Incorporating Ecosystem Services of a Natural Capital to Perform Relative Valuation of Household's Storm-inflicted Health Outcomes in Bangladesh Coastal Areas

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Background

The increasing frequency of storms pose significant health risks in coastal areas with high population density and abject poverty (IPCC, 2014; The World Bank, 2013).

Government support to reduce health risks of such vulnerable coastal population usually come in the form of publicly constructed protective barriers or embankments and public disaster relief and rehabilitation programs (Board, 2014; Few et al. 2013). Besides public programs, the presence of a natural barrier, such as a mangrove forest, can also play possible storm protection role with respect to saving lives (Barbier, 2013).

However, a poor coastal household's decision to engage in private defensive strategies to insulate themselves against storm-inflicted health risks might also be influenced by their expectation of receiving public protection programs and their location relative to the coast and the mangroves.

The purpose of our paper is to model and estimate a poor coastal household's valuation of reducing storm-inflicted health through private defensive activities, given the presence of public programs and a natural barrier.

Research Objective

- To propose a theoretical model under an endogenous risk framework that allows estimation of a poor coastal household's valuation of reducing its storm-inflicted adverse health "outcomes" or "impacts".
- To estimate the relative value of better storm-inflicted health outcomes for a household under optimal self-protection and self-insurance spending with improved access to public programs and a natural barrier.

Willingness-to-pay Measures

We derive the household's marginal willingness-to-pay (WTP) measure for risk reductions based on positive changes from three different sources:

(1) improvement in household's access to storm protection services of mangroves, in terms of increase in area of the forest or decrease in the distance between the mangrove forest and the household;

(2) improvement in household's access to *ex-ante* public storm protection programs, which can be achieved if the government allocate more resources on embankments or dams; and

(3) improvement in household's access to public post-disaster relief and rehabilitation programs, through guaranteed access or more availability of such public programs.

Background Framework

Reducing Storm-inflicted Health Outcomes

- Public Protection Programs
  - Publicly constructed embankment
  - Post-disaster relief and rehabilitation programs
- Natural Barrier
  - Mangrove forest
- Private Storm Protection Behavior
  - Self-protection (a form of prevention)
  - Self-insurance (a form of adaptation)

Methodology

Introduce a **theoretical model** combining the household health production function with an endogenous risk framework.

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Household choose the level of private storm protection actions:

(a) To reduce the likelihood that a household will face adverse health impacts from a major storm

(b) To reduce the adverse impacts, or severity, of any such health outcomes if they occur.

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Perform **an empirical analysis** on Southwest coast of Bangladesh affected by a major storm

Theoretical Framework

A representative low-income coastal household's maximization problem,

$$\underset{Z^k, T^t}{Max}\, EU = \sum_{n=1}^{N} \left[Q^n\left(Z^k; G, M, C\right) \cdot U^n\left(X, H^n\left(T^t; R\right); \psi\right) \right]$$

subject to,

$$I = X + P^{k^*} \cdot Z^k + P^{t^*} \cdot T^t + L^n\left(T^t, R\right)$$

In our paper, we first solved for household's *willingness-to-pay* (WTP) measures using our endogenous risk framework model. Since the initial WTPs include unobservable marginal utility terms, which complicate data collection and empirical estimation, we performed further mathematical computations. By expressing the initial WTPs in a matrix form and then, applying unique solution conditions under linear algebra, we derived WTPs as a function of prices and technological parameters only, i.e., our final WTPs are independent of preferences (or the marginal utility terms).

WTPs for Public Protection programs: $-\dfrac{\partial I}{\partial G} = \Theta_G \cdot \left[\Theta_Z^{-1}\right]' \cdot P_Z^k$

$$-\frac{\partial I}{\partial R} = \Theta_R \cdot \left[\Theta_T^{-1}\right]' \cdot P_T^t$$

WTP for mangroves: $-\dfrac{\partial I}{\partial M} = \Theta_M \cdot \left[\Theta_Z^{-1}\right]' \cdot P_Z^k$

Empirical Analysis Framework

For our empirical analysis framework, our reduced form linear representation of the WTPs are derived as,

$$Q^{n^*} = \delta_1 + \delta_2' \cdot \left(P_Z^k \cdot Z^k\right) + \delta_3 \cdot M + \delta_4 \cdot G + \delta_5 \cdot C + \delta_6 \cdot \psi + \varepsilon$$

$$L^{n^*} = \beta_1 + \beta_2' \cdot \left(P_T^t \cdot T^t\right) + \beta_3 \cdot \psi + \eta$$

where,

$\eta \equiv \varepsilon\text{-}B \cdot e$ is the heteroscadastic error term with $\varepsilon(0,1)$, $e \sim (\mu, 1)$,

and, $B = \varphi_1 + \varphi_2 \cdot R$

$$H^{n^*} = \gamma_1 + \gamma_2' \cdot \left(P_T^t \cdot T^t\right) + \gamma_3 \cdot R + \gamma_4 \cdot \psi + \omega$$

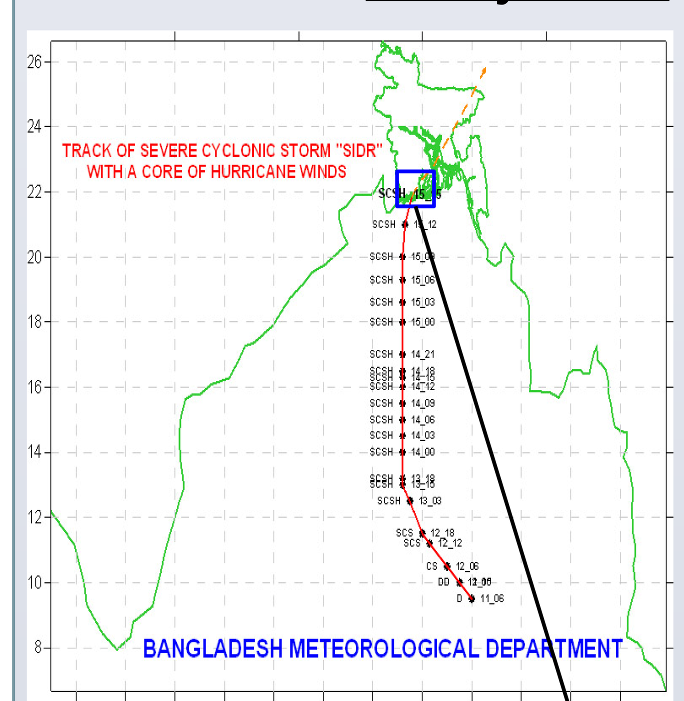
With identification requirements met, measures of the WTPs for an improvement in health can be derived from these estimates,

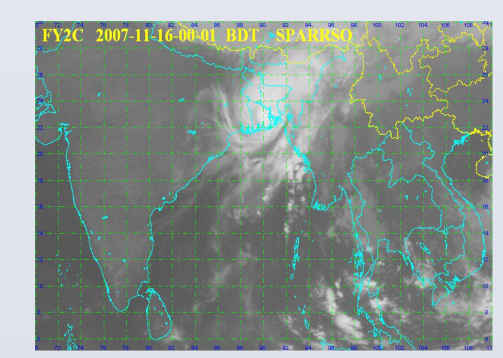
$$-\frac{\partial I}{\partial G} = \Theta_G \cdot \left[\Theta_Z^{-1}\right]' \cdot P_z^k = \delta_4 \cdot \delta_2 \cdot P_z^k$$

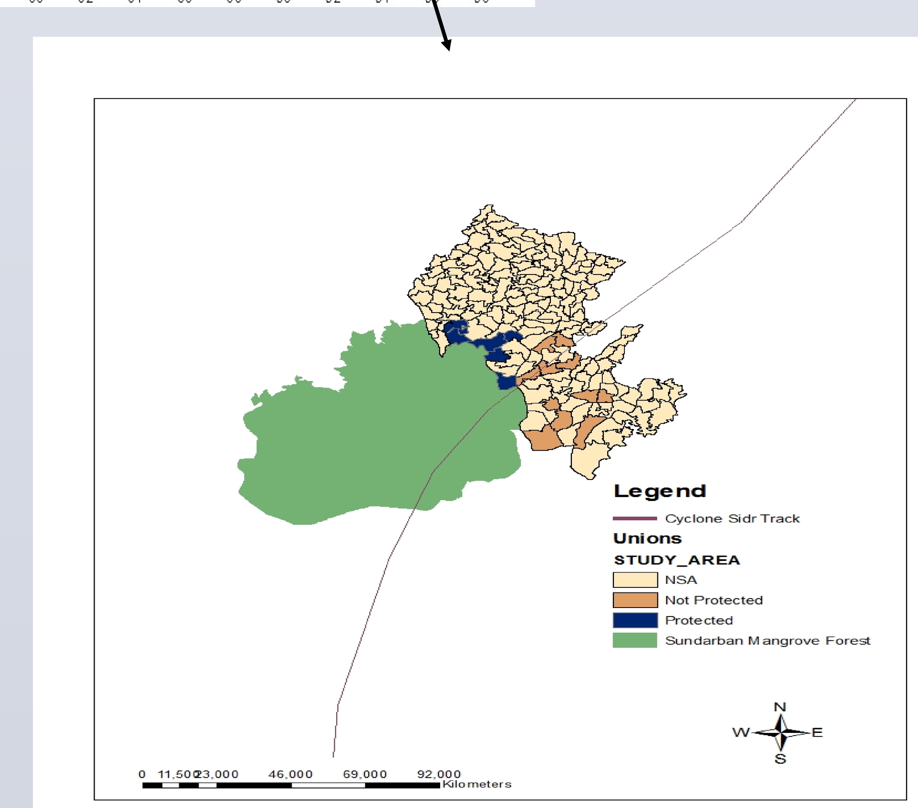
$$-\frac{\partial I}{\partial R} = \Theta_R \cdot \left[\Theta_T^{-1}\right]' \cdot P_T^t = \left[\varphi_2 \quad \varphi_3\right] \cdot \begin{bmatrix} \beta_2 \\ \gamma_2 \end{bmatrix} \cdot P_T^t$$

$$-\frac{\partial I}{\partial M} = \Theta_M \cdot \left[\Theta_Z^{-1}\right]' \cdot P_z^k = \delta_3 \cdot \delta_2 \cdot P_z^k$$

Study Area



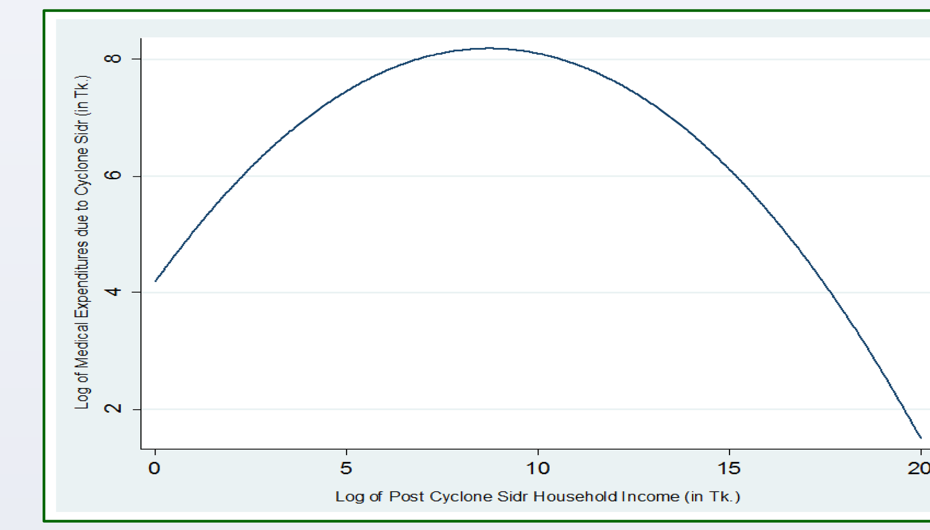




Sl. No	Area type	No. of Households
1.	Protected areas (P)	220
2.	Not protected areas (NP)	280
	Grand total	500

Key Empirical Study Findings

The following figure shows inverted U-shaped Kuznets Curve between Medical Expenditures and Household Income



To reduce damaging health outcomes from a major storm, results reveal that the households are *willing-to-pay (WTP)* the highest amount for greater storm protection from mangroves followed by embankments and disaster relief programs.

Willingness-to-pay (WTP) for storm-inflicted health risks as a result of …	WTP expression in the model	MWTP per household	Total WTP for the entire study area (in million)
an improvement in households' access to storm protection role of mangroves	$-\frac{\partial I}{\partial M}$	Taka 3372.23 or US $ 48.87	Taka 12443.38 or US $ 180.33 million
an improvement in households' access to publicly constructed embankments	$-\frac{\partial I}{\partial G}$	Taka 2520.88 or US $ 36	Taka 9302.05 or US $ 132.84 million
an improvement in households' access to public post-disaster relief and rehabilitation programs	$-\frac{\partial I}{\partial R}$	Taka 249.72 or US $ 3.62	Taka 921.47 or US $ 13.35 million

Policy Implications

- Considering our WTP results, a collaborative tree plantation program along the Bangladesh coast should be encouraged. This could be achieved by involving the local stakeholders and identifying trees besides coastal mangroves to play a significant storm protection role in reducing storm-inflicted health risks.
- Following our other study findings, government can earmark more funds for public programs of households with more elderly, female, and child members.
- Given the uncertainties, it is justifiable for the government to encourage more collective and individual participation in private storm protection actions.

References

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