# A Macroeconomic Model For Damage Evaluation of Sea Level Rise for Developing Countries -The Revised Model and It's Application to Bangladesh Economy-

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## 1.INTRODUCTION

The impact of Sea Level Rise (SLR) due to global warming on facing sea is a great concern. We have already proposed a macroeconomic model in Ueda, Morisugi and Syeda Asma (1996) for analyzing the impact of SLR on developing countries. This paper reports the revised model and it's application to Bangladesh economy

## 2.MODEL

The model, based on Harris-Todaros model. The two regions in the country are the rural area and the urban area. The urban area specializes in production of manufactured good, while crops, fisheries, forest sectors are located in urban area. Other production sectors are assumed not to be affected by SLR. The free mobility of people is assumed in the model.

### 2.1. INDIVIDUAL'S BEHAVIOR

We introduce the indirect utility function. The utility level is expressed to be dependent on the individual's location:

$V_m = V(W_m + Y, P_c)$ for a labor in the manufacture (1)

$V_r = V(W_r + Y, P_c)$ for a labor in the rural area. (2)

$V_{ue} = kV_m$ for an individual unemployed person in urban area (3)

*m:* Manufacturing sector, *r:* Rural area, *ue*: Unemployed situation, *p* Price variables, *Y:* Dividend income, *W:* Wage income, *K*: a given coefficient

The expected utility level in the urban area is,

$$E(V_u) = \frac{N_m}{N_u} V_m + \frac{N_{ue}}{N_u} \overline{V}_{ue}. \quad (4)$$

$N_u$ :Urban population, $N_m$ :Manufacturing labors,

$N_{ue}$ :Unemployed population

Assuming that location choice between the urban and rural areas is expressed by the Logit Model, we have the urban population as,

$$N_u = N_T \frac{\exp\{\theta E(V_u)\}}{\exp\{\theta E(V_u)\} + \exp(\theta V_r)} \quad (5)$$

$\theta$: Logit parameter, $N_T$ :Population in the country unemployed people in the urban area, $N_{ue} = N_u - N_m$ (6)

### 2.2 PRODUCTION SECTOR

Each industrial sector chooses the level of output and input so as to maximize the profit under the condition that the input levels of the industry-specific factor or the capital are fixed. This is formulated sector by sector in what follows.

**Manufacturing**

The manufacturing sector controls the level labor input and uses the fixed amount of capital which is specific to manufacturing production and is exogenous in the model. The price of manufactured product is an exogenous The manufacturing sector is formulated :

$$\pi_m = \max_{X_m, N_m} X_m - W_m N_m \quad (7.a)$$

$$s.t. X_m = F_m(N_m) \quad (7.b)$$

where $m$ labels the manufacturing sector. $X$ : output, $N$ : labor input , $W$ : wage. L: land input, R: land rent, $F(N)$ is the production function. The FOCs yield to the input demand function, the product supply function and the profit function respectively :

$$N_m = N_m^d(W_m) \quad (8.a), \qquad X_m = X_m^s(W_m) \quad (8.b)$$

$$\pi_m = X_m^d(W_m) - W_m N_m^d(W_m) \quad (8.c)$$

**Crop**

The crop sector controls the level of labor and land inputs and uses the capital which are specific to crops production. The capital input as an industry-specific factor is exogenous in the model so that it can drop out from the production function. The crop's price is endogenous. These assumptions are formalized :

$$\pi_c = \max_{X_c, N_c} P_c X_c - W_c N_c - R_c L_c \quad (9.a)$$

$$s.t. X_c = F_c(N_c, L_c) \quad (9.b)$$

where $c$ is the crops sector. The FOCs yield to the input demand functions, the product supply function and the profit function:

$$N_c = N_c^d(W_c, R_c, P_c) \quad (10.a), \qquad L_c = L_c^d(W_c, R_c, P_c) \quad (10.b)$$

$$X_c = X_c^s(W_c, R_c, P_c) \quad (10.c)$$

$$\pi_c = P_c X_c^s(W_c, R_c, P_c) - W_c N_c^d(W_c, R_c, P_c) - R_c L_c^d(W_c, R_c, P_c) \quad (10.d)$$

**Forestry**

The forestry sector controls the level of labor input and uses the land which is specific to forest sector. The land input appears in the production function explicitly but is not controlled by the forest industry itself. The product price is exogenous These assumptions are formulated:

$$\pi_g (= R_g L_g) = \max_{X_g, N_g} X_g - W_g N_g \quad (11.a)$$

$$s.t. X_g = F_g(N_g, L_g) \quad (11.b)$$

where $g$ labels the forest sector. The FOCs yield to the labor input demand function, the product supply function, and the profit function respectively:

$$N_g = N_g^d(W_g, L_g) \quad (12.a), \qquad X_g = X_g^s(W_g, L_g) \quad (12.b)$$

$$\pi_g = X_g^d(W_g, L_g) - W_g N_g^d(W_g, L_g) \quad (12.c)$$

**Fishery**

The fishery sector controls the level of labor inputs and uses the capital which is specific to fishery sector. The product price is exogenous The assumptions are formulated:

$$\pi_f = \max_{X_f, N_f} X_f - W_f N_f \quad (13.a)$$

$$s.t. X_f = F_f(N_f) \quad (13.b)$$

where $f$ labels the fishery sector. The FOCs yield to the labor demand function, the product supply function and the profit function respectively:

$$N_f = N_f^d(W_f) \quad (14.a), \qquad X_f = X_f^s(W_f) \quad (14.b)$$

$$\pi_f = X_f^s(W_f) - W_f N_f^d(W_f) \quad (14.c)$$

### 2.3. DIVIDEND SCHEME

The capital owners and landowners are to receive their profit or land revenue from each related sectors. To define the benefit in terms of labor's income, we introduce the dividend scheme so that such types of owner's income should be uniformly distributed to all individuals as a sort of dividend income defined as,

$$Y = \frac{\pi_m + \pi_c + R_c L_c + \pi_g + \pi_f}{N_T} \quad (15)$$

where $Y$ is the per capita dividend income.

### 2.4. MARKET EQUILIBRIUM / DISEQUILIBRIUM

We should assume that the labor market for manufacturing is in disequilibrium. The disequilibrium results from the fixed wage rate in manufacturing:

$$\frac{\partial F_m}{\partial N_m} = \overline{W} \quad (16)$$

where $\overline{W}$ is the fixed wage rate of the manufacturing sector.

In contrast, we assume that the labor market in the rural area are equilibrium.

$$W_r = W_c = W_g = W_f \quad (17)$$

where $W_r$: the wage common for sectors in the rural area.

We have already assumed that some of price variables in the model are exogenous because their markets are internationally open and others are endogenous because their markets are domestic ones. According to the assumptions of price variables, we should define market equilibrium conditions so as to determine the endogenous prices. The conditions are formalized as,

for the labor market in the rural area,

$$N_c^d(W_r, R_c, P_c) + N_g^d(W_r) + N_f^d(W_r) = N_r \quad (18.a)$$

for the land market for the crop sector,

$$L_c^d(W_r, R_c, P_c) = \overline{L}_c \quad (18.b)$$

and for the crop market,

$$\begin{aligned} & N_m x_m{}^d(Y + \overline{W}, P_c) + N_c x_c{}^d(Y + W_c, P_c) \\ & + N_g x_g{}^d(Y + W_g, P_c) + N_f x_f{}^d(Y + W_f, P_c) \\ & + N_{ue} x_{ue}{}^d(Y + \overline{W}, P_c) + N_o x_o{}^d = X_c^s(W_r, R_c, P_c) \end{aligned} \quad (18.c)$$

where $x_i{}^d(\cdot)$ is the individual demand function for crop and $i$ labels the sector for $i = m, c, g, f, ue, o$. $N_o$: the population in remaining sectors other than ones taken into account in the model. $\overline{L}_c$: fixed land area specified to the crop sector. Focusing only on the endogenous variables $P_c, W_r$ and $R_c$ and fixing other variables, we can suppose that the system of equations [(18.a), (18.b) and (18.c) ] can give a solution.

### 3. DAMAGE DEFINITION

We define the social welfare for the modeled economy as the log-sum function of the Logit Model, which can indicate the utility level of a representative individual in the economy:

$$SW = N_T\left(\frac{1}{\theta}\right)\ln\{\exp\{\theta E(V_u)\} + \exp(\theta V_r)\} \quad (19)$$

Due to the SLR the available land for crops and forestry will decrease. The impact of SLR change the individual utility level and therefore the social welfare. we introduce the concept of Equivalent Variation (EV). Here we define two variants of EV:

1) Location Contingent EV (LCEV) denoted as $LCEV_m$ and $LCEV_r$ such that for the manufacturing labor,

$$V_m(P_c^A, \overline{W}^A + Y^A + LCEV_m) = V_m^B \quad (20.a)$$

and for the rural labor, $V_r(P_c^A, W_r{}^A + Y^A + LCEV_r) = V_r^B$ (20.b)

where superscript A: the Case without SLR, B: the case with SLR

2) Non Contingent EV (NCEV) noted as $NCEV$ such that

$$SW\{V_m(P_c^A, \overline{W}^A + Y^A + NCEV), V_r(P_c^A, W_r{}^A + Y^A + NCEV)\} = SW^B \quad (21)$$

The LCEVs are different between the rural and the urban areas, but the NCEV is uniform in country. Finely we define the social net damage

with the LCEV, $SND = N_r LCEV_r + N_m LCEV_m$ (22.a)

and with the NCEV, $SND = (N_r + N_m)EV$ (22.b)

### 4. CASE STUDY APPLICATION OF THE MODEL

Some authors have estimated that the maximum of SLR along the Bay of Bengal coast is 45 cm or 100cm, We try to estimate the damage of Bangladesh for these two cases in the year of max. SLR by the model. Then we estimate the damage in each year until the year of max. SLR by linear interpolation, because the SLR would gradually advance year by year. In the case of 45cm (100cm) SLR, the damage is 358 million US $/year (548 million US $/year). The damage is equivalent to 2.1% (3.?%) of the total GDP and to 4.4% (7.1%) of the Value Added from 4 sectors in the model. Considering that the growth rate of GDP in Bangladesh is at most 1.6%, we can conclude that the damage of the SLR will be very serious. The damage year by year is illustrated in Figure 1.

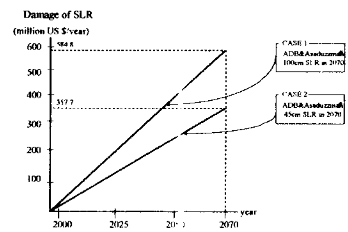


**Figure 1 Damage of SLR year by year**

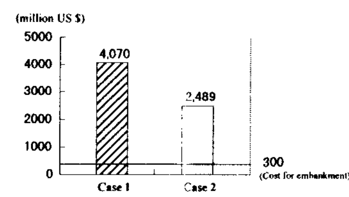


**Figure 2 Net Present Value of Damage**

With indentations in the land mass made the coast line 2000km length. To build embankments for the 2000km coastline the coast is 300 million US$(Huq and Ali 1990). We compare the cost with the damage in terms of Net Present Value for the period from the base year to the year of the max. SLR and with the social discount rate of 4%, as illustrated in Fig 2. The damage is larger than the embankments cost in any cases.

### 5.CONCLUSION

Firstly in this study we have shown the revised model Secondly the model has been applied in the case of Bangladesh to evaluate the damage of the SLR. The damage in any cases exceeds the embankment cost. So the prevention project should be implemented in the coast of Bay of Bangle.

### References

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