Are private defensive expenditures against storm damages affected by public programs and natural barriers?
Evidence from the coastal areas of Bangladesh

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ONLINE APPENDIX

Appendix A

Given the expressions (1)-(3), the household optimization framework with non-negative inequality constraints is:[1]

$$\underset{Z,A,X}{Max}\, EU = \left[\pi\left(Z;G,M,C\right)\cdot U^{L}\left(X\right)+\left(1-\pi\left(Z;G,M,C\right)\right)\cdot U^{NL}\left(X\right)\right]$$

subject to

$$\begin{array}{ll} X+Z+A+L(A;R)\leq I & \text{(income constraint)} \\ X\geq 0 & \text{(composite good consumption constraint)} \\ Z\geq 0 & \text{(self-protection constraint)} \\ A\geq 0 & \text{(Self-insurance constraint)} \end{array} \qquad \text{(A.1)}$$

Given the problem, the Lagrangian function is:

$$\begin{aligned} \mathrm{L}\left(Z,A,X,\lambda\right) &= \left[\pi\left(Z;G,M,C\right)\cdot U^{L}\left(X\right)+\left(1-\pi\left(Z;G,M,C\right)\right)\cdot U^{NL}\left(X\right)\right] \\ &\quad +\lambda\cdot\left[I-X-Z-A-L\left(A;R\right)\right] \end{aligned} \qquad \text{(A.2)}$$

The first-order Kuhn-Tucker conditions are

$$Z: \quad \frac{\partial \mathrm{L}}{\partial Z}=\frac{\partial \pi}{\partial Z}\left(U^{L}-U^{NL}\right)-\lambda\leq 0$$
$$Z\cdot\frac{\partial \mathrm{L}}{\partial Z}=0$$
$$Z\geq 0$$

(A.3)

$$A: \quad \frac{\partial \mathrm{L}}{\partial A}=\left[-\left(1+\frac{\partial \mathrm{L}}{\partial A}\right)\cdot\lambda\right]\leq 0$$
$$A\cdot\frac{\partial \mathrm{L}}{\partial A}=0 \qquad \text{(A.4)}$$
$$A\geq 0$$

$$X: \quad \frac{\partial \mathrm{L}}{\partial X}=\pi\cdot\frac{\partial U^{L}}{\partial X}+\left(1-\pi\right)\cdot\frac{\partial U^{NL}}{\partial X}-\lambda\leq 0$$
$$X\cdot\frac{\partial \mathrm{L}}{\partial X}=0 \qquad \text{(A.5)}$$
$$X\geq 0$$

[1] There is a distinction between the expected utility stated in equation (3) and the expected utility stated in equation (A.1). In equation (3), we substituted for *X* (i.e. the composite good) considering the income constraint. Thus, the choice variables for equation (4) are *Z* and *A*. But for the maximization problem with constraints in equation (A.1), we do not perform any substitution since we are interested in the Kuhn-Tucker conditions in order to explain the household behavioral responses to private storm protection strategies (i.e. the four types). Thus, for this case, the choice variables are *Z*, *A*, and *X*.

$$\lambda: \quad \frac{\partial \mathcal{L}}{\partial \lambda} = I - X - Z - A - L(A;R) \geq 0$$

$$\lambda \cdot \frac{\partial \mathcal{L}}{\partial \lambda} = 0 \qquad \text{(A.6)}$$

$$\lambda \geq 0 .$$

Starting with expression (A.5), assuming a representative household has positive consumption of the composite good, i.e. $X > 0$,

$$\frac{\partial \mathcal{L}}{\partial X} = 0$$

$$\Rightarrow \pi(.) \cdot U_X^L + \left(1 - \pi(.)\right) \cdot U_X^{NL} = \lambda \; . \qquad \text{(A.7)}$$

Expression (A.7) reveals that a household will prefer to have positive consumption of the composite good if the expected marginal benefit from consuming the composite good under both states of the world, i.e. adverse and non-adverse states, is equivalent to its shadow price. The shadow prices of the composite good X can also be expressed as the marginal imputed cost (opportunity cost) of consuming the good or the expected marginal utility of income.

Considering a household will exhaust its budget, which is equivalent to, say, $\lambda > 0$ and $\frac{\partial \mathcal{L}}{\partial \lambda} = 0$ from expression (A.6), we will now proceed with our discussion of the four types of household behavioral responses to reduce the likelihood and the severity of experiencing damages to property from a major storm. For all types, we assume that a household will always tend to consume the composite good at least at the subsistence level, i.e. $X \geq X^0$.

Type (a): Interior solution of both self-protection and self-insurance

From (A.3), if $Z > 0$, then the first order condition with respect to Z is an unconstrained maximum of the Lagrangian.

$$\frac{\partial \mathcal{L}}{\partial Z} = 0 \quad \Rightarrow \frac{\partial \pi}{\partial Z} \cdot \left(U^L - U^{NL}\right) = \lambda \, . \qquad \text{(A.9)}$$

Expression (A.9) implies that a household will pursue self-protection up to the point where the expected marginal benefit of self-protection is equal to its expected marginal imputed cost (opportunity cost) or the expected marginal utility of income. The latter can also be identified as the shadow price or virtual price of self-protection.

Similarly, from (A.4), if $A > 0$, then,

$$\frac{\partial \mathcal{L}}{\partial A} = 0 \qquad \Rightarrow \left[-\left(1 + \frac{\partial L}{\partial A}\right)\right] \cdot \lambda = 0 \; . \qquad \text{(A.10)}$$

Since $\lambda > 0$, we can infer from expression (A.10) and by re-arranging terms,

$$-\frac{\partial L}{\partial A} = 1 \; . \qquad \text{(A.10.1)}$$

Expression (A.10.1) suggests that a household could pursue self-insurance strategies if the marginal benefit of self-insurance, as defined by the averted monetary loss to damages to property, is equal to its marginal cost. The latter can be characterized as the unit cost of self-insurance based on our simplification that the price of the self-insurance is $1.

Thus, given certain assumptions about a household's utility in states of damage or no damage and its level of composite good consumption, expressions (A.9) and (A.10.1) ensure that an interior solution exists for a household that allocates resources both for self-protection and self-insurance.

Type (b): Self-protection only corner solution

For the corner solution where the household allocates resources only for self-protection $(Z > 0)$ but not for self-insurance $(A = 0)$, we have the following based on expression (A.4):

$$\frac{\partial \mathrm{L}}{\partial A} \leq 0 \;\Rightarrow \left[-\left(1+\frac{\partial L}{\partial A}\right)\right] \cdot \lambda \leq 0 . \tag{A.11}$$

But since $\lambda > 0$,

$$\left[-\left(1+\frac{\partial L}{\partial A}\right)\right] \leq 0 \quad \text{or, } -\frac{\partial L}{\partial A} \leq 1 . \tag{A.11.1}$$

Thus, expression (A.11.1) implies that a household will not pursue self-insurance if it considers the marginal benefit from self-insurance to be lower than the marginal cost (i.e. the unit cost equivalent to price) of self-insurance.

In addition, we consider that condition (A.9) should hold to ensure that a household has positive allocation for self-protection $(Z > 0)$. Hence, given conditions (A.9) and (A.11.1) under certain assumptions, we can express the self-protection only corner solution $\left(Z > 0;\ A = 0;\ \text{and } X \geq X^0\right)$.

Type (c): Self-insurance only corner solution

In the case of the self-insurance only corner solution, it follows from expression (A.3) that we should have

$$\frac{\partial \mathrm{L}}{\partial Z} \leq 0 \quad \text{or, } \frac{\partial \pi}{\partial Z} \cdot \left(U^{SE} - U^{NSE}\right) \leq \lambda , \tag{A.12}$$

where expression (A.12) indicates that a household will not practice self-protection if and only if it perceives that the expected marginal benefit of self-protection is less than or equal to the expected marginal imputed costs of self-protection (i.e., the shadow price of self-protection). But unlike previously, we will consider that expressions (A.10.1) and (A.12) hold to ensure we can express the self-insurance only corner solution $\left(Z = 0;\ A > 0;\ \text{and } X \geq X^0\right)$.

Type (d): No self-protection and self-insurance

For the no self-protection and no self-insurance case, we argue that the conditions such as (A.11.1) and (A.12) hold so that a household considers that the expected marginal benefits from self-protection and self-insurance are lower than the expected costs of their take up.

Appendix B

Proof of Proposition 1. Comparative analyses results show that we cannot determine the direction of the relationship between a household's averting behavior and public spending on protective dams and embankments unless we impose additional restrictions.

Using the first order conditions (4) and (5) 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

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

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 (4); $F^2\equiv EMB_A$ is the first order condition with respect to self-insurance, i.e. the expected marginal benefits of self-insurance based on expression (5); 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 (B.1), the first term in the numerator on the right hand side is the direct effect of the public investment on dams and embankments 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

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

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 (4); $F^2\equiv EMB_A$ is the first order condition with respect to self-insurance, i.e. the expected marginal benefits of self-insurance based on expression (5); 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 (B.2), the first term in the numerator on the right hand side is the direct effect of the public spending on dams and embankments on self-protection, while the second term is the indirect effect.

Expressions (B.1) and (B.2) show that the sign and magnitude of the direct effect depends on how a change in G 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 effect 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 public investments in dams and embankments, 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 (B.1) leads to

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

Similarly, substituting the influence of public investments, 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 (B.2) yields

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

It is not possible to sign expressions (B.3) and (B.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.[2] 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.

[2] 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 government spending on building dams and embankments G can accentuate the influence of self-protection, Z, in reducing the probability of a hazardous event that inflicts damages to property.

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

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

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

Therefore, under additional restrictions, comparative statics results show that government spending on dams and embankments, 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 government disaster relief and rehabilitation programs R on household defensive expenditures show that the direction of the relationship can be determined only under certain restrictions. Comparative static results show

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

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

Expressions (B.6) - (B.7) reveal that the sign and magnitude of the direct effects depend on the own partials, H_{ZZ} and H_{AA}, as well as on how a change in the public-assisted disaster relief and rehabilitation programs influence 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 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 public programs R and the private defensive expenditures remain ambiguous because it is not possible to determine the direction of influence of disaster relief programs, R, on the expected marginal benefits of self-protection $\left(EMB_Z = \dfrac{\partial EU}{\partial Z_{ij}} \right)$. However, if the households are assumed to be risk neutral, then it is possible to establish the direction of the relationships by imposing some additional conditions.

Substituting the influence of public disaster relief, R, on the expected marginal benefits of self-protection, EMB_Z, and the expected marginal benefits of self-insurance, EMB_A, in expressions (B.6) and (B.7) leads to

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

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

For self-insurance, A,

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

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

Assuming households to be risk neutral, comparative static results show

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

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

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

Condition 3. The probability of a hazardous event inflicting 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 to more self-insurance expenditure.

Condition 5. $\frac{\partial^2 L(.)}{\partial R\partial A}<0$. Condition 5 states that more 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 expressions (B.10) and (B.11) indicating the following relationship

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

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

Expression (B.12) shows that self-protection, *Z*, is expected to go down but self-insurance, *A*, is expected to go up if there are more 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. It is not possible to come to a conclusion if the household is risk averse.

Proof of Proposition 3. Comparative analyses could examine the plausible impact of mangrove forests as a natural storm protection barrier on household defensive behavior. The initial comparative static results reveal that we require additional restrictions to establish any relationship between the two variables.

Comparative static results on the influence of mangrove forests, *M*, on self-protection, *Z*, reveals the following:

$$\frac{\partial Z}{\partial M}=\frac{\overset{'-'}{H_{AA}}\cdot\begin{bmatrix}-\overbrace{\frac{\partial^2\pi(.)}{\partial M\,\partial Z}}^{'?'}\cdot\overbrace{\left(U(W_1)-U(W_2)\right)}^{'-'}\\+\overbrace{\frac{\partial\pi}{\partial M}}^{'-'}\cdot\overbrace{\left(U^{'}(W_1)-U^{'}(W_2)\right)}^{'+'}\end{bmatrix}+\overset{'?'}{H_{ZA}}\cdot\begin{bmatrix}-\overbrace{\frac{\partial\pi(.)}{\partial M}}^{'-'}\cdot\overbrace{U^{'}(W_1)}^{'+'}\cdot\overbrace{\left(1+\frac{\partial L}{\partial A}\right)}^{'-'}\\+\overbrace{U^{'}(W_2)}^{'+'}\cdot\overbrace{\frac{\partial\pi(.)}{\partial M}}^{'-'}\end{bmatrix}}{|H|}\qquad\text{(B.13)}$$

Similarly, it is possible to state the influence of *M* on self-insurance *A* as:

$$\frac{\partial A}{\partial M}=\frac{\overset{'-'}{H_{ZZ}}\cdot\begin{bmatrix}\overbrace{\frac{\partial\pi(.)}{\partial M}}^{'-'}\cdot\overbrace{U^{'}(W_1)}^{'+'}\cdot\overbrace{\left(1+\frac{\partial L}{\partial A}\right)}^{'-'}\\-\overbrace{U^{'}(W_2)}^{'+'}\cdot\overbrace{\frac{\partial\pi(.)}{\partial M}}^{'-'}\end{bmatrix}+\overset{'?'}{H_{AZ}}\cdot\begin{bmatrix}\overbrace{\frac{\partial^2\pi(.)}{\partial M\,\partial Z}}^{'?'}\cdot\overbrace{\left(U(W_1)-U(W_2)\right)}^{'-'}\\-\overbrace{\frac{\partial\pi}{\partial M}}^{'-'}\cdot\overbrace{\left(U^{'}(W_1)-U^{'}(W_2)\right)}^{'+'}\end{bmatrix}}{|H|}\qquad\text{(B.14)}$$

As before, it is not possible to sign expressions (B.13) and (B.14) unambiguously unless we impose additional restrictions. It is possible to sign them using condition 1 (i.e., $H_{AZ}=H_{ZA}<0$) as well as by introducing the following restriction.

Condition 6. $\frac{\partial^2\pi(.)}{\partial M\,\partial Z}<0$. This condition states that more storm protection from mangroves, *M*, accentuates the influence of self-protection, *Z*, in reducing the probability of facing damages to property conditional on the storm event. Condition 6 suggests that the marginal probability of facing damages to property conditional on the storm event as a result of self-protection expenditures *Z* decreases at an increasing rate for an increase in the household's exposure to the storm-protection services of mangrove forests *M*.

Assuming it is possible to meet conditions (4) and (7), expressions (B.13) and (B.14) show that:

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

$$\frac{\partial A}{\partial M}=\frac{\overbrace{H_{zz}}^{"-"}\cdot\overbrace{\text{2nd bracketed term}}^{"+"}+\overbrace{H_{AZ}}^{"-"}\cdot\overbrace{\text{4th bracketed term}}^{"+"}}{|H|}=\frac{"-"\ +\ "-"}{|H|}<0.\qquad\text{(B.15)}$$

With additional restrictions, the comparative statics result now demonstrates that exposure to greater storm protection services of mangrove forests, *M*, leads to decrease in a households' ex - ante self-protection strategies, *Z*. However, it causes an increase in a household's self-insurance actions, *A*.

Appendix C. Figures and tables

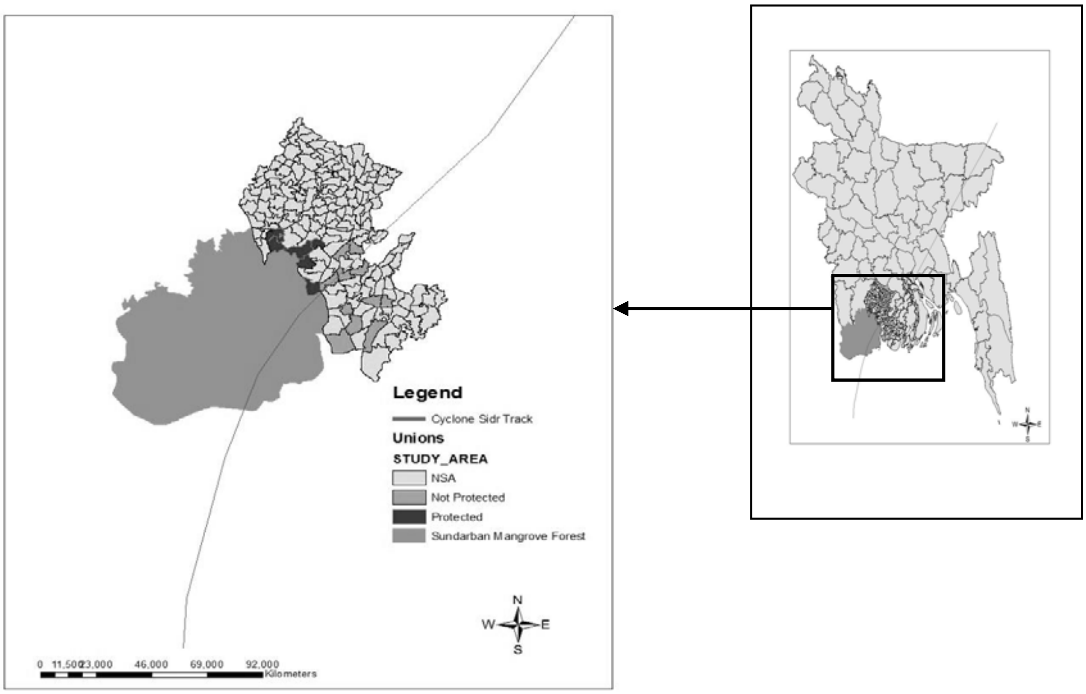

Figure A1. *The study area – the protected and non-protected areas*

Table A1. *Comparative static results of the household model of defensive strategies*

Self-protection (Z)		
	Outcome	**Required Conditions**
Public spending on dams and embankments	$\frac{dZ}{dG} > 0$	1. $H_{AZ} = H_{ZA} < 0$ 2. $\frac{\partial^2 \pi(.)}{\partial G \partial Z} < 0$
Storm protection by mangrove forest	$\frac{dZ}{dM} > 0$	1. $H_{AZ} = H_{ZA} < 0$ 2. $\frac{\partial^2 \pi(.)}{\partial M \partial Z} < 0$
Public spending on relief and rehabilitation programs	$\frac{dZ}{dR} < 0$ (Holds only for risk neutral households)	$\frac{\partial^2 L(A,R)}{\partial R \partial A} < 0$
Self-insurance (A)		
Public spending on dams and embankments	$\frac{dA}{dG} < 0$	1. $H_{AZ} = H_{ZA} < 0$ 2. $\frac{\partial^2 \pi(.)}{\partial G \partial Z} < 0$
Storm protection by mangrove forest	$\frac{dA}{dM} < 0$	1. $H_{AZ} = H_{ZA} < 0$ 2. $\frac{\partial^2 \pi(.)}{\partial M \partial Z} < 0$
Public spending on relief and rehabilitation programs	$\frac{dA}{dR} > 0$ (Holds only for risk neutral households)	$\frac{\partial^2 L(A,R)}{\partial R \partial A} < 0$

Table A2. *Summary statistics of household based on the study area*

Household Characteristics		Value	
		Protected	Non-protected
Respondent average age (mean)		42.89	41.69
Respondent gender (%)	Male	84.09	71.79
	Female	15.91	28.21
Literacy rate of respondent (%)	Illiterate	7.83	8.36
	Primary School	52.07	45.45
	High School	26.73	27.27
Respondent occupation (%)	Farmer	24.09	39.78
	Fisherman	6.82	7.17
	Trader	15.91	13.26
	Service	6.36	6.45
	Wage worker	35.91	11.93
Respondent is head of household (%)		81.36	63.08
Respondent living in the village since birth (%)		91.82	90.68
Average number of family members (Min-Max)		4.97 (1-11)	5.66 (0-25)
Average number of adults (Min-Max)		3.68 (1-10)	4.43 (1-15)
Average number of children (Min-Max)		1.89 (1-7)	1.72 (1-10)
Average number of males at work (Min-Max)		1.33 (1-4)	1.55 (1-7)
Type of wall used for dwelling at present (%)	Katcha/ Earthen	18.26	5.02
	Tin/ C.I. Sheet	21.46	46.58
	Pacca (brick)	9.13	11.42
	Wood	37.44	42.92
	Jhupri/ Chon	10.50	17.35
Type of roof used for dwelling at present (%)	Katcha/ Earthen	0.46	1.07
	Tin/ C.I. Sheet	73.97	80.71
	Pacca (brick)	2.28	1.79
	Wood	4.57	2.50
	Jhupri/ Chon	18.72	13.93
Nature of house in past (%)	Same	52.51	74.29
Floors of house at present (%)	Ground floor	90.91	78.85
	Up to first floor	9.09	21.15
Tenure of residence (%)	Rented	3.67	3.94
	Owned	89.45	92.11
Elevation status of the house (%)	High land	6.82	5.00
	Mid land	37.27	41.07
	Low land	55.91	53.93
Size of homestead (Mean in hectare)		0.13 ha	0.14 ha
Type of latrine (%)	Sanitary	7.73	21.94
	Ring/slab	83.18	64.03
	Katcha	9.55	12.95
Source of drinking water – multiple responses (%)	Deep Tube well	0.45	26.43
	Tube well	12.27	33.57
	Pond/ River	67.73	31.79
	Rain water	48.64	15.36
	Filtered Pond	24.09	11.79
Percentage with electricity connection		21.46	31.79
Percentage with access to cell phone		48.18	45.16
Average household income (US $ /year)		815.47	857.19
Main source of energy- multiple responses (%)	Wood/ Coal	93.52	98.55
	Twigs/ Leafs	83.80	61.82

Table A3. *Summary statistics of the key variables used for regression analysis*

Variable	Definition	No. of observations	Mean	Standard Deviation
L(DAMAGE)	Log of the nominal value of Cyclone Sidr inflicted damages (in Tk.)	493	10.885	1.1381
L(PREINC)	Log of Pre-Cyclone Sidr HH Income (in Tk.)	449	11.569	1.079
L(PREINC2)	Square of the log of Pre-Cyclone Sidr HH Income (in Tk.)	449	135.02	25.28
L(POSTINC)	Log of Post-Cyclone Sidr HH Income (in Tk.)	489	10.648	1.262
L(POSTINC2)	Square of the log of Post-Cyclone Sidr HH Income (in Tk.)	489	114.96	24.44
AREA	Area of homestead, crop land, and the pond (in decimal)	500	142.6	24.441
DCOAST	Distance from the coast (in Km.)	500	44.10	18.248
AGE	Age of the respondent (in years)	497	42.221	13.252
EDUYR	Average years of respondent education	492	6.868	3.643
CREDIT	If household has access to credit (=1, 0 otherwise)	492	0.5752	0.4948
MEMBER	If household is a member of village level organizations (=1, 0 otherwise)	486	0.1934	0.3954
MFRATIO	Male/ Female ratio of the household	498	1.248	0.7933
CHILDREN	Number of children in the household	500	1.26	1.1896
LOCCLE	If household house is always exposed to major storm given its location (=1, 0 otherwise)	498	0.032	0.177
HELEV2	If household falls into medium elevation area (=1, 0 otherwise)	500	0.394	0.4891
HELEV3	If household falls into high elevation area (=1, 0 otherwise	500	0.058	0.2339
MIGRATION	If planning to migrate in the future (=1, 0 otherwise)	494	0.328	0.469
ELEC	If household has access to electricity (=1, 0 otherwise)	499	0.273	0.4457
PHONE	If household has access to phone (=1, 0 otherwise)	499	0.465	0.4993
PROTECTED	If household falls into the mangrove protected area (=1, 0 otherwise)	500	0.44	0.497
MDIST	Distance between the union and the mangrove forest (in km.)	500	7.536	7.981
MDIR	If household is located to the south or the southwest direction relative to the coast and the Sundarban mangrove forest (=1, 0 otherwise)	500	0.548	0.498
EMB	If household is protected by the embankment (=1, 0 otherwise)	497	0.6097	0.4883
ARELIEF	If household has access to relief (=1, 0 otherwise)	499	0.8938	0.3084
AREHABN	If household has access to rehabilitation (=1, 0 otherwise)	492	0.5508	0.4979
SURGEHT	Approximate average Cyclone Sidr induced Storm surge height (in meter)	500	3.982	0.7085
STORMEXP	If household falls into counter-clockwise direction from Cyclone Sidr (=1, 0 otherwise)	500	0.42	0.4941
STORMDIS	Directional Distance between Household and the Track for the Cyclone Sidr (in km)	500	15.839	10.124

Table A4. *Full information maximum likelihood (FIML) of the sample selection model for participation (selection) in self-protection (sample includes the entire study area [a])*

Selection Equation (dependent variable is the probability of households participating in self-protection)								
Variable	(1)		(2)		(3)		(4)	
	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.
CONSTANT	-15.568 (-1.98)**		-16.554 (-2.08)**		-16.843 (-2.00)**		-14.660 (-1.76)**	
L(DAMAGE)	0.1768 (2.44)***	0.0477	0.1978 (2.66)***	0.0523	0.2128 (2.74)***	0.0536	0.1899 (2.43)***	0.0466
L(PREINC)	2.084 (1.59)*	0.5617	2.325 (1.76)**	0.6135	2.391 (1.70)**	0.6024	1.956 (1.41)*	0.4801
L(PREINC2)	-0.0857 (-1.55)*	-0.0231	-0.095 (-1.71)**	-0.0251	-0.0968 (-1.63)*	-0.0244	-0.0794 (-1.36)*	-0.0195
AREA	0.0006 (2.33)***	0.0001	0.0006 (2.03)**	0.0001	0.0005 (1.83)**	-0.0019	0.0006 (1.75)**	0.0001
DCOAST	0.0114 (2.90)***	0.0031	0.0014 (0.19)	0.0004	0.0063 (0.80)	0.0016	0.0074 (0.74)	0.0018
AGE	-0.0022 (-0.39)	-0.0006	-0.0041 (-0.72)	-0.0011	-0.0076 (-1.25)	-0.0019	-0.0079 (-1.26)	-0.0019
LOCCLE	0.2067 (0.55)	0.0604	0.0014 (0.00)	0.0004	-0.3833 (-0.98)	-0.08	-0.3487 (-0.85)	-0.0719
EDUYR	0.0155 (0.70)	0.0042	0.0111 (0.49)	0.0029	0.0081 (0.35)	0.0020	0.0094 (0.39)	0.0023
CREDIT	-0.2543 (-1.63)**	-0.0696	-0.3426 (-2.12)**	-0.0923	-0.4249 (-2.52)***	-0.1097	-0.4291 (-2.48)***	-0.1080
MEMBER	0.2653 (1.37)*	0.0763	0.2216 (1.09)	0.0618	0.3358 (1.58)*	0.0925	0.2864 (1.29)*	0.0761
CHILD	-0.1209 (-1.77)**	-0.0326	-0.1243 (-1.74)**	-0.0328	-0.1293 (-1.63)**	-0.0326	-0.1184 (-1.40)*	-0.0291
ELEC	0.0167 (0.10)	0.0045	0.11 (0.64)	0.0297	0.1526 (0.88)	0.0397	0.1747 (0.95)	0.0446
PHONE	-0.3537 (-2.28)**	-0.095	-0.3107 (-2.00)**	-0.0817	-0.3589 (-2.30)**	-0.0901	-0.3236 (-1.92)**	-0.0792
HELEV2	0.2783 (1.75)**	0.0774	0.2791 (1.70)**	0.0759	0.1666 (0.97)	0.0429	0.1308 (0.68)	0.0327
HELEV3	0.2539 (0.81)	0.075	0.1936 (0.60)	0.0549	0.289 (0.87)	0.0815	0.4260 (1.25)	0.1233
MIGRATION	-0.073 (-0.45)	-0.0195	-0.2386 (-1.35)*	-0.0605	-0.2605 (-1.46)*	-0.0627	-0.2093 (-0.98)	-0.0495
PROTECTED			0.5425 (1.62)*	0.1463	0.3569 (1.05)	0.0914	-0.6388 (-1.25)	-0.1519
MDIST			-0.0315 (-1.32)*	-0.0083	-0.0299 (-1.18)	-0.0075	-0.0486 (-1.81)**	-0.0119
MDIR			-0.4869 (-1.51)*	-0.1275	-0.4535 (-1.33)*	-0.1136	-0.5583 (-1.61)*	-0.1361
EMB					-0.2133 (-1.04)	-0.0548	-0.270 (-1.02)	-0.068
ARELEIF					-0.4091 (-1.55)*	-0.1189	-0.3663 (-1.34)*	-0.1028
AREHABN					0.3635 (2.02)**	0.0902	0.2299 (1.21)	0.0559
SURGEHT							0.2925 (1.40)*	0.0718
STORMEXP							-0.7539 (-1.92)**	-0.1713
STORMDIS							0.0342 (3.15)***	0.0084

[a] Z-tests are shown in parentheses beneath coefficient estimates. Significance levels: ***1%, **5%, *10%.

Table A5. *Full information maximum likelihood (FIML) of the sample selection model for the outcome in self-protection conditional on participation (sample includes the entire study area* [a,b])

Outcome Equation (dependent variable is the level of household self-protection expenses (in Tk.) conditional on participation in self-protection activities)

Variable	(1)		(2)		(3)		(4)	
	Coeff.	Marginal Effect	Coeff.	Marginal Effect	Coeff.	Marginal Effect	Coeff.	Marginal Effect
CONSTANT	5012499 (2.61)***		4824857 (2.36)***		2950481 (1.47)*		2777406 (1.33)*	
L(DAMAGE)	31414.17 (2.09)**	44923.1	24557.77 (1.57)*	40554.6	29679.57 (1.88)**	49160.5	31806.89 (1.95)**	45494.81
L(PREINC)	-935330.2 (-3.01)***	-776090.8	-899233.7 (-2.75)***	-711072.6	-575624.9 (-1.75)**	-356740.2	-521966 (-1.56)*	-374203.1
L(PREINC2)	42147.74 (3.20)***	35599.76	40958.9 (2.96)***	33272.25	26576.42 (1.89)**	17713.34	24181.45 (1.69)**	18158.33
AGE	449.59 (0.45)	281.23	546.27 (0.56)	211.068	-42.049 (-0.04)	-736.54	-242.53 (-0.26)	-701.92
EDUYR	-2545.32 (-0.62)	-1361.56	-5409.89 (-1.27)	-4507.78	-4036.27 (-0.95)	-3293.11	-3939.07 (-0.93)	-3537.97
CREDIT	60455.59 (2.05)**	41081.37	68927.8 (2.29)**	41332.78	84707.43 (2.73)***	45990.64	71259.19 (2.29)**	42720.4
MEMBER	-57153.8 (-1.57)*	-37143.19	-52587.16 (-1.36)*	-34848.24	-61786.5 (-1.55)*	-31531.49	-49364.74 (-1.20)	-34437
HELEV2	-50837.99 (-1.63)*	-29703.08	-58545.41 (-1.90)**	-36105.7	-61397.25 (-1.92)**	-46199.14	-47904.82 (-1.66)**	-40963.73
HELEV3	-55360.76 (-1.01)	-36327.12	-81923.15 (-1.50)*	-66475.8	-121005.4 (-2.11)**	-95085.01	-91877.5 (-1.54)*	-68853.65
PROTECTED			68426.17 (1.51)*	112066.5	114195.1 (2.29)**	146762.2	145357.8 (1.50)*	105508.6
MDIST			1065.49 (0.30)	-1486.69	1483.77 (0.41)	-1255.26	-158.71 (-0.04)	-3278.65
MDIR			-34526.22 (-0.68)	-73922.3	-48006.21 (-0.96)	-89521.16	-67997.52 (-1.40)*	-103706.2
EMB					92285.14 (2.20)**	72824.25	117533.6 (2.06)**	101743.1
ARELEIF					-21934.62 (-0.41)	-58372.31	-44006.35 (-0.86)	-69109.94
AREHABN					-17993.46 (-0.54)	-15334.42	-3048.42 (-0.10)	12152.6
SURGEHT							-42107.52 (-1.04)	-25373.06
STORMEXP							24155.5 (0.31)	-25939.13
STORMDIS							-1273.51 (-0.49)	1265.82
RHO	-0.700009 (-4.07)***		-0.7477589 (-4.21)***		-0.8336851 (-6.20)***		-0.7919759 (-3.90)***	
SIGMA	138735.6 (6.25)***		136971.7 (5.41)***		137969.1 (5.27)***		129815.8 (4.45)***	
LOG LIKE.	-1308.99		-1300.28		-1229.22		-1222.58	
LR test (ρ=0)	5.16** (χ^2=1)		4.12* (χ^2=1)		6.14** (χ^2=1)		3.65 (χ^2=1)	
LR test (prob>χ^2)	0.0231		0.0425		0.000		0.0560	
CENS. OBS.	315		315		309		309	

[a] Under FIML, the LR stat to test independence between the error terms of the participation and outcome equations provide strong evidence against the null in all cases. That is, we reject the null or accept the dependence between the error terms.

[b] Z-tests are shown in parentheses beneath coefficient estimates. Significance levels: ***1%, **5%, *10%.

Table A6. *Probit and Tobit model for self-insurance*

Variable	**Probit Model** [a] (dependent variable is the probability of households participating in self-insurance)				**Tobit Model** [b] (dependent variable is the level of household self-insurance expenditures in Taka)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
CONSTANT	-5.556 (-2.22)**	-5.448 (-2.04)**	-6.683 (-2.35)***	-5.766 (-1.92)**	387428.9 (3.53)***	388326.1 (3.52)***	357000.4 (3.20)***	428488.2 (3.56)***
L(DAMAGE)	0.0923 (1.50)*	0.0832 (1.33)*	0.0730 (1.07)	0.0543 (0.79)	9793.67 (3.26)***	9584.08 (3.24)***	10291.85 (3.44)***	10127.24 (3.37)***
L(POSTINC)	0.6360 (1.31)	0.6619 (1.29)*	0.6617 (1.23)	0.6649 (1.22)	-130195.5 (-6.13)***	-130509.5 (-6.21)***	-129021.6 (-6.13)***	-131729.7 (-6.25)***
L(POSTINC2)	-0.0307 (-1.24)	-0.0315 (-1.20)	-0.0284 (-1.04)	-0.0280 (-1.01)	7267.94 (6.64)***	7243.68 (6.67)***	7180.74 (6.60)***	7329.67 (6.73)***
AREA	0.00002 (0.06)	-0.00008 (-0.30)	-0.00009 (-0.38)	-0.00013 (-0.53)	0.7022 (0.06)	-2.106 (-0.17)	-1.910 (-0.15)	-1.593 (-0.13)
DCOAST	0.0117 (2.76)***	0.0211 (2.72)***	0.0302 (3.38)***	0.0238 (2.15)**	-46.081 (-0.24)	762.35 (2.20)**	886.99 (2.34)***	447.89 (0.95)
AGE	0.0024 (0.46)	0.0032 (0.60)	0.0015 (0.26)	0.0025 (0.42)	432.58 (1.74)**	445.73 (1.81)**	424.28 (1.69)**	442.43 (1.75)**
EDUYR	-0.0414 (-1.85)**	-0.0337 (-1.47)*	-0.0331 (-1.35)*	-0.0332 (-1.35)*	1498.51 (1.47)*	2183.19 (2.13)**	2349.95 (2.29)**	2365.25 (2.31)**
CREDIT	0.1359 (0.96)	0.2324 (1.56)*	0.1739 (1.08)	0.1742 (1.07)	3207.58 (0.48)	7940.03 (1.18)	9088.85 (1.33)*	8787.12 (1.29)*
MEMBER	-0.4831 (-2.36)***	-0.6923 (-3.17)***	-0.8197 (-3.50)***	-0.8227 (-3.47)***	739.53 (0.08)	-6456.38 (-0.70)	-7200.24 (-0.77)	-6517.14 (-0.70)
CHILD	0.0952 (1.59)*	0.1159 (1.87)**	0.1503 (2.31)**	0.1584 (2.39)***	13108.13 (4.56)***	14150.84 (4.95)***	14053.71 (4.85)***	13571.03 (4.65)***
MIGRATION	0.0248 (0.16)	0.0499 (0.30)	0.1028 (0.56)	0.1904 (1.02)	-4938.25 (-0.68)	2271.79 (0.30)	1944.53 (0.25)	2919.96 (0.36)
ELEC	0.3372 (2.02)**	0.3885 (2.23)**	0.4097 (2.20)**	0.4221 (2.23)**	-2779.96 (-0.35)	-5137.66 (-0.63)	-5726.66 (-0.70)	-7504.53 (-0.90)
HELEV2	-0.0042 (-0.03)	-0.1881 (-1.17)	-0.1784 (-1.04)	-0.1803 (-0.99)	-8206.32 (-1.18)	-15536.18 (-2.18)**	-15403.54 (-2.11)**	-11114.02 (-1.41)*
HELEV3	0.2806 (0.94)	0.2349 (0.77)	0.4257 (1.29)*	0.5306 (1.56)*	-16811.23 (-1.10)	-17389.07 (-1.15)	-15976.48 (-1.04)	-12461.09 (-0.80)
PROTECTED		-0.7958 (-2.51)***	-1.289 (-3.68)***	-1.117 (-2.31)**		-56169.82 (-3.76)***	-52976.78 (-3.46)***	-48332.69 (-2.32)***
MDIST		-0.0499 (-2.09)**	-0.0572 (-2.15)**	-0.0553 (-1.98)**		-1748.22 (-1.62)*	-2113.72 (-1.87)**	-2014.65 (-1.70)**
MDIR		0.1043 (0.32)	-0.0557 (-0.15)	0.0201 (0.05)		10926.43 (0.74)	5752.64 (0.37)	9379.12 (0.59)
EMB			-0.2765 (-1.49)*	-0.0289 (-0.13)			12148.98 (1.47)*	17964.47 (1.79)**
ARELEIF			0.7493 (2.24)**	0.7314 (2.18)**			12978.14 (1.14)	11824.92 (1.04)
AREHABN			0.9098 (5.36)***	0.9161 (5.30)***			-6969.99 (-0.95)	-5460.13 (-0.73)
SURGEHT				-0.2876 (-1.45)*				-10935.65 (-1.29)*
STORMEXP				0.0723 (0.21)				-10575.4 (-0.74)
STORMDIS				0.0126 (1.26)				-4.919 (-0.01)
Log Like.	-222.30	-214.113	-188.25	-186.28	-3464.78	-3454.87	-3399.99	-3398.75
LR Chi2	36.39	52.77	98.05	102.00	106.04	125.85	129.34	131.82
OBS.	444	444	432	432	447	447	435	435

[a] For the Probit model, Z-tests are shown in parentheses beneath coefficient estimates. Significance levels: ***1%, **5%, *10%.

[b] For the Tobit model, t-tests are shown in parentheses beneath coefficient estimates. Significance levels: ***1%, **5%, *10%.

Table A7. *Seemingly bivariate Probit model of self-protection and self-insurance* [a]

Variables	Basic Model		With Mangroves Characteristics		With Public Programs		With Storm Surge Characteristics	
	SPROT	SINSUR	SPROT	SINSUR	SPROT	SINSUR	SPROT	SINSUR
CONSTANT	-13.044 (-1.73)**	-5.295 (-2.03)**	-13.417 (-1.73)**	-5.126 (-1.88)**	-13.232 (-1.59)*	-7.407 (-2.59)***	-10.777 (-1.29)*	-6.446 (-2.15)**
L(DAMAGE)	0.1479 (2.11)**	0.0850 (1.32)*	0.1716 (2.36)***	0.0824 (1.26)	0.1953 (2.55)***	0.1124 (1.54)*	0.1659 (2.15)**	0.1120 (1.51)*
L(PREINC)	1.757 (1.40)*		1.892 (1.47)*		1.868 (1.34)*		1.298 (0.93)	
L(PREINC2)	-0.0706 (-1.34)*		-0.0761 (-1.41)*		-0.0752 (-1.28)*		-0.0514 (-0.88)	
L(POSTINC)		0.5997 (1.18)		0.5944 (1.13)		0.5725 (1.07)		0.5604 (1.04)
L(POSTINC2)		-0.0302 (-1.17)		-0.0300 (-1.12)		-0.0255 (-0.94)		-0.0235 (-0.86)
AREA	0.0006 (2.27)**	0.0005 (1.55)*	0.0006 (1.92)**	0.0004 (1.17)	0.0006 (1.90)**	0.0005 (1.55)*	0.0006 (1.90)**	0.0005 (1.61)*
DCOAST	0.0075 (1.83)**	0.0133 (3.08)***	0.0069 (0.89)	0.0237 (3.07)***	0.0086 (1.00)	0.0326 (3.65)***	0.0136 (1.32)*	0.0251 (2.29)**
AGE	-0.0027 (-0.50)	0.0029 (0.55)	-0.0037 (-0.67)	0.0034 (0.63)	-0.0059 (-1.00)	0.0004 (0.07)	-0.0068 (-1.13)	0.0015 (0.25)
EDUYR	0.0144 (0.64)	-0.0444 (-1.94)**	0.0122 (0.53)	-0.0383 (-1.64)*	0.0089 (0.38)	-0.0439 (-1.75)**	-0.0088 (-0.36)	-0.0441 (-1.76)**
CREDIT	-0.2127 (-1.44)*	0.2229 (1.50)*	-0.2784 (-1.82)**	0.2637 (1.72)**	-0.3500 (-2.18)**	0.1789 (1.08)	-0.3489 (-2.13)**	0.1643 (0.98)
MFRATIO	-0.1262 (-1.29)*	-0.0163 (-0.18)	-0.1009 (-1.03)	-0.0289 (-0.31)	-0.1160 (-1.13)	0.0053 (0.05)	-0.1296 (-1.22)	0.0285 (0.27)
CHILD	-0.1307 (-1.92)**	0.0651 (1.09)	-0.1463 (-2.09)**	0.0779 (1.27)	-0.1724 (-2.31)**	0.1070 (1.65)**	-0.1519 (-1.95)**	0.0988 (1.50)*
ELEC	-0.1023 (-0.58)	0.3626 (2.16)**	-0.0237 (-0.13)	0.3858 (2.20)**	0.0282 (0.15)	0.4318 (2.29)**	0.0944 (0.49)	0.4063 (2.14)**
PHONE	-0.2920 (-1.83)**	-0.1279 (-0.81)	-0.3075 (-1.90)**	-0.1686 (-1.06)	-0.3701 (-2.19)**	-0.3246 (-1.90)**	-0.3217 (-1.80)**	-0.3036 (-1.74)**
PROTECTED			0.1231 (0.39)	-0.6596 (-2.16)**	0.0526 (0.16)	-0.9193 (-2.76)***	-0.9809 (-1.99)**	-0.3422 (-0.70)
MDIST			-0.0516 (-2.12)**	-0.0415 (-1.76)**	-0.0424 (-1.67)**	-0.0378 (-1.48)*	-0.0638 (-2.38)***	-0.0284 (-1.05)
MDIR			-0.5943 (-1.82)**	-0.0725 (-0.22)	-0.4897 (-1.41)*	-0.1886 (-0.53)	-0.6559 (-1.85)**	-0.0895 (-0.24)
EMB					-0.1584 (-0.79)	-0.1362 (-0.71)	-0.2225 (-0.86)	0.0925 (0.37)
ARELEIF					-0.3935 (-1.57)*	1.179 (2.58)***	-0.3161 (-1.20)	1.163 (2.52)***
AREHABN					0.3546 (2.03)**	0.9375 (5.19)***	0.1825 (0.98)	1.0021 (5.41)***
SURGEHT							0.3665 (1.85)**	-0.3435 (-1.78)**
STORMEXP							-0.7162 (-1.91)**	0.2576 (0.75)
STORMDIS							0.0386 (3.61)***	-0.0044 (-0.43)
LOG LIKE. (OBS)	-401.978 (402)		-392.845 (402)		-355.536 (392)		-345.119 (392)	
Wald χ^2 (df)	52.89 (26)		67.86 (32)		102.95(38)		116.71 (44)	
LR test $(\rho = 0)$	$\chi^2(1)$ = 4.607**		$\chi^2(1)$ =4.128**		$\chi^2(1)$ =2.273*		$\chi^2(1)$ = 2.971*	

[a] Dependent variables are the probability of households participating jointly in self-protection and self-insurance activities. Z-tests are shown in parentheses beneath coefficient estimates. Significance levels: ***1%, **5%, *10%.