even if the household is considered to be averse to storm risks. We show later in Appendix A how imposing additional restrictions in determining the signs of these cross-partial derivatives plays a significant role in determining the key comparative static results.

3. Comparative Static Analysis of Self-protection and Self-insurance

A household's choice of self-protection and self-insurance to reduce extensive storm-inflicted damage is influenced by its access to ex-ante and ex-post government protection programs as well as private remittances. We examine these effects through comparative static analysis of the interior solution of the model. The full results are depicted in Appendix A, and they show that we cannot determine the directions of the relationships between a household's private defensive strategies and the public programs (both ex-ante and ex-post) unless we impose additional conditions on the model. Likewise, the relationship between a household's private defensive strategies and its access to private inward remittances remains ambiguous without additional conditions, which are also shown in Appendix A.

The results from the comparative static analysis reveal the following propositions.

PROPOSITION 1: For a risk-averse household, *ex-ante* government spending on public programs G leads to crowding-in of self-protection Z, i.e. $\frac{\partial Z}{\partial G} > 0$ but crowding-out of self-insurance A, i.e. $\frac{\partial A}{\partial G} < 0$. That is, public protection programs act as a complement to self-protection but as a substitute to self-insurance. The proof of Proposition 1 depends on Conditions 1 and 2 (derived in Appendix A), which are,

Condition 1. $H_{AZ} = H_{ZA} < 0$. That is, assuming self-protection and self-insurance to be stochastic substitutes.[4] This implies that the marginal utility of self-protection, Z, decreases if more self-insurance, A, activities are taken by the household and vice-versa.

Condition 2. $\frac{\partial^2 \pi(.)}{\partial G \partial Z} < 0$. This suggests that more ex-ante government programs, G, can accentuate the influence of self-protection, Z, in reducing the probability of facing storm-inflicted damages to property.

If either of these conditions is violated, then the signs of $\frac{\partial Z}{\partial G}$ and $\frac{\partial A}{\partial G}$ remain ambiguous.

Supporting evidence for Condition 2 abounds based on the contemporary literature on the relationship between public and private investment (Blejer and Khan, 1984; Greene and Villanueva, 1991; Erenburg, 1993; Ramirez, 1994, 2000; Oshikoya, 1994; Mitra, 2006). Findings by Erenburg (1993) reveal that public infrastructure capital has a stimulating effect on private investment in equipment and machinery. Using a panel data on developing economies for 1980 to 1997, Erden and Holcombe (2005) showed that a 10% increase in public investments lead to a 2% increase in private investments. Blejer and Khan (1984) for a panel of developing countries and Oshikoya (1994) for a panel of African countries presented evidence that public infrastructure investments has a positive impact on private investment. Kollamparambil and Nicolau (2011) study on South Africa found that public investment on infrastructure and social sectors is likely to enhance private investment; whereas, Hussain et al. (2004) detected positive influence of public development expenditures, such as infrastructure, health and education, on private investment based on annual time series data of Pakistan between 1975 and 2008. Mistra (2006) and Sterven (2004) also presented evidence of crowding-in over the long run and crowding-out over the short run following their research on India.

For our research, we consider the positive influence of ex-ante government spending on public programs on infrastructures such as roads and embankments on private self-protection expenditures. However, we also acknowledge that the direction of the sign for an increase of

[4] Hiebert (1983) introduced the terms 'stochastic substitutes' and 'stochastic complements' to define the relationships between technological inputs to reduce risks of a competitive firm facing production uncertainty. Archer *et al.* (2006) later applied the same terms to sign their comparative static results under the endogenous risk framework to study a parent's child care choices among alternative childcare technologies when the child could be exposed to some environmental hazard.

ex-ante government spending on the optimum levels of private self-protection (as well as self-insurance) is an empirical question.

PROPOSITION 2: For a risk-averse household, it is not possible to determine the direction of the influence of ex-post public-assisted disaster relief and rehabilitation programs on ex-ante self-protection and self-insurance. However, for a risk-neutral household and with some additional restrictions, self-protection Z declines (i.e., becomes a substitute) but self-insurance A increases (i.e., becomes a complement) if households have more access to ex-post public-assisted disaster relief and rehabilitation programs R, i.e. $\frac{\partial Z}{\partial R} < 0$ and $\frac{\partial A}{\partial R} > 0$. The proof of Proposition 3 for a risk-neutral household depends on Conditions 3-5.

Condition 3. The probability of facing ex-post storm inflicted property damages, $\pi(.)$, is strictly quasi-convex with respect to self-protection expenditure, Z : $\frac{\partial \pi(.)}{\partial Z} < 0; \frac{\partial^2 \pi(.)}{\partial Z^2} > 0.$ This implies that the probability of facing monetary losses to property as a result of a cyclone induced storm surge decreases as household self-protection expenditure increases.

Condition 4. A strict quasi-convex relationship exists between storm-inflicted monetary losses to property and self-insurance expenditures, $\frac{\partial L}{\partial A} < 0; \frac{\partial^2 L}{\partial A^2} > 0$. This means that monetary losses to property decrease as a household commits more self-insurance expenditure.

Condition 5. $\frac{\partial^2 L(.)}{\partial R \partial A} < 0.$ Condition 5 states that more ex-post public-assisted disaster relief and rehabilitation programs, R, accentuate the effect of self-insurance in reducing monetary loss or damages to property as a result of a severe storm event.

Conditions 3 and 4 are self-explanatory. However, Condition 5 requires justifications and supporting evidence. Condition 5 proposes that access to more *ex-post* public disaster relief and rehabilitation programs can further accentuates the effectiveness of self-insurance in reducing storm-inflicted monetary loss or damages to property. Based on empirical findings on twelve (12) low-and middle-incomes countries that encountered economic crises and natural disasters, Skoufias (2003) highlighted some ex-post public strategies that can be more effective in protecting households from adverse aggregate shocks. Baez and Mason (2008) suggests how ex-post public complimentary policies through education, training, and critical information after a natural disaster event in Latin American countries can empower households with characteristics that enhance their capacity to diversify their income and crop portfolios. Following our theoretical model, these outcomes do assume that the household is risk neutral. The behavioral response of risk-averse households is much more difficult to discern. Hence, further understanding of the possible direction of the sign requires empirical analysis.

PROPOSITION 3: For a risk-averse household, it is not possible to determine the direction of the influence of private inward remittances on self-protection and self-insurance. For a risk-neutral household, self-protection Z declines (i.e., becomes a substitute) but self-insurance A increases (i.e., becomes a complement) if households have more access to private inward remittances N from migrant household members that is specifically allocated to reduce severity of the storm event, i.e. $\frac{\partial Z}{\partial N} < 0$ and $\frac{\partial A}{\partial N} > 0$. Proof of Proposition 3 for a risk-neutral household depends on Conditions 3, 4, and 6.

Condition 6. $\frac{\partial^2 L(.)}{\partial N \partial A} < 0$. Condition 6 states that more ex-post private transfers through remittances, N, from migrant family members accentuate the effect of self-insurance in reducing monetary loss or damages to property from a major storm event.

If Condition 6 is not met, the crowding in effect based on the sign of $\frac{\partial A}{\partial R}$, remain ambiguous. Moreover, for a risk-averse household, it is not possible to determine the direction of the influence of expected increasing flow of private transfers through remittances from migrant family members specifically targeted to reduce severity from a major storm event. Empirical analysis might help to further understand the possible direction of the sign. Some empirical studies do reveal the influence of private remittances on private coping strategies against natural disasters, which might be considered as complimentary in nature (Yang and Choi; 2007; Mozumder et al., 2009). However, these empirical studies do not focus on the effect of disaster-related private transfers in terms of remittances on private economic actions to reduce disaster risk.

Table 1 summarizes the comparative statics results with the accompanying conditions. We observe that factors that are in place before a storm occurs, such as government protection programs, are complements to self-protection expenditures by the household, whereas these exogenous influences are substitutes for self-insurance by the household. The latter effect implies that, if the household is receiving protection from government spending programs, then it is less likely to have to allocate expenditures for *ex-post* reduction in losses incurred from a storm. Moreover, if the household is already protected by public programs, it can enhance its welfare by using complementary self-protection measures to reduce the risk of storm damage even further.

Conversely, factors that are in place after a storm occurs, such as the increased availability of private transfers through remittances from migrant family members and public disaster relief and rehabilitation programs reduces self-protection by the household but increases its self-insurance. If the household expects more post-disaster government programs to be implemented and more private transfers, it is less likely to take *ex-ante* actions to reduce the probability of storm damage to its property. On the other hand, if more *ex-post* relief and rehabilitation and *ex-post* private transfers through remittances are available, the household may allocate more expenditure to self-insure against damages. Considering the disaster relief and rehabilitation programs are normally driven by community-wide or district-level efforts, such public programs might also spur individual households to adopt their own measures to safeguard their income and property after the storm. Likewise, for private transfers, households might be encouraged to pursue more self-insurance actions after the storm if they are confident that they gather sufficient funds to recover their storm-inflicted losses to property. However, these outcomes assume that the household is risk neutral. Comparative results from our endogenous risk framework model show that the behavioral response of risk-averse households is much more difficult to establish.

Concluding Remarks

How does bailing out victims of major storm events, such as cyclones and tsunamis, influence the economic behavior of households living in disaster prone areas? Are private protective investments of households living in the coastal areas along the flood plains reduced in anticipation of public-sponsored programs and private transfers? Our paper endeavors to fill in the knowledge gap by proposing a theoretical model of household private investment in storm-protection given public programs and private inward remittances.

To examine the issues, we classified a household' investment in storm protection into two categories: (1) *self-protection expenditures*, a form of ex-ante prevention, are private investments that reduce expected storm-inflicted damages from occurring; and, (2*) self-insurance expenditures*, a form of ex-post adaptation, are private investments in human, physical, and social capital by the households to reduce their losses in the event of storm-inflicted damages. Our household model of private investment in storm protection in terms of self-protection and self-insurance are based on an endogenous risk framework where our goal is to determine possible influence of government programs and private inward remittances on a household's decision to invest in self-protection and self-insurance. By imposing additional restrictions on the model, our results show that ex-ante public programs, such as publicly constructed protective barriers, embankments, or dams that can reduce the probability of flooding as a result of the storm, are complements to self-protection investments by a risk-averse household. However, these same factors are substitutes to household self-insurance expenditures. But possible directions of the influence of ex-post public disaster relief and rehabilitation programs and private inward remittances on private storm protection behaviour cannot be determined for risk-averse household. By assuming the household to be risk-neutral and introducing further restrictions, we are able to show that ex-post public programs and private inward remittances reduce self-protection by the household but increase its self-insurance.

We identified there is evidence abound on some of the important conditions applied in our theoretical model. But we also acknowledge that the direction of the sign of relationships between public programs and private storm protection behavior is an empirical question to provide credence to our theoretical underpinnings. Same also applies in determining the sign of the relationships between private inward remittances received from a migrant family member and its possible influence on private storm protection behavior. It will be interesting to see whether access to either public programs or private inward remittances is enough to deter or encourage private investments to reduce risks from storm-inflicted damages to property by averting the likelihood as well as reducing the severity or magnitude of such risk event.

We think that theory of household private investment in storm protection that we have developed could be generalized to all coastal communities which are affected by climate change. Hypotheses based on the research questions and the Propositions derived from the theoretical model could be tested empirically. Findings from such studies could recommend the steps that the governments might take to develop an institutional setup under joint public-private partnerships by encouraging more collective and individual participation in storm-protection activities among the vulnerable communities from major storm events. We believe by identifying and nurturing such form of institutions, governments representing the low-and middle-income countries would be able to mitigate the impacts of market failures due to moral hazard and adverse selection problems that arise from public-sponsored programs. In addition, we consider that identifying the channels through which private inward remittances directly and indirectly influence private storm protection behavior or attitudes towards reducing the likelihood as well as severity from storm-inflicted damages to property has some serious policy implications in the future. Lastly, outcomes from our research will be particularly relevant for developing countries, especially from south-east Asia and small island states of the Pacific, intention to promote and support sustainable development projects by improving their resilience and response capacity to cope against natural disaster events as a result of global climate change.

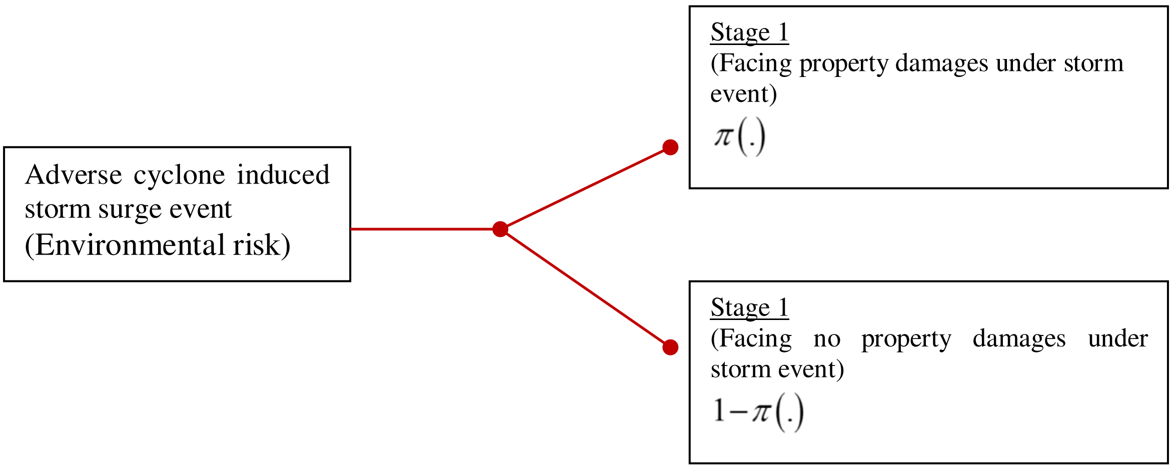

Figure 1: Probability Tree of a Sequence of Events

Table 1: Comparative Static Results of the Household Model of Defensive Strategies

Household Self-protection (Z)		
	Conditional Result	**Requirements for Signing Conditional Result**
Access to ex- ante public protection spending	$\frac{dZ}{dG} > 0$	1. $H_{AZ} = H_{ZA} < 0$ 2. $\frac{\partial^2 \pi(.)}{\partial G \partial Z} < 0$
Expectation of receiving increased flow of remittances from migrant family members	$\frac{dZ}{dN} < 0$ (Hold only for risk neutral households)	$\frac{\partial^2 L(A,R)}{\partial N \partial A} < 0$
Access to ex-post relief and rehabilitation programs	$\frac{dZ}{dR} < 0$ (Holds only for risk neutral households)	$\frac{\partial^2 L(A,R)}{\partial R \partial A} < 0$
Household Self-insurance (A)		
Access to ex- ante public protection spending	$\frac{dA}{dG} < 0$	1. $H_{AZ} = H_{ZA} < 0$ 2. $\frac{\partial^2 \pi(.)}{\partial G \partial Z} < 0$
Expectation of receiving increased flow of remittances from migrant family members	$\frac{dA}{dN} > 0$ (Holds only for risk neutral households)	$\frac{\partial^2 L(A,R)}{\partial N \partial A} < 0$
Access to ex-post relief and rehabilitation programs	$\frac{dA}{dR} > 0$ (Holds only for risk neutral households)	$\frac{\partial^2 L(A,R)}{\partial R \partial A} < 0$

Appendix A

Proof of PROPOSITION 1. Comparative analyses results show that we cannot determine the direction of the relationship between a household's averting behavior and ex-ante public protection spending unless we impose additional restrictions.

Using the first order conditions (5) and (6) of the main paper and the implicit function theorem, the comparative static effects of a decrease in G on the optimal levels of self-protection Z yields,

$$\frac{\partial Z^*}{\partial G} = \frac{\begin{vmatrix} -\frac{\partial F^1}{\partial G} & H_{ZA} \\ -\frac{\partial F^2}{\partial G} & H_{AA} \end{vmatrix}}{|H|} \Rightarrow \frac{\begin{vmatrix} -\frac{\partial EMB_Z}{\partial G} & H_{ZA} \\ -\frac{\partial EMB_A}{\partial G} & H_{AA} \end{vmatrix}}{|H|} = \frac{\overbrace{H_{AA} \cdot \left(-\frac{\partial EMB_Z}{\partial G}\right)}^{\text{direct effect}} + \overbrace{H_{AZ} \cdot \left(\frac{\partial EMB_A}{\partial G}\right)}^{\text{indirect effect}}}{|H|} \tag{A.1}$$

where, $F^1 \equiv EMB_Z$ is the first order condition with respect to self-protection, i.e. the expected marginal benefits of self-protection based on expression (5); $F^2 \equiv EMB_A$ is the first order condition with respect to self-insurance, i.e. the expected marginal benefits of self-insurance based on expression (6); H_{AA} is the own-partial of self-insurance; and H_{ZA} is the cross-partial of self-protection and self-insurance. Both partials are based on the Hessian matrix $|H| = \begin{vmatrix} H_{ZZ} & H_{ZA} \\ H_{AZ} & H_{AA} \end{vmatrix}$.

In expression (A.1), the first term in the numerator on the right hand side is the direct effect of the ex-ante public spending on self-insurance while the second term is the indirect effect.

Likewise, the comparative static effects of a decrease in G on the optimal level of self-insurance A yields,

$$\frac{\partial A^*}{\partial G} = \frac{\begin{vmatrix} H_{ZZ} & -\frac{\partial F^1}{\partial G} \\ H_{AZ} & -\frac{\partial F^2}{\partial G} \end{vmatrix}}{|H|} \Rightarrow \frac{\begin{vmatrix} H_{ZZ} & -\frac{\partial EMB_Z}{\partial G} \\ H_{AZ} & -\frac{\partial EMB_A}{\partial G} \end{vmatrix}}{|H|} = \frac{\overbrace{H_{ZZ} \cdot \left(-\frac{\partial EMB_A}{\partial G}\right)}^{\text{direct effect}} + \overbrace{H_{AZ} \cdot \left(\frac{\partial EMB_Z}{\partial G}\right)}^{\text{indirect effect}}}{|H|} \tag{A.2}$$

where, $F^1 \equiv EMB_Z$ is the first order condition with respect to self-protection, i.e. the expected marginal benefits of self-protection based on expression (5); $F^2 \equiv EMB_A$ is the first order condition with respect to self-insurance, i.e. the expected marginal benefits of self-insurance based on expression (6); H_{AA} is the own-partial of self-insurance; and H_{ZA} is the cross-partial of self-protection and self-insurance. Both partials are based on the Hessian matrix $|H| = \begin{vmatrix} H_{ZZ} & H_{ZA} \\ H_{AZ} & H_{AA} \end{vmatrix}$.

In expression (A.2), the first term in the numerator on the right hand side is the direct effect of the ex-ante public spending on self-protection while the second term is the indirect effect.

Expression (A.1) and (A.2) show that the sign and magnitude of the direct effect depends on how a change in ex-ante public spending affects the expected marginal benefits of self-protection $\left(\frac{\partial EMB_Z}{\partial G}\right)$ and the expected marginal benefits of self-insurance $\left(\frac{\partial EMB_A}{\partial G}\right)$. In addition, it depends on the signs of H_{ZZ} and H_{AA} which are both negative by the second-order conditions. Like the direct effect, the indirect depends on the influence of ex-ante public spending on the expected marginal benefits of self-protection and self-insurance. However, it also depends on the signs of the cross partials of self-protection and self-insurance $(H_{AZ} = H_{ZA})$ which cannot be determined.

Substituting the influence of ex-ante public programs, G, on the expected marginal benefits of self-protection, $\frac{\partial EMB_Z}{\partial G}$, and the expected marginal benefits of self-insurance, $\frac{\partial EMB_A}{\partial G}$, in expression (A.1) leads to

$$\frac{\partial Z}{\partial G} = \frac{\overset{'-'}{H_{AA}} \cdot \left[-\overbrace{\frac{\partial^2 \pi(.)}{\partial G \partial Z}}^{'?'} \cdot \overbrace{\left(U(W_1) - U(W_2)\right)}^{'-'} + \overset{'-'}{\frac{\partial \pi}{\partial G}} \cdot \overbrace{\left(U'(W_1) - U'(W_2)\right)}^{'+'} \right] + \overset{'?'}{H_{ZA}} \cdot \left[-\overset{'-'}{\frac{\partial \pi(.)}{\partial G}} \cdot \overbrace{U'(W_1)}^{'+'} \cdot \overbrace{\left(1 + \frac{\partial L}{\partial A}\right)}^{'-'} + \overbrace{U'(W_2)}^{'+'} \cdot \overset{'-'}{\frac{\partial Q(.)}{\partial G}} \right]}{|H|} \tag{A.3}$$

Similarly, Substituting the influence of ex-ante public programs, G, on the expected marginal benefits of self-protection, $\frac{\partial EMB_Z}{\partial G}$, and the expected marginal benefits of self-insurance, $\frac{\partial EMB_A}{\partial G}$, in expression (A.2) yields

$$\frac{\partial A}{\partial G} = \frac{\overset{'-'}{H_{ZZ}} \cdot \left[\overset{'-'}{\frac{\partial \pi(.)}{\partial G}} \cdot \overbrace{U'(W_1)}^{'+'} \cdot \overbrace{\left(1 + \frac{\partial L}{\partial A}\right)}^{'-'} - \overbrace{U'(W_2)}^{'+'} \cdot \overset{'-'}{\frac{\partial \pi(.)}{\partial G}} \right] + \overset{'?'}{H_{AZ}} \cdot \left[\overbrace{\frac{\partial^2 \pi(.)}{\partial G \partial Z}}^{'?'} \cdot \overbrace{\left(U(W_1) - U(W_2)\right)}^{'-'} + \overset{'-'}{\frac{\partial \pi}{\partial G}} \cdot \overbrace{\left(U'(W_1) - U'(W_2)\right)}^{'+'} \right]}{|H|} \tag{A.4}$$

It is not possible to sign expression (A.3) and (A.4) unambiguously. They can only be signed if the following conditions hold,

Condition 1. $H_{AZ} = H_{ZA} < 0$. That is, assuming self-protection and self-insurance to be stochastic substitutes.[5] This implies that the marginal utility of self-protection, Z, decreases if more self-insurance, A, activities are taken by the household and vice-versa.

[5] Hiebert (1983) introduced the terms 'stochastic substitutes' and 'stochastic complements' to define the relationships between technological inputs to reduce risks of a competitive firm facing production uncertainty. Archer *et al.* (2006) later applied the same terms to sign their comparative static results under the endogenous risk framework to study a parent's child care choices among alternative childcare technologies when the child could be exposed to some environmental hazard.

Condition 2. $\frac{\partial^2 \pi(.)}{\partial G \partial Z} < 0$. This suggests that more ex-ante government protection activities G can accentuate the influence of self-protection, Z, in reducing the probability of facing storm-inflicted damages to property.

Assuming conditions (1) and (2) are met, it is possible to sign - expressions (A.1) and (A.2) accordingly.

$$\frac{\partial Z}{\partial G} = \frac{\overset{"-"}{H_{AA}} \cdot \overbrace{\text{2nd bracketed term}}^{"-"} + \overset{"-"}{H_{ZA}} \cdot \overbrace{\text{4th bracketed term}}^{"-"}}{|H|} = \frac{"+" + "+"}{|H|} > 0$$

$$\frac{\partial A}{\partial G} = \frac{\overset{"-"}{H_{zz}} \cdot \overbrace{\text{2nd bracketed term}}^{"+"} + \overset{"-"}{H_{AZ}} \cdot \overbrace{\text{4th bracketed term}}^{"+"}}{|H|} = \frac{"-" + "-"}{|H|} < 0 \qquad (A.5)$$

Therefore, under additional restrictions, comparative statics result show that ex-ante government protection spending, G, is a complement to self-protection, Z, but is a substitute to self- insurance, A.

Proof of PROPOSITION 2. Starting with the risk-averse case, comparative results on the influence of ex-post government risk-reducing programs like disaster relief and rehabilitation activities on household private defensive strategies show that the direction of the relationship can be determined only under certain restrictions. Comparative static results show

$$\frac{\partial Z^*}{\partial R} = \frac{\begin{vmatrix} -\frac{\partial F^1}{\partial R} & H_{ZA} \\ -\frac{\partial F^2}{\partial R} & H_{AA} \end{vmatrix}}{|H|} \Rightarrow \frac{\begin{vmatrix} -\frac{\partial EMB_Z}{\partial R} & H_{ZA} \\ -\frac{\partial EMB_A}{\partial R} & H_{AA} \end{vmatrix}}{|H|} = \frac{\overbrace{H_{AA} \cdot \left(-\frac{\partial EMB_Z}{\partial R}\right)}^{\text{direct effect}} + \overbrace{H_{AZ} \cdot \left(\frac{\partial EMB_A}{\partial R}\right)}^{\text{indirect effect}}}{|H|} \qquad (A.6)$$

$$\frac{\partial A^*}{\partial R} = \frac{\begin{vmatrix} H_{ZZ} & -\frac{\partial F^1}{\partial R} \\ H_{AZ} & -\frac{\partial F^2}{\partial R} \end{vmatrix}}{|H|} \Rightarrow \frac{\begin{vmatrix} H_{ZZ} & -\frac{\partial EMB_Z}{\partial R} \\ H_{AZ} & -\frac{\partial EMB_A}{\partial R} \end{vmatrix}}{|H|} = \frac{\overbrace{H_{ZZ} \cdot \left(-\frac{\partial EMB_A}{\partial R}\right)}^{\text{direct effect}} + \overbrace{H_{AZ} \cdot \left(\frac{\partial EMB_Z}{\partial R}\right)}^{\text{indirect effect}}}{|H|} \qquad (A.7)$$

Expressions (A.6)-(A.7) reveal that the sign and magnitude of the direct effects depend on the own partials, H_{ZZ} and H_{AA}, as well as how a change in the ex-post public-assisted disaster relief and rehabilitation programs influences expected marginal benefits of self-protection, $\frac{\partial EMB_Z}{\partial R}$, and self-insurance, $\frac{\partial EMB_A}{\partial R}$. Conversely, the indirect effects depend on the cross partials, H_{ZA} and H_{AZ}, and the influence of ex-post public-assisted disaster relief and rehabilitation programs on the expected marginal benefit of self-protection and self-insurance.

Under the risk-averse assumption, results reveal that the direction of the relationship between ex-post public programs and the private averting strategies remain ambiguous because it is not possible to determine the direction of influence of ex-post public programs, R, on the expected marginal benefits of self-protection $\left(EMB_Z = \frac{\partial EU}{\partial Z_{ij}} \right)$. However, if the households are assumed to be risk neutral, then it is possible to establish the direction of the relationships by imposing the additional restriction.

Substituting the influence of ex-post public programs, R, on the expected marginal benefits of self-protection, EMB_Z, and the expected marginal benefits of self-insurance, EMB_A, in expressions (A.6) and (A.7) lead to,

$$\frac{\partial Z}{\partial R} = \frac{\overset{'-'}{H_{AA}} \cdot \left[\overset{'-'}{\frac{\partial \pi(.)}{\partial Z}} \cdot \overbrace{U^{'}(W_1)}^{'+'} \cdot \overset{'-'}{\frac{\partial L(.)}{\partial R}} - \overset{'+'}{\pi} \cdot \overbrace{U^{''}(W_1)}^{'-'} \cdot \overset{'-'}{\frac{\partial L}{\partial R}} \right] + \overset{'?'}{H_{ZA}} \cdot \left[\begin{array}{l} -\overset{'+'}{\pi(.)} \cdot \overbrace{U^{'}(W_1)}^{'+'} \cdot \overbrace{\frac{\partial^2 L(.)}{\partial R \partial A}}^{"?"} \\ +\overset{'+'}{\pi(.)} \cdot \overbrace{\left(1 + \frac{\partial L(.)}{\partial A}\right)}^{'-'} \cdot \overbrace{U^{''}(W_1)}^{"-"} \cdot \overset{"-"}{\frac{\partial L}{\partial R}} \end{array} \right]}{|H|} \tag{A.8}$$

Under the first term of the numerator, the bracketed portion representing $\frac{\partial EMB_Z}{\partial R} = \frac{\partial F^1}{\partial R}$ cannot be signed. Therefore, the sign of $\frac{\partial Z}{\partial R}$ remains ambiguous.

On self-insurance, A,

$$\frac{\partial A}{\partial R} = \frac{\overset{'-'}{H_{ZZ}} \cdot \left[\begin{array}{l} \overset{'+'}{\pi(.)} \cdot \overbrace{U^{'}(W_1)}^{'+'} \cdot \overbrace{\frac{\partial^2 L(.)}{\partial R \partial A}}^{"?"} \\ +\overset{'+'}{\pi(.)} \overbrace{\left(1 + \frac{\partial L(.)}{\partial A}\right)}^{'-'} \cdot \overbrace{U^{''}(W_1)}^{"-"} \cdot \overset{"-"}{\frac{\partial L(.)}{\partial R}} \end{array} \right] + \overset{'?'}{H_{AZ}} \cdot \left[-\overset{'-'}{\frac{\partial \pi(.)}{\partial Z}} \cdot \overset{'-'}{\frac{\partial L(.)}{\partial R}} \cdot \overbrace{U^{'}(W_1)}^{'+'} + \overset{'+'}{\pi(.)} \cdot \overset{'-'}{U^{''}(W_1)} \cdot \overset{'-'}{\frac{\partial L}{\partial R}} \right]}{|H|} \tag{A.9}$$

It is not possible to sign expression (A.9) unambiguously because we cannot determine the directions of the influence of ex-post public assisted relief and rehabilitation program on the expected marginal benefit of self-protection $\left(\frac{\partial EMB_Z}{\partial R} = \frac{\partial F^1}{\partial R} \right)$ under the indirect effect. Moreover, additional restrictions need to be imposed to sign the term $\frac{\partial^2 L}{\partial R \partial A}$ and the cross partial H_{ZA}.

Assuming household to be risk neutral, comparative static results show

$$\frac{\partial Z}{\partial R} = \frac{\overbrace{-\pi \cdot \frac{\partial^2 L}{\partial A^2}}^{'-'} \cdot \overbrace{\frac{\partial \pi}{\partial Z} \cdot \left(\frac{\partial L}{\partial R} \right)}^{'+'} + \overbrace{\left(\frac{\partial \pi}{\partial Z} \cdot \frac{\partial L}{\partial A} \right)}^{'+'} \cdot \overbrace{\left(\pi \cdot \frac{\partial^2 L}{\partial R \partial A} \right)}^{'?'}}{|H|} \tag{A.10}$$

$$\frac{\partial A}{\partial R}=\frac{\overbrace{-\frac{\partial^2\pi}{\partial Z^2}\cdot L(.)}^{'-'}\cdot\overbrace{\pi\cdot\frac{\partial^2 L}{\partial R\partial A}}^{"?"}+\overbrace{\left(\frac{\partial\pi}{\partial Z}\cdot\frac{\partial L}{\partial A}\right)}^{'+'}\cdot\overbrace{\left(\frac{\partial L}{\partial R}\cdot\frac{\partial\pi}{\partial Z}\right)}^{'+'}}{|H|} \tag{A.11}$$

Under the risk neutral case, it is possible to sign both (A.10) and (A.11) if the following condition holds:

Condition 3. The probability of facing ex-post storm inflicted property damages, $\pi(.)$, is strictly quasi-convex with respect to self-protection expenditure, Z : $\frac{\partial\pi(.)}{\partial Z}<0;\frac{\partial^2\pi(.)}{\partial Z^2}>0.$ This implies that the probability of facing monetary losses to property as a result of a cyclone induced storm surge decreases as household self-protection expenditure increases.

Condition 4. A strict quasi-convex relationship exists between storm-inflicted monetary losses to property and self-insurance expenditures, $\frac{\partial L}{\partial A}<0;\frac{\partial^2 L}{\partial A^2}>0$. This means that monetary losses to property decrease as a household commits more self-insurance expenditure.

Condition 5. $\frac{\partial^2 L(.)}{\partial R\partial A}<0$. Condition 5 states that more ex-post public-assisted disaster relief and rehabilitation programs, R, accentuate the effect of self-insurance in reducing monetary loss or damages to property as a result of a severe storm event. If Conditions (5) along with the other conditions hold, then it is possible to sign expression (A.10) and (A.11) indicating the following relationship

$$\frac{\partial Z}{\partial R}=\frac{\overset{'-'}{H_{AA}}\cdot\overbrace{\text{2nd bracketed term}}^{"+"}-\overset{"-"}{H_{ZA}}\cdot\overbrace{\text{4th bracketed term}}^{"+"}}{|H|}=\frac{"-"+"-"}{"+"}<0$$

$$\frac{\partial A}{\partial R}=\frac{\overset{'-'}{H_{ZZ}}\cdot\overbrace{\text{2nd bracketed term}}^{"-"}-\overset{"-"}{H_{AZ}}\cdot\overbrace{\text{4th bracketed term}}^{"+"}}{|H|}=\frac{"+"+"+"}{"+"}>0 \tag{A.12}$$

Expression (A.12) shows that self-protection, Z, is expected to go down but self-insurance, A, is expected to go up if households have more access to ex-post government-assisted disaster relief and rehabilitation programs, R. Consequently, one might observe a ‘crowding out effect’ on households’ self-protection but a ‘crowding in effect’ of self-insurance as a result of an increase in R, assuming the household to be risk neutral. However, it is not possible to come to a conclusion if the household is risk averse.

Proof of PROPOSITION 3 Comparative static results reveal that we require additional restrictions to establish any relationship between the increase in private inward remittances to the household from its migrant family member(s) and the household’s private defensive strategies in terms of self-protection and self-insurance.

Substituting the influence of private remittances, N, on the expected marginal benefits of self-protection, EMB_Z, and the expected marginal benefits of self-insurance, EMB_A, in expressions (A.6) and (A.7) lead to,

$$\frac{\partial Z}{\partial N}=\frac{\overset{'-'}{H_{AA}}\cdot\left[\overset{'-'}{\frac{\partial \pi(.)}{\partial Z}}\cdot\overbrace{U^{'}(W_1)}^{'+'}\cdot\overset{'-'}{\frac{\partial L(.)}{\partial N}}-\overset{'+'}{\pi}\cdot\overbrace{U^{''}(W_1)}^{'-'}\cdot\overset{'-'}{\frac{\partial L}{\partial N}}\right]+\overset{'?'}{H_{ZA}}\cdot\left[\begin{array}{l}-\overset{'+'}{\pi(.)}\cdot\overbrace{U^{'}(W_1)}^{'+'}\cdot\overbrace{\frac{\partial^2 L(.)}{\partial N\partial A}}^{"?"}\\+\overset{'+'}{\pi(.)}\cdot\overbrace{\left(1+\frac{\partial L(.)}{\partial A}\right)}^{'-'}\cdot\overbrace{U^{''}(W_1)}^{"-"}\cdot\overset{"-"}{\frac{\partial L}{\partial N}}\end{array}\right]}{|H|} \tag{A.13}$$

Under the first term of the numerator, the bracketed portion representing $\frac{\partial EMB_Z}{\partial N}=\frac{\partial F^1}{\partial N}$ cannot be signed. Therefore, the sign of $\frac{\partial Z}{\partial N}$ remains ambiguous.

On self-insurance, A,

$$\frac{\partial A}{\partial N}=\frac{\overset{'-'}{H_{ZZ}}\cdot\left[\begin{array}{l}\overset{'+'}{\pi(.)}\cdot\overbrace{U^{'}(W_1)}^{'+'}\cdot\overbrace{\frac{\partial^2 L(.)}{\partial N\partial A}}^{"?"}\\+\overset{'+'}{\pi(.)}\overbrace{\left(1+\frac{\partial L(.)}{\partial A}\right)}^{'-'}\cdot\overbrace{U^{''}(W_1)}^{"-"}\cdot\overset{"-"}{\frac{\partial L(.)}{\partial N}}\end{array}\right]+\overset{'?'}{H_{AZ}}\cdot\left[-\overset{'-'}{\frac{\partial \pi(.)}{\partial Z}}\cdot\overset{'-'}{\frac{\partial L(.)}{\partial N}}\cdot\overbrace{U^{'}(W_1)}^{'+'}+\overset{'+'}{\pi(.)}\cdot\overset{'-'}{U^{''}(W_1)}\cdot\overset{'-'}{\frac{\partial L}{\partial N}}\right]}{|H|} \tag{A.14}$$

It is not possible to sign expression (A.13) unambiguously because we cannot determine the directions of the influence of private inward remittances on the expected marginal benefit of self-protection $\left(\frac{\partial EMB_Z}{\partial N}=\frac{\partial F^1}{\partial N}\right)$ under the indirect effect. Moreover, additional restrictions need to be imposed to sign the term $\frac{\partial^2 L}{\partial N\partial A}$ and the cross partial H_{ZA}.

Assuming household to be risk neutral, comparative static results show

$$\frac{\partial Z}{\partial N}=\frac{\overbrace{-\pi\cdot\frac{\partial^2 L}{\partial A^2}}^{'-'}\cdot\overbrace{\frac{\partial \pi}{\partial Z}\cdot\left(\frac{\partial L}{\partial N}\right)}^{'+'}+\overbrace{\left(\frac{\partial \pi}{\partial Z}\cdot\frac{\partial L}{\partial A}\right)}^{'+'}\cdot\overbrace{\left(-\pi\cdot\frac{\partial^2 L}{\partial N\partial A}\right)}^{'?'}}{|H|} \tag{A.15}$$

$$\frac{\partial A}{\partial N}=\frac{\overbrace{-\frac{\partial^2 \pi}{\partial Z^2}\cdot L(.)\cdot\pi}^{'-'}\cdot\overbrace{\frac{\partial^2 L}{\partial N\partial A}}^{'?'}+\overbrace{\left(\frac{\partial \pi}{\partial Z}\cdot\frac{\partial L}{\partial A}\right)}^{'+'}\cdot\overbrace{\left(\frac{\partial L}{\partial N}\cdot\frac{\partial \pi}{\partial Z}\right)}^{'+'}}{|H|} \tag{A.16}$$

Under the risk neutral case, it is possible to sign both (A.15) and (A.16) if the following condition holds:

Condition 6. $\frac{\partial^2 L(.)}{\partial N\partial A}<0$. Condition 6 states that more ex-post private transfers through remittances, N, from migrant family members accentuate the effect of self-insurance in reducing monetary loss or damages to property from a major storm event. If Condition (6) along with the other conditions hold, then it is possible to sign expression (A.15) and (A.16) indicating the following relationship

$$\frac{\partial Z}{\partial N}=\frac{\overset{'-'}{H_{AA}}\cdot\overbrace{\text{2nd bracketed term}}^{"+"}-\overset{"-"}{H_{ZA}}\cdot\overbrace{\text{4th bracketed term}}^{"+"}}{|H|}=\frac{"-"+"-"}{"+"}<0$$

$$\frac{\partial A}{\partial N}=\frac{\overset{'-'}{H_{ZZ}}\cdot\overbrace{\text{2nd bracketed term}}^{"-"}-\overset{"-"}{H_{AZ}}\cdot\overbrace{\text{4th bracketed term}}^{"+"}}{|H|}=\frac{"+"+"+"}{"+"}>0 \qquad \text{(A.17)}$$

Expression (A.17) shows that self-protection, Z, is expected to go down but self-insurance, A, is expected to go up if households expect to receive more private remittances, N, from migrant family members. Assuming a household to be risk-neutral, we might observe a 'crowding out effect' on households' self-protection but a 'crowding in effect' of self-insurance for an increase in N. It is not possible to come to a conclusion if the household is risk averse.

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