A Macroeconomic Model for Damage Evaluation of Sea Level Rise for Developing Countries

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1. INTRODUCTION

The impact of sea level rise due to global warming on developing countries facing sea is a great concern. For example recent estimates indicate about 11% and 21% area of Bangladesh will submerge if sea level rise 45cm and 100 cm respectively along the Bangladesh cost. By modifying the Harris-Todaro's model this paper proposes a macroeconomic model for analyzing the impact of sea level rise on developing countries.

2. MODEL

The model, based on the Harris -Todaro's model, describes a developing country including rural-urban migration and unemployment.(for detail, see J.R.Harris and M.P.Todaro (1970)). 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 the rural area. The free mobility of people is assumed in the model.

2.1 PRODUCTION

Each industrial sector chooses the level of output and input so as to maximize the profit formulated as follows.

$$\pi_i = \max_{X_i, N_i, L_i, K_i} P_i X_i - W_i N_i - R_i L_i - H_i K_i \tag{1.a}$$

$$s.t. \quad X_i = F_i(N_i, L_i, K_i) \tag{1.b}$$

where $i=m$:manufacture, $i=c$:crops , $i=f$:fishery , $i=g$:forest,

Xi: output, Ni: labor input, Li: land input,

Ki: capital input, Pi: product price, Wi :wage,

R_i: land price, and H_i: capital rent.

In manufacture and fisheries, land input drops out from the production function and capital is ignored in forest. By solving the above problems we can get the F.O.C. and input demand functions as,

$$\frac{\partial \pi}{\partial N_i} = P\frac{\partial F}{\partial N_i} = \overline{W_i} \quad (2.a), \qquad \frac{\partial \pi}{\partial L_i} = P\frac{\partial F}{\partial L_i} = R_i \quad (2.b), \qquad \frac{\partial \pi}{\partial K_i} = P\frac{\partial F}{\partial K_i} = H_i \quad (2.c),$$

and

$$N_i = N_i^d(W_i, R_i, H_i, P_i) \tag{3.a}$$

$$L_i = L_i^d(W_i, R_i, H_i, P_i) \tag{3.b}$$

$$K_i = K_i^d(W_i, R_i, H_i, P_i) \tag{3.c}$$

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2.2 MARKET EQUILIBRIUM / DISEQUILIBRIUM

We assume that demand and supply in all markets in the rural area are in equilibrium, but in the urban area the labor market for manufacture is in disequilibrium. We assume that some price variables in the model are exogenous because their markets are internationally open, and wage in manufacture always remains at the exogenous minimum level ($\overline{W}$). Prices are classified as shown in the table.

Table 1 Classification of price variables

		Product price	Wage	Land rent	Capital rent
Rural	Crops	P_c :endogenous	W_r :endogenous	R_c :endogenous	H :exogenous
	Forestry	P_g: exogenous		R_g :endogenous	
	Fisheries	P_f :exogenous			
Urban	Manufacture	P_m :exogenous	$\overline{W}$:exogenous		

According to these assumptions we can formulate market equilibrium as,

$$N_c^d(W_r, R_c, H, P_c) + N_g^d(W_r, R_g, P_g) + N_f^d(W_r, H, P_f) = N_r \tag{4}$$

$$L_c^d(W_r, R_c, H, P_c) = \overline{L}_c \tag{5}$$

$$L_g^d(W_r, R_g, H, P_g) = \overline{L}_g \tag{6}$$

$$N_T F^d(P_c) = F_c(W_r, R_c, H, P_c) \tag{7}$$

Here are 4 equations and 4 unknown variables W_r, R_c, P_c, R_g. The disequilibrium in the labor market in the urban area is expressed as,

$$P_m \frac{\partial F_m}{\partial N_m} = \overline{W} \tag{8}$$

2. 3 MIGRATION BEHAVIOR

We introduce the indirect utility function as,

$$V_m = V(\overline{W}, P_c, P_f, P_g) \text{ for labors in the manufacture} \tag{9}$$

$$V_r = V(W_r, P_c, P_f, P_g) \text{ for labors in the rural area.} \tag{10}$$

The expected utility level in the urban area is,

$$E(V_u) = \frac{N_m}{N_u} V_m + \frac{N_{ue}}{N_u} \overline{V}_{ue} \tag{11}$$

Where, $\overline{V}_{ue}$: exogenous level of utility for unemployed people in the urban area

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

$$N_u = N_T \frac{\exp\{\theta E(V_u)\}}{\exp\{\theta E(V_u)\} + \exp(\theta V_u)} \tag{12}$$

where, θ : Logit parameter

Since all urban people can not be employed by manufacture, there exist unemployed people in the urban area,

$$N_{ue} = N_u - N_m \tag{13}$$

The set of equations from (4) to (8) and (12) and (13) should be solved simultaneously for determining the states of macroeconomy of the developing country.

3. IMPACT OF SEA LEVEL RISE

Although the model is applicable for any developing country, it has been built in the context of Bangladesh. One of ADB reports says that about 11% (21%) of the national land in Bangladesh is likely to be under the sea water if 45cm (100cm) relative rise in sea level occurs until 2070.

Therefore, in the model, the sea level rise is expressed as the decrease of the available land for corps and forest like,

$$\overline{L}_c \rightarrow \overline{L}_c + d\overline{L}_c \quad (d\overline{L}_c < 0) \tag{14.a}$$

$$\overline{L}_g \rightarrow \overline{L}_g + d\overline{L}_g \quad (d\overline{L}_g < 0). \tag{14.b}$$

The changes in the available land should be propagated into markets, migration, and therefore utility level. The flow chart for the propagation of the impact is illustrated in Figure 1.

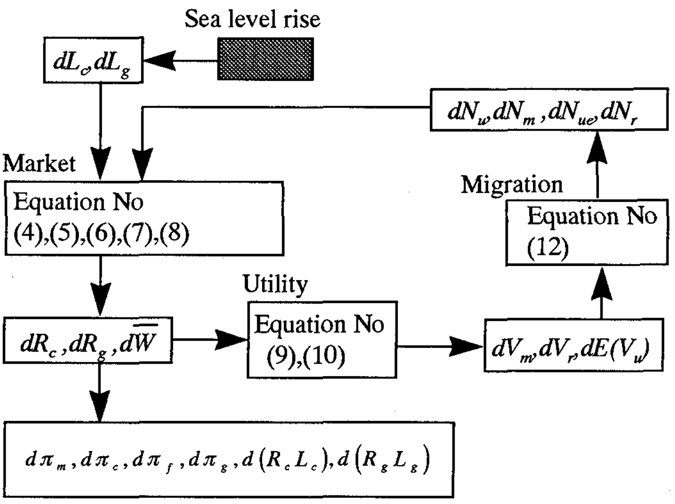

Figure 1 Flow chart of impact propagation

The change of each endogenous variable can be followed through comparative statics. The social damage should be measured in the inclusive utility function based on individual utility, profit functions defined for industrial sectors, and land profits. Since we introduce the Logit Model, the inclusive utility function to be specified consistently with it is written as,

$$SW = N_T\left(\frac{1}{\theta}\right).\ln\left\{\exp\{\theta E(V_u)\} + \exp(\theta V_r)\right\} \tag{15}$$

and profit functions as,

$$\pi_i, R_i L_i \qquad for \quad i = m, c, f, g$$

4.DAMAGE DEFINITION

Due to the sea level rise the indirect utility (9) and (10) might be change. From the idea of utility changes between before sea level rise and after sea level rise we introduce the equivalent variation (EV). In our model we have two types of EV,

1) Location contingent (EV)

$$V_m\left(P_c^B, P_f^B, P_g^B, \overline{W}^B + EV_m\right) = V_m^A; \quad V_r\left(P_c^B, P_f^B, P_g^B, W_r^B + EV_r\right) = V_r^A \tag{16}$$

2) Non contingent (EV)

$$SW\left\{V_m\left(P_c^B, P_f^B, P_g^B, \overline{W}^B + EV\right), V_r\left(P_c^B, P_f^B, P_g^B, W_r^B + EV\right)\right\} = SW^A \tag{17}$$

This model finely shows the social net damage (SND) by using land value change and equivalent variation(EV).
Social net damage defined with location contingent EV is,

$$SND = N_r EV_r + N_m EV_m + N_{ue}(0) + \Delta(R_c L_c) + \Delta(R_g L_g) \tag{18}$$

Social net damage with non contingent EV is,

$$SND = (N_r + N_m)EV + \Delta(R_c L_c) + \Delta(R_g L_g) \tag{19}$$

5. CONCLUSION

Firstly in this study we have built up a macroeconomic model which considers migration and unemployment. This paper investigates the impacts of sea level rise on socio-economy of developing countries. Although it has been built up in the context of Bangladesh, it is applicable for any developing countries. By introducing the indirect utility functions (9) and (10) and expected utility level (12), the model is applicable to the analysis of location choice between urban area and rural area. We also mentioned damage definition and finely we show the social net damage. Secondly we are now preparing for the application of this model in the case of Bangladesh, and developing the monetary measure for the damage and for the benefit of prevention project.

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