

DR<sup>2</sup>AD Model (Ver1.4)

Handbook

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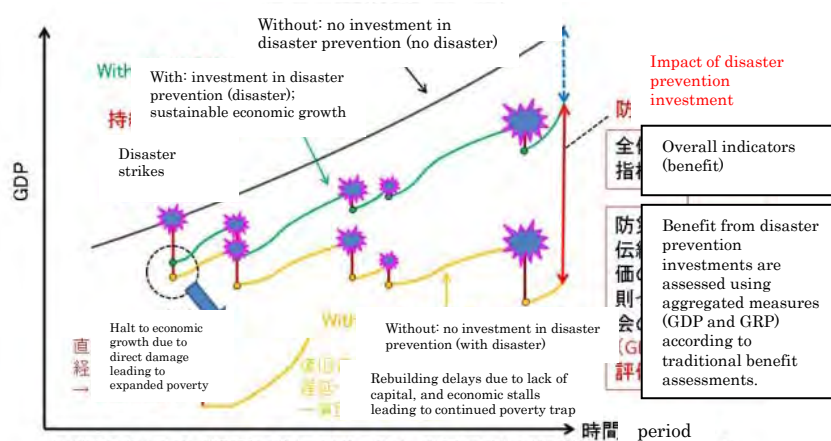
# Part 1 Structure of the DR<sup>2</sup>AD Model

## 1 Outline of the DR<sup>2</sup>AD Model

### (1) Outline of the DR<sup>2</sup>AD Model

The DR<sup>2</sup>AD Model (Disaster Risk Reduction investment Accounts for Development) is a dynamic, stochastic, general equilibrium model for quantitatively evaluating the effects of DRR (Disaster Risk reduction) countermeasure investments on the economy, with an objective of reduction of poverty, primarily in developing countries.

For economic agents that recognize disaster risks, simulations are carried out both with and without DRR, or with varying scales of DRR, and the effects of DRR are evaluated by comparing the prediction and actual results in terms of economic growth and reduction of poverty.



\* Larger poverty stratum, wider gaps, and the expansion or continuation of those unable to escape poverty due to disasters.

Figure 1. Evaluation of economic growth in the presence and absence of DRR.

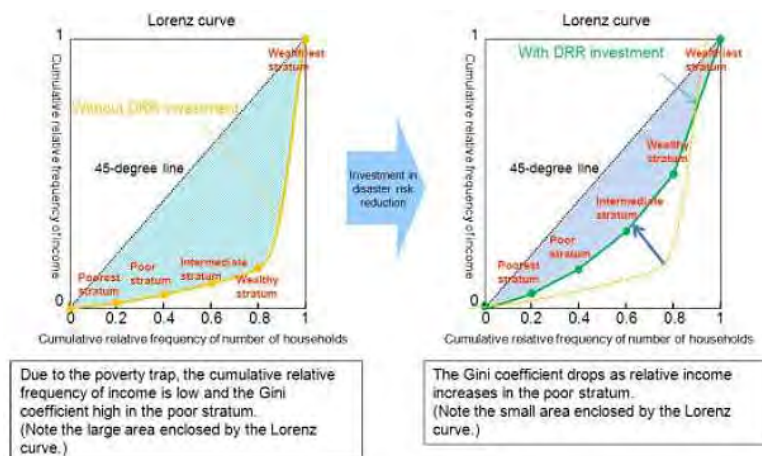


Figure 2. Evaluation of economic and social disparity with and without DRR.



## (2) Background of the Development of the DR<sup>2</sup>AD Model

The Hyogo Framework for Action, adopted by the United Nations World Conference on Disaster Reduction in 2005, is expected to produce positive results in “the construction of flexible countries and regions gearing toward the reduction of human suffering and loss of social and economic resources due to disasters” by 2015. Both the incorporation of DRR into sustainable development and the establishment and capacity building within DRR systems are positioned as a strategic goal. This incorporation can be seen in the establishment of the millennium development goals (MDGs) for developing countries, and through international efforts, such as the United Nations Conference on Environment and Development in 1992 and the “Johannesburg Plan of Implementation” (which was adopted in 2002 on the basis of the theme of sustainable development and included the need to develop DRR). DRR has been gaining recognition not only within the DRR field itself but also in the broader international community as a major factor in the alleviation of poverty.

Economic development, stability, and poverty reduction initiatives within developing countries can be negatively affected by natural disasters. The poor, in particular, are susceptible to disasters, as they do not enjoy protection through insurance or social security systems. According to the Global Assessment Report on Disaster Risk Reduction in 2009, it is stipulated that the impact of disasters frequently leads to a slump in income and consumption over a long period of time and also adversely affects welfare and the educational environment, leading to a further delay in poverty reduction. This situation occurs because, although the recognition of the need for DRR is growing, an appropriate method for evaluating the effects of DRR countermeasures has yet to be established. In regard to the evaluation of the current state of DRR countermeasures, even in the United Nations Development Programme (UNDP) there is no detailed description beyond the fact that “each time one dollar is contributed in advance to reduce the degree of damage, seven dollars’ worth of economic loss can be avoided in the event of a disaster.” It can, therefore, be said that a method has yet to be established to clarify the degree of contribution from the standards of advanced DRR investments at the national level, or the effects that DRR have on economic growth and poverty alleviation.

From the above, it is apparent that developing a method for measuring the effects of advanced DRR in developing countries that can lead to the implementation of advanced DRR countermeasures is vital for their economic growth and poverty reduction.

The “**DR<sup>2</sup>AD Model**” was developed through JICA (Japan International Cooperation Agency) as a model capable of evaluating the effects that advanced DRR has on economic growth and the reduction of poverty in developing countries.

## 2 Basic Structure of the DR<sup>2</sup>AD Model

The DR<sup>2</sup>AD model is developed to properly demonstrate how DRR contributes to economic growth and poverty alleviation in developing countries, This model is based on a dynamic stochastic general equilibrium model. The basic structure of the model is as shown follows.

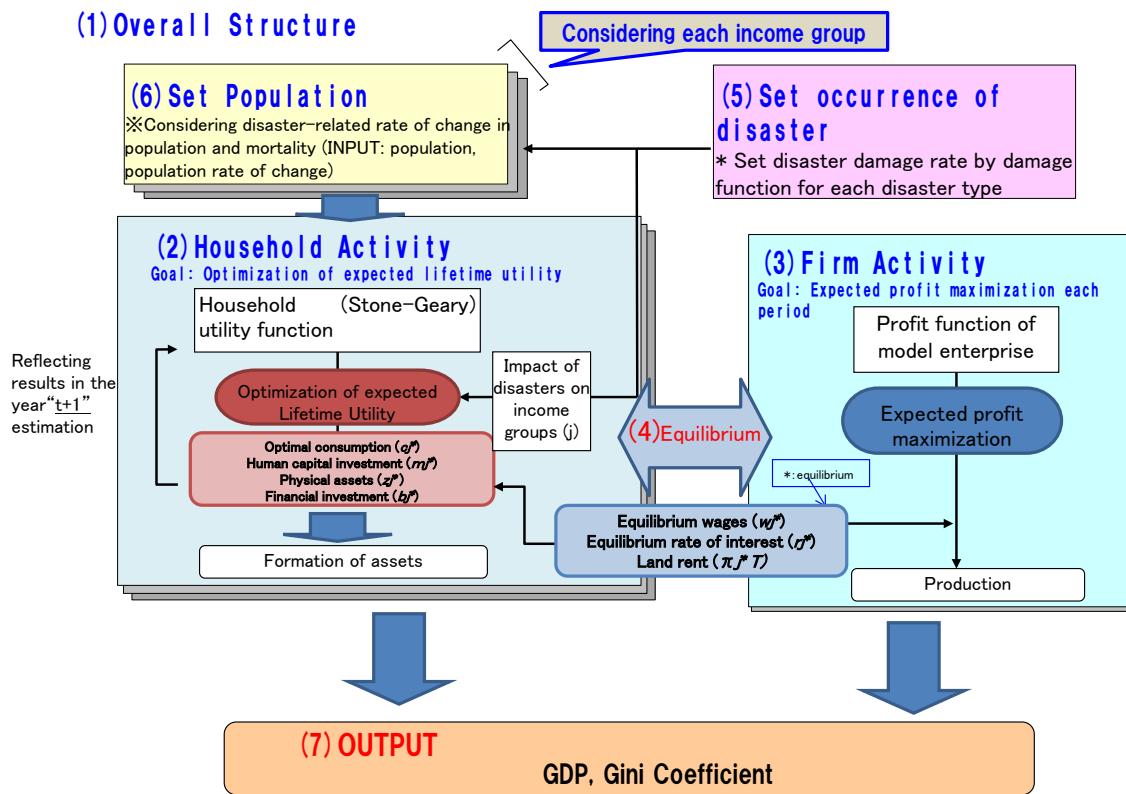


Figure 3. Model Structure

The characteristics of this model are listed below.

### (1) Overall Structure

- The effects of DRR are evaluated in terms of economic growth and poverty reduction.
- The elements of disasters, poverty, and education are incorporated, as they are closely related to economic growth.
- The model consists of two economic entities: households and firms. It does not consider government actions, trade, or aid from other governments.
- The model has been designed for developing countries in particular; households are classified into income groups, and the behavior of each group is focused on separately in order to accurately evaluate poverty reduction.

- For each income group, there is a representative firm.
- The economy is closed for each income group, and within each group, households and firms achieve market equilibrium.

## (2) Household Behavior

- Household behavior is assumed to be completely rational, including the awareness of the risk of disaster. In other words, households consume and invest in physical assets, human capital, and saving activities based on the risk of disaster to maximize expected lifetime utility.
- Households receive income from wages, capital rent, and land rent.
- Households are classified into groups based on their income levels and household behavior is considered to be level specific.
- Household behavior is based on a representative consumer in each group.
- In the utility function, when spending is near the minimum amount of consumption required for survival, asset formation is postponed, making it possible to escape the poverty trap.
- To show that improvement in human capital leads to improvement in productivity as well as reduction of poverty, human capital is provided. Based on the premise that education is provided for the growth of human capital, by setting indicators related to education, such as the number of schooling years, as a proxy for human capital, it is possible to reproduce a situation where the improvement of human capital increases overall production efficiency.
- It is assumed that the amount of labor payment = human capital  $\times$  wage rate  $\times$  the amount of labor, its potential is evaluated by multiplying human capital accumulated by education investment, and the impact of both natural depreciation and temporal decrease of human capital by disaster is considered at each income level.
- It is assumed that the total labor force equals to the total population.

## (3) Firm Activity

- It is assumed that companies have a field-of-view of only one period, are completely rational, and act with the goal of maximizing the expected profit for each period.
- It is assumed that a firm model is present in each income group.
- For production, human capital stock (labor), financial capital stock (capital investment), and land are required.
- It is assumed that household savings are all corporate capital investments by means of banks.
- It is assumed that there is no rapid technological growth due to changes in social and economic structure.

#### (4) Market Equilibrium

- By solving the household optimization problem and the firm expected profit maximization problem, the market equilibrium problem for the goods and production factors for each period can also be solved.
- Markets are assumed to be perfectly competitive.

#### (5) Disasters

- For each type of disaster, multiple disaster scales are set, and any particular scale of disaster (including “without disaster”) is assumed to occur for each period, according to the steady stochastic process.
- Since the DRR concept of behavior for individuals (inclusive of insurance) is not included, it is not possible to mitigate the damage from disaster unless DRR is carried exogenously.
- It is assumed that the DRR is only carried by investment for DRR exogenously. While investment cost is not considered in this model.

#### (6) Output

- The GDP function is assumed to be a Cobb–Douglas function composed of human capital stock (labor), financial capital stock (capital investment), and land.
- The GDP and Gini coefficient difference that is attained from the variance in disaster damage, which depends on the presence or absence of DRR, is regarded as the effect of DRR.



### 3 Equation of the DR<sup>2</sup>AD Model (Ver1.4)

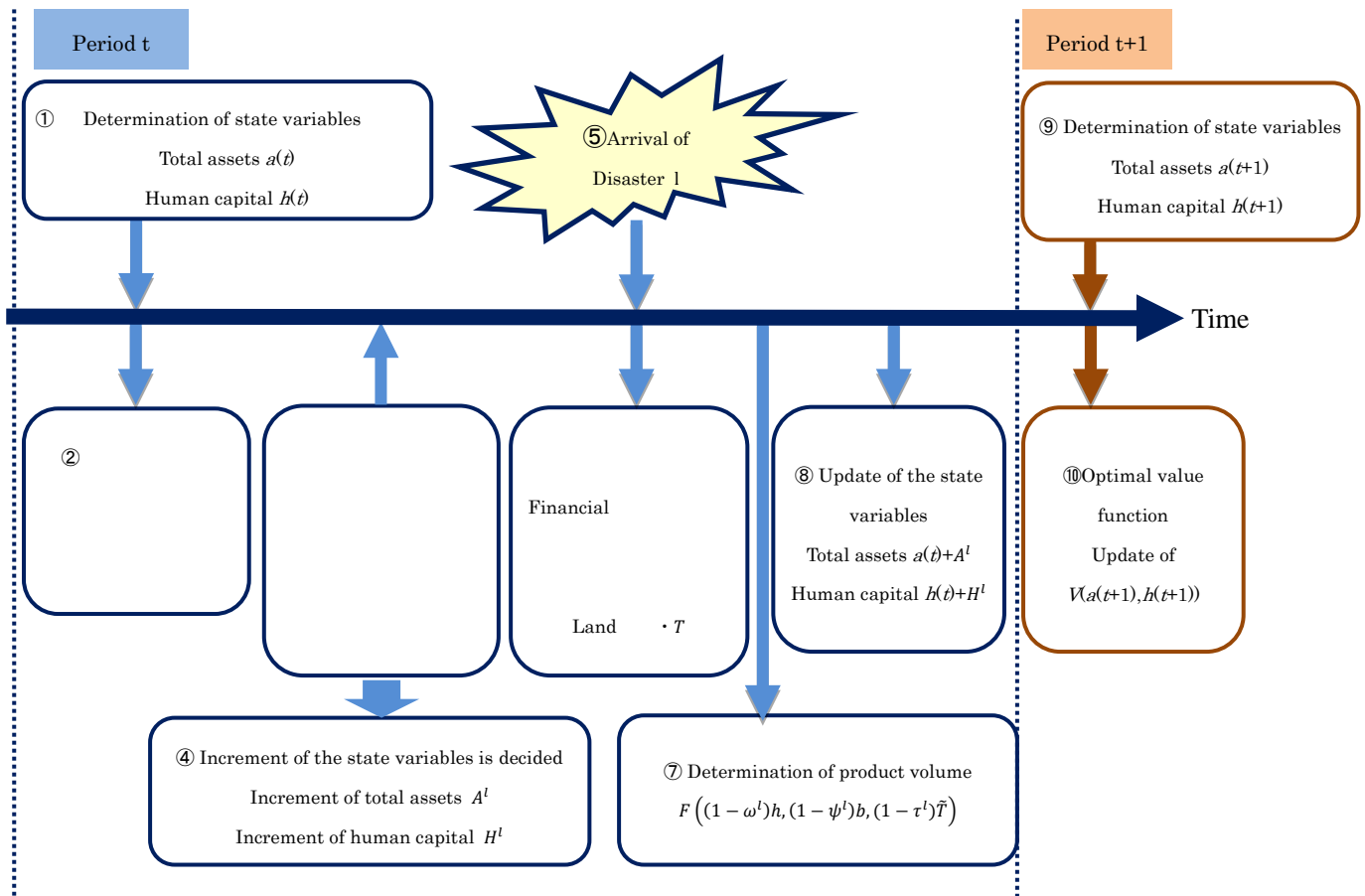
In this section, the specific settings of the DR<sup>2</sup>AD model are explained (Ver1.4).

#### 3.1 Prerequisites

The following are prerequisites for the Equation of the DR<sup>2</sup>AD model (Ver1.4).

- In the economy, only two entities, households and firms, exist; government does not play a role.
- Developing countries are the target in particular ; to evaluate the reduction of poverty, households are classified into five income groups: poorest, poor, middle, wealthy, and wealthiest.
- For simplicity, the premise of a closed economy<sup>1</sup> has been set for each income group. Therefore, international and inter-regional trade, exchanges between income groups, and aid from other governments are not included.
- Multiple disaster scales  $\ell$  ( $= 1, 2, \dots, L$ ) are present as disasters occur stochastically.

The sequence of events in this model is shown as follows.



<sup>1</sup> Closed economy: An economy with no external exchange or trade.

Figure 4. Sequence of post-disaster events

## 3.2 Modeling

### 3.2.1 Configuration for Disasters

The disaster probability  $\mu^\ell$  corresponding with each disaster scale  $\ell$  ( $= 0, 1, \dots, L$ ) is set. However, the disaster probability  $\mu^\ell$  is understood to satisfy the following equation:

$$\sum_{\ell=0}^L \mu^\ell = 1$$

(Eq. 1)

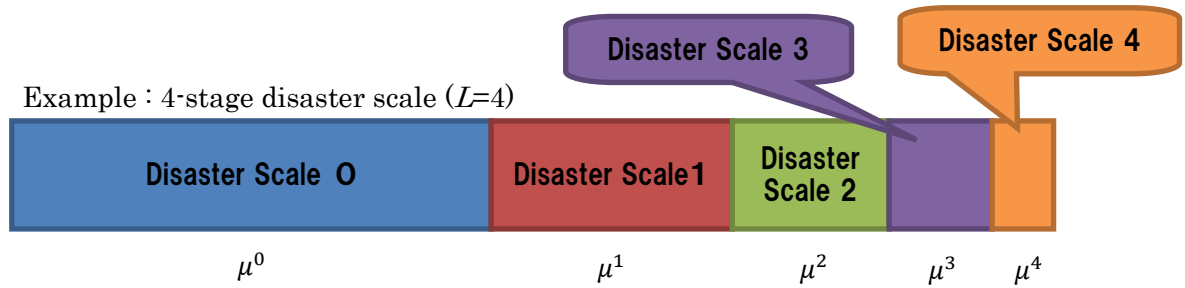


Figure 5. Image corresponding to the disaster probability and disaster scale

### 3.2.2 Configuration for Households

#### (1) Population

The population  $n_j$  of income groups  $j$  ( $= 1, 2, \dots, J$ ) is always constant and is set as follows:

$$n_j(t+1) = n_j(t), \quad (\text{Eq. 2})$$

where

$n_j$ : population of income group  $j$ .

In addition, since the total population  $N$  is the sum of the population of each income group, it can be expressed as follows:

$$N = \sum_{j=1}^J n_j$$

(Eq. 3)

Hereafter, unless it is necessary, the subscript  $j$  indicating income groups will be omitted from equations for simplicity.

It is assumed that the total labor force equals to the total population.

## (2) Human Capital

The human capital  $h$  of income groups  $j$  will be set as follows. Human capital is assumed to depreciate naturally and to not be lost by disaster; however, it is temporarily reduced at the time of a disaster, leading to a reduction in labor productivity. Moreover, the acquisition of real data on human capital is difficult, so a proxy variable<sup>2</sup> for the average years of schooling is set. A temporal gap between the growth in human capital and the improvement in labor productivity is inherently present; although due to the data constraints in this case, it is assumed that the improvement in human capital immediately leads to the improvement in labor productivity, given by

$$h(t + 1) = h(t) + H^l(t), \quad (\text{Eq. 4})$$

where

$$H^l(t) = -\delta_h \cdot h(t) + \iota \cdot m^l(t),$$

$h$ : human capital

$\delta_h$ : human capital depreciation rate

$\iota$ : correction coefficient associated with the time adjustment cost

$m^l$ : time unit of human investment (time invested in education in years)

The depreciation rate  $\delta_h$  is assumed to be constant, regardless of the income group  $j$ , and it is assumed that knowledge degrades uniformly when left alone, regardless of income group. By taking into consideration depreciation, including replacement due to the obsolescence of knowledge and the turnover of the workforce, the overall turnover of generations can be observed.

## (3) Physical Assets

Physical assets  $z$  refers to nondurable goods, such as houses and household goods. The physical assets of income group  $j$  are as follows:

$$z(t + 1) = (1 - \delta_z)(1 - \varphi^l)z(t) + \xi, \quad (\text{Eq. 5})$$

$z$ : physical assets

$\delta_z$ : depreciation rate of physical assets

$\varphi^l$ : physical asset depreciation rate due to disaster scale 1

$\xi$ : formation of physical assets

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<sup>2</sup>Proxy variable: It is a variable that can be handled in theory, but since it is difficult to attain actual statistical data, it is used as a close representation of said statistical data.

#### (4) Financial Assets

Financial assets represent household savings and are also equivalent to corporate and capital investment. The financial assets of income group  $j$  are as follows:

$$b(t+1) = \{1+r(t)\} \cdot (1-\psi^l)b(t) + w(t) \cdot (1-\omega^l)h(t) + \pi^l(t) \cdot (1-\tau^l)T - c^l(t) - \eta^l(m^l(t)) - \xi \quad (\text{Eq. 6})$$

where

$$\eta^l(m^l) = \eta_0 + \eta_1 \cdot m^l + \eta_2^l \cdot (m^l)^2$$

$$\pi^l = \frac{\Pi^l}{n \cdot (1-\tau^l)T}$$

$b$ : financial assets

$w$ : wage rate per 1 human capital

$r$ : capital rent

$\Pi^l$ : company profit for disaster scale  $\ell$

$\pi^l$ : rent for land which can produce one unit for disaster scale  $\ell$

$T$ : land area owned by an individual

$\delta_k$ : depreciation rate of production capital

$\omega^l$ : human asset damage rate for disaster scale  $\ell$

$\psi^l$ : production capital damage rate for disaster scale  $\ell$

$\tau^l$ : land damage rate for disaster scale  $\ell$

$c^l$ : expenditures for disaster scale  $\ell$

$\eta^l$ : education investment for disaster scale  $\ell$

$B_0$ : exogenous growth coefficient

$\eta_i$ : parameters of human capital cost function  $i \in \{0,1,2\}$

$\times \eta_2^l$ : parameters that change depending on the disaster scale

(reflects situation such as when schools are used as evacuation centers)

#### (5) Land Area

Retention area of land  $\tilde{T}$  is set depending on income group.

$$\tilde{T} = n \cdot T$$

$\tilde{T}$ : total land area

$T$ : land area owned by an individual

Since land is used as a factor of production for firms, each household rents all land for which it is a landlord to firms and receives rent revenue as compensation. Thus, each household reaps a rent amount for the land area owned proportionate to corporate profit.

(6) Total Assets

Total assets  $a$  is the sum of physical and financial assets:

$$\begin{aligned} a(t+1) &= b(t+1) + z(t+1) \\ &= a(t) + A^l(t), \end{aligned} \tag{Eq. 7}$$

Where

$$\begin{aligned} A^l(t) &= w(t) \cdot (1 - \omega^l)h(t) + \{r(t) + \delta_k\} \cdot (1 - \psi^l)k(t) + \pi^l(t) \cdot (1 - \tau^l)T \\ &\quad - \{\delta_k + (1 - \delta_k) \cdot \psi^l\}a(t) - c^l(t) - \eta^l(m^l(t)) \\ &\quad - \{(1 - \psi^l)(1 - \delta_k) - (1 - \varphi^l)(1 - \delta_z)\}z(t) \end{aligned}$$

$a$ : total assets

(7) Optimal Value Function and the Utility Function

An individual representative of income group  $j$  acts in a manner to maximize expected life utility  $V^3$ , as shown below. In this case, each household acts while aware of the risk of disaster, and the income from each period (labor income, capital income, land income) is assumed to be allocated to consumption, the formation of physical assets<sup>4</sup>, human capital investment<sup>5</sup>, and savings, according to the following equation:

$$V(a, h) = \max E \left[ \sum_{t=0}^{\infty} u(c^l(t), (1 - \varphi^l)z(t)) \left( \frac{1}{1 + \rho} \right)^t \right]$$

where

$E$ : expected value operation

$u$ : utility function

$\rho$ : generalized discount rate

The utility function utilizes a Stone–Geary utility function that is capable of expressing households falling into the poverty trap<sup>6</sup>. Thus, a minimal expenditure required for survival  $\bar{c}$  exists in consumption. Through the incorporation of a measure of minimal expenditure in the utility function, as shown by  $\bar{c}$  below, when the level of consumption approaches  $\bar{c}$ , marginal utility<sup>7</sup> increases and consumption becomes a priority; as a result, income can no longer be used for other investments. This method shows households falling into the poverty trap. In addition, all groups are assumed to have the same utility function:

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<sup>3</sup>Expected life utility: the sum of the expected value of utility from the present to the future. A discount rate is applied to the utility of the future making its value current.

<sup>4</sup>Formation of physical assets: increasing nondurable goods (homes and household goods).

<sup>5</sup>Human capital investment: investments in human capital. In this model, it corresponds with the investment in education.

<sup>6</sup>Poverty trap: the state of being stuck near the minimal expenditure required for survival

<sup>7</sup>Marginal utility: the amount of change in utility.

$$u(c^l(t), (1 - \varphi^l)z(t)) = \frac{[(c^l - \bar{c})^{\gamma_1} \{(1 - \varphi^l) \cdot z\}^{\gamma_2}]^{1-\theta} - 1}{1 - \theta}$$

$$s. t. \gamma_1 + \gamma_2 = 1$$

(Eq. 8)

$\bar{c}$ : minimal expenditure required for survival

$\gamma_i$ : shared parameters of consumption  $i \in \{1,2\}$

$\theta$ : relative risk aversion

Since the financial assets of households formed by savings become firm capital for production through financial institutions, they are able to improve productivity. On the other hand, human investment improves productivity as future human capital. In this way, human investment and savings are actions with the purpose of keeping track of future consumption increases.

### 3.2.3 Corporate Setup

The production function  $F$  of the model firm for income level  $j$  follows the Cobb–Douglas production function, as shown below, and the three factors of production human capital stock (labor), capital investment, and land are assumed to be factors of production.

The damage rate and recovery process of the physical capital of land and capital investments will vary as

$$\begin{aligned} Y &= F\left((1 - \omega^l)H, (1 - \psi^l)K, (1 - \tau^l)\tilde{T}\right) \\ &= B\{(1 - \omega^l)H\}^{\alpha_1}\{(1 - \psi^l)K\}^{\alpha_2}\{(1 - \tau^l)\tilde{T}\}^{\alpha_3}, \end{aligned} \quad (\text{Eq. 9})$$

where

$F$ : production function

$B$ : exogenous growth coefficient

$H$ : human capital input

$K$ : production capital input

$T$ : land area

$\alpha_i$ : shared parameters of production function  $i \in \{1,2,3\}$

Exogenous growth coefficient is set as

$$B(t) = B_0(1 + \beta)^{t-1} \quad (\text{Eq. 10})$$

$\beta$ : rate of exogenous growth

### 3.2.4 Output Index

Output is added to the GDP and Gini coefficient, the periodical stock index of human capital input

$H$ , and production capital input  $K$ , as well as the periodical flow index of consumption  $c^l$  and physical assets  $z$ . For example, the GDP is dependent on the disaster scale  $l$  and period  $t$ , and is aggregated and calculated separately for each income group.

$$\begin{aligned}
\text{GDP} &= \sum_j Y_j \\
&= \sum_j F\left((1 - \omega_j^l)H_j, (1 - \psi^l)K_j, (1 - \tau^l)\tilde{T}_j\right) \\
&= \sum_j B_j \{(1 - \omega_j^l)H_j\}^{\alpha_1} \{(1 - \psi^l)K_j\}^{\alpha_2} \{(1 - \tau^l)\tilde{T}_j\}^{\alpha_3}
\end{aligned}
\tag{Eq. 11}$$

### 3.3 Optimization Problems

#### 3.3.1 Optimizing Behavior for Households

The optimization problem for households in this model is described as follows:

$$V(a, h) = \max_{s, t} E \left[ \sum_{t=0}^{\infty} u(c^l(t), (1 - \varphi^l)z(t)) \cdot \Lambda^t \right]$$

$$b(t+1) = \{1+r(t)\} \cdot (1 - \psi^l)b(t) + w(t) \cdot (1 - \omega^l)h(t) + \pi^l(t) \cdot (1 - \tau^l)T - c^l(t) - \eta^l(m^l(t)) - \xi$$

$$\begin{aligned}
h(t+1) &= (1 - \delta_h) \cdot h(t) + \iota \cdot m^l(t) \\
\eta^l(m^l) &= \eta_0 + \eta_1 \cdot m^l + \eta_2 \cdot (m^l)^2
\end{aligned}$$

$$\Lambda = \frac{1}{1 + \rho}$$

The recursive equation for the optimal value function is as follows:

$$\begin{aligned}
V(a, h) &= \max E[u(c^l, (1 - \varphi^l)z) + \Lambda \cdot V(a + A^l, h + H^l)] \\
&= \max \left\{ \sum_t \mu^l [u(c^l, (1 - \varphi^l)z) + \Lambda \cdot (V + V_a \cdot A^l + V_h \cdot H^l)] \right\} \\
(1 - \Lambda) \cdot V(a, h) &= \max \left\{ \sum_t \mu^l [u(c^l, (1 - \varphi^l)z) + \Lambda \cdot (V_a \cdot A^l + V_h \cdot H^l)] \right\}
\end{aligned}
\tag{Eq. 12}$$

The household optimization problem is equivalent to maximizing the right hand side of Equation 12. From the first-order condition of the recurrence equation,

$$c^l : u_c(c^l, (1 - \varphi^l)z) - \Lambda \cdot V_a = 0, \quad \text{for all } l \tag{Eq. 13}$$

$$z : \sum_l \mu^l (1 - \varphi^l) \{u_z(c^l, (1 - \varphi^l)z) + \Lambda \cdot V_a \cdot (1 - \delta_z)\} = \Lambda \cdot V_a \sum_l \mu^l (1 - \psi^l) \{r(t) + 1\}$$



(Eq. 14)

$$m^l: -V_a \cdot \frac{\partial \eta^l(m^l)}{\partial m^l} + V_h \cdot \iota = 0, \quad \text{for all } l \quad (\text{Eq. 15})$$

Since the functional form of the optimal value function is unknown, the functional form of the optimal value function is approximated as

$$V(a, h) = v_0 + v_1 \cdot a^{1-\theta} + v_2 \cdot h^{1-\theta}. \quad (\text{Eq. 16})$$

From the first derivative,

$$V_a = (1 - \theta)v_1 \cdot a^{-\theta}, \quad (\text{Eq. 17})$$

$$V_h = (1 - \theta)v_2 \cdot h^{-\theta}. \quad (\text{Eq. 18})$$

After determining the disaster scale  $\ell$  for period  $t$ ,  $h_j^*$  and  $b_j^*$  is decided for period  $t+1$ , so the supply of the factors of production is determined as follows:

$$H^S(t) = n \cdot h(t), \quad (\text{Eq. 19})$$

$$K^S(t) = n \cdot b(t) \quad (\text{Eq. 20})$$

### 3.3.2 Firm Profit Maximization

Firms in each income group  $j$  act to maximize the following expected profit functions under a perfectly competitive market:

$$\begin{aligned} \max E \Pi^l &= \sum_t \mu^l F((1 - \omega^l)H, (1 - \psi^l)K, (1 - \tau^l)\tilde{T}) - \sum_t \mu^l \cdot w(t) \cdot (1 - \omega^l)H \\ &\quad - \sum_t \mu^l \{r(t) + \delta_k\} \cdot (1 - \psi^l)K \\ &= P \cdot F(H, K, \tilde{T}) - w(t) \cdot P_h \cdot H - \{r(t) + \delta_k\} \cdot P_k \cdot K \end{aligned}$$

where

$$\begin{aligned} P &= \sum_t \mu^l (1 - \omega^l)^{\alpha_1} \cdot (1 - \psi^l)^{\alpha_2} \cdot (1 - \tau^l)^{\alpha_3} \\ P_h &= \sum_t \mu^l (1 - \omega^l) \\ P_k &= \sum_t \mu^l (1 - \psi^l) \end{aligned}$$

(Eq. 21)

From the first-order conditions of the expected profit functions,

$$H : \frac{\alpha_1 PF(H_j, K_j, T_j)}{H_j} - w_j(t) P_h = 0, \quad (\text{Eq. 22})$$

$$K : \frac{\alpha_2 PF(H_j, K_j, T_j)}{K_j} - (r_j(t) + \delta_k) P_k = 0. \quad (\text{Eq. 23})$$

Thus, demand for factors of production is determined so as to satisfy the following:

$$H^D(t+1) = \left[ B_0 \left\{ \frac{\alpha_1}{w(t)} \right\}^{1-\alpha_2} \left\{ \frac{\alpha_2}{r(t) + \delta_k} \right\}^{\alpha_2} \frac{P}{P_h^{1-\alpha_2} P_k^{\alpha_2}} \right]^{\frac{1}{\alpha_3}} \cdot \tilde{T}$$

$$K^D(t+1) = \left[ B_0 \left\{ \frac{\alpha_1}{w(t)} \right\}^{\alpha_1} \left\{ \frac{\alpha_2}{r(t) + \delta_k} \right\}^{1-\alpha_1} \frac{P}{P_h^{\alpha_1} P_k^{1-\alpha_1}} \right]^{\frac{1}{\alpha_3}} \cdot \tilde{T}$$

### 3.3.3 Market Equilibrium Problem

The equilibrium for the market factors of production between households and firms can be obtained by solving the following equations:

$$H^S(t) = H^D(t), \quad (\text{Eq. 24})$$

$$K^S(t) = K^D(t). \quad (\text{Eq. 25})$$

From this, the equilibrium wage rate  $w^*(t)$  and the equilibrium capital rent  $r^*(t)$  are derived.

## Part 2 Program construction of the DR<sup>2</sup>AD Model

### 4 Program Construction of Ver1.4

Programming is done utilizing MATLAB (numerical software), based on the formulation in the previous section. In this section, the prerequisites and procedures for performing the program construction will be presented.

A significant characteristic of programming is performing calculations on the framework of the social optimization problem.

#### 4.1 Prerequisites

Ver1.4 of the program is constructed on the basis of calculations using the social optimization problem.

Since there are no external economies in the market equilibrium problem defined in Section 3.3.3, social optimization problems that lead to the same distribution (first-best problem) exist as a solution. For dynamic and stochastic problems, it is easier to calculate using social optimization problems in a large number of cases; thus this model replaces the market equilibrium problem with equivalent social optimization problems and calculations are performed.

Social optimization problems in this model are set separately for each income group. For the problems of each income group, one social planner determines the variables for all households and firms so as to maximize the expected lifetime utility level of the representative household.

## 4.2 Program Flow

The program is performed in accordance with the execution flow listed below.

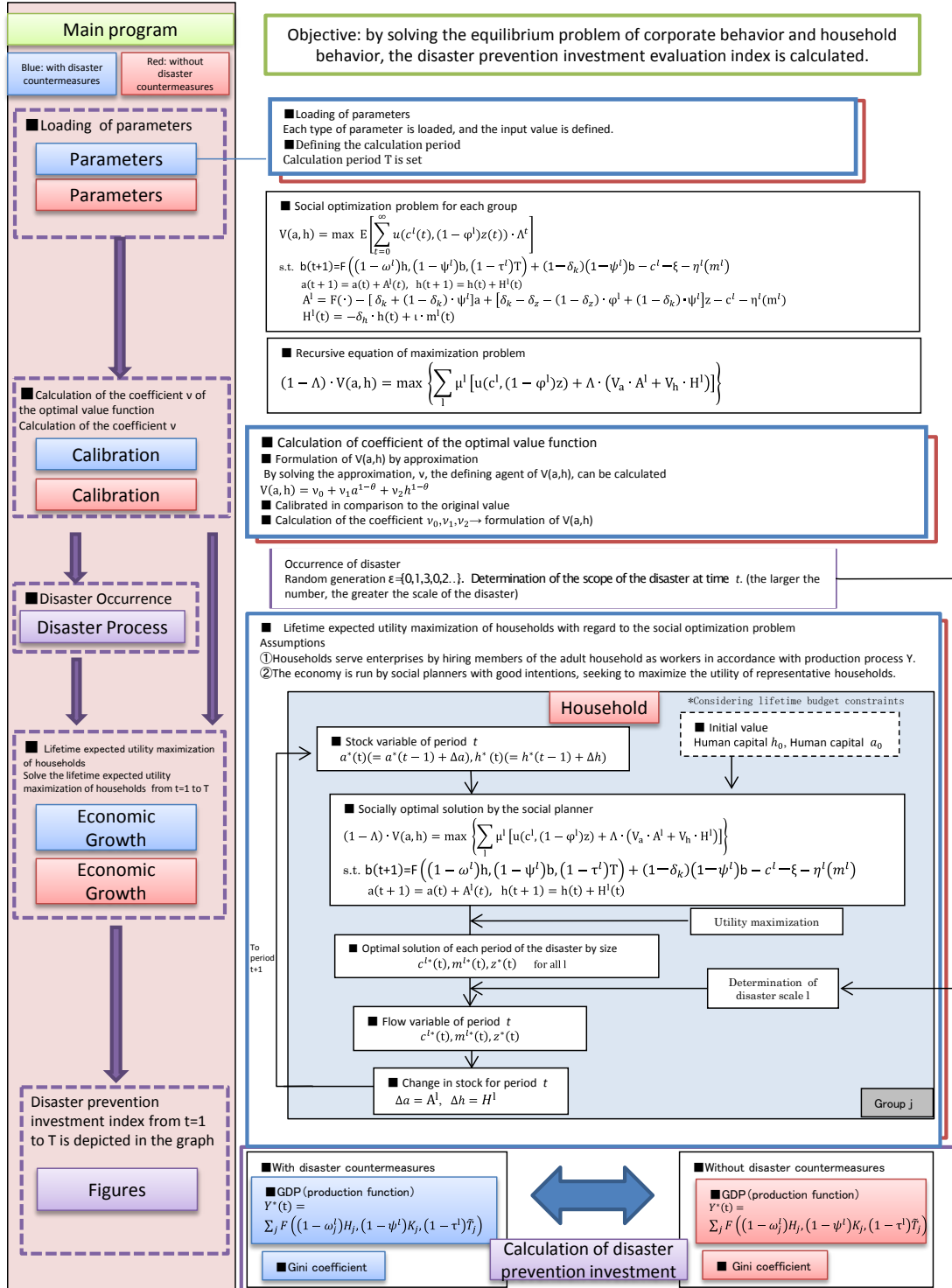


Figure 6. Execution flow of program Ver1.4

### 4.3 Program Construction

To actually calculate a model that has been formulated, the way the required data should be handled and the concepts of calculation are organized in accordance with the execution flow.

#### 4.3.1 Setting of DRR Measures

As shown in Figure 6, the two cases of with DRR and without DRR are presented in order to evaluate the effects of DRR countermeasures. The effects of DRR are verified by comparing these two cases.

The variables that will vary depending on DRR are the three variables of  $\omega$ ,  $\varphi$ , and  $\psi$ , as will be defined in Section 4.3.2.

#### 4.3.2 Loading of Parameters

##### (1) Loading of Parameters

All types of parameters in the model are set first. The input variables consist of exogenous variables, endogenous variables, and default variables. The individual data values and estimation method are described separately in Chapter 5.

Table 7. Variable Setting and Characteristics of the Input Value

■Socio-economic Data		
Variable		Characteristics of the Input Value
$n_j$	Population	exogenous variable
$\rho$	Social discount rate	exogenous variable
$\delta_z$	Physical assets depreciation rate	exogenous variable
$\delta_k$	Production capital depreciation rate	exogenous variable
$r_j$	Capital rent	endogenous variable
$\beta$	Exogenous growth coefficient	exogenous variable
$\alpha_i$	Share parameters for the production function ( $i \in \{1, 2, 3\}$ )	exogenous variable

■Household Data		
$c_j^l$	Consumption goods (nondurable goods)	endogenous variable
$z_j$	Physical assets (home, household goods)	endogenous variable
$\theta$	Relative risk aversion	exogenous variable (assumed constant in each country)
$\bar{c}$	Minimal consumption amount for survival	exogenous variable (assumed constant in each country)
$b_j$	Financial assets	initial value is an exogenous variable, and thereafter an endogenous variable
$T_j$	Land area (per person)	exogenous variable
$F$	Production function	endogenous variable
$\xi_j$	Physical assets formation	endogenous variable
$h_j$	Human capital	initial value is an exogenous variable, and thereafter an endogenous variable
$m_j^l$	Hourly human capital (the amount of time spent on education)	endogenous variable
$\delta_h$	human capital depreciation rate	exogenous variable
$w_j$	Wage rate (per 1 human capital)	endogenous variable
$\eta_i$	Human capital cost function parameters ( $i \in \{0, 1, 2\}$ )	exogenous variable
$\gamma_i$	Consumption shared parameters ( $i \in \{1, 2\}$ )	exogenous variable
■Disaster Data* <sup>1</sup>		
$\omega_j^l$	Human capital damage rate due to disaster	exogenous variable
$\phi_j^l$	Physical assets damage rate due to disaster	exogenous variable
$\psi^l$	Production capital damage rate due to disaster	exogenous variable
$\tau^l$	Damage rate of land due to disaster	exogenous variable

\*1: set by changing the damage rate depending on the presence or absence of DRR.

## (2) Setting of the Calculation Period

The calculation period in the program is set. The length of the period (field-of-view) that can be considered for the household lifetime expected utility is the finite period  $TT$ .

### 4.3.3 Calculation of the Coefficient $\mathbf{v}$ of the Optimal Value Function

The optimal value function that represents the lifetime expected utility function is approximated as follows:

$$V(a, h) = v_0 + v_1 a^{1-\theta} + v_2 h^{1-\theta}.$$

$V(a, h)$ , from the approximation equation above, can be described as an optimal value function of a first-level differential equation, as shown below:

$$V_a = (1 - \theta)v_1 a^{-\theta},$$

$$V_h = (1 - \theta)v_2 h^{-\theta}.$$

Tasks in this section are to identify the unknown values  $\mathbf{v}$  of  $V(a, h)$ , which reproduce the initial values  $c(0)$ ,  $m(0)$ , and  $z(0)$ . However, households are assumed to have the same optimal value functions, regardless of income group, and are assumed to want to obtain the optimal social solution. Thus, the value of  $\mathbf{v}$  is the same for all groups.

The optimization problem for households is as seen in Section 3.3.1 and below:

$$\begin{aligned} V(a, h) &= \max E \left[ \sum_{t=0}^{\infty} u(c^l(t), (1 - \varphi^l)z(t)) \cdot \Lambda^t \right] \\ \text{s.t. } b(t+1) &= \{1+r(t)\} \cdot (1 - \psi^l)b(t) + w(t) \cdot (1 - \omega^l)h(t) + \pi^l(t) \cdot (1 - \tau^l)T \\ &\quad - c^l(t) - \eta^l(m^l(t)) - \xi \\ h(t+1) &= (1 - \delta_h) \cdot h(t) + \iota \cdot m^l(t) \\ &F\left((1 - \omega^l)h, (1 - \psi^l)b, (1 - \tau^l)T\right) \\ &= B_0 \{ (1 - \omega^l)h \}^{\alpha_1} \cdot \{ (1 - \psi^l)b \}^{\alpha_2} \cdot \{ (1 - \tau^l)T \}^{\alpha_3} \\ \eta^l(m^l) &= \eta_0 + \eta_1 \cdot m^l + \eta_2 \cdot (m^l)^2 \\ \Lambda &= \frac{1}{1 + \rho} \end{aligned}$$

The problems mentioned above are solved by modifying the recurrence equation:

$$\begin{aligned} V(a, h) &= \max E[u(c^l, (1 - \varphi^l)z) + \Lambda \cdot V(a + A^l, h + H^l)] \\ &= \max \left\{ \sum_t \mu^l [u(c^l, (1 - \varphi^l)z) + \Lambda \cdot (V + V_a \cdot A^l + V_h \cdot H^l)] \right\} \\ (1 - \Lambda) \cdot V(a, h) &= \max \left\{ \sum_t \mu^l [u(c^l, (1 - \varphi^l)z) + \Lambda \cdot (V + V_a \cdot A^l + V_h \cdot H^l)] \right\} \end{aligned}$$

Where

$$\begin{aligned}
A^l &= F(\cdot) - \{\delta_k + (1 - \delta_k) \cdot \psi^l\}a(t) - c^l(t) - \eta^l(m^l(t)) \\
&\quad - \{(1 - \psi^l)(1 - \delta_k) - (1 - \varphi^l)(1 - \delta_z)\}z(t) \\
H^l &= -\delta_h \cdot h + \iota \cdot m^l
\end{aligned}$$

$A^l, H^l$  represent changes in assets and the average schooling years, respectively, depending on the disaster scale.

The optimal social solution for households can be derived by solving the first-order optimization conditions of  $c^l$ ,  $m^l$ , and  $z$ . First-order optimization conditions of each of these variables are shown below.

$$c^l : u_c(c^l, (1 - \varphi^l)z) - \Lambda \cdot V_a = 0 \quad (\text{Eq. 26})$$

$$\begin{aligned}
z : \sum_l \mu^l (1 - \varphi^l) \{u_z(c^l, (1 - \varphi^l)z) + \Lambda \cdot V_a \cdot (1 - \delta_z)\} &= \Lambda \cdot V_a \sum_l \mu^l (1 - \psi^l) \{F_b / (1 - \\
\psi^l) + (1 - \delta_k)\} & \quad (\text{Eq. 27})
\end{aligned}$$

$$m^l : -V_a \cdot \frac{\partial \eta^l(m^l)}{\partial m^l} + V_h \cdot \iota = 0. \quad (\text{Eq. 28})$$

Coefficients  $v_0, v_1, v_2$  of  $V(a, h)$  are calibrated using the following procedure. In Ver1.4, it is assumed that calibration is performed in light of the actual statistical data.

- ① In addition to the data  $c(0), a(0), h(0)$  and the optimal conditions expression of the first stage of  $z$  and  $c$ ,  $v_1, \gamma_1, \gamma_2$  are sought from  $\gamma_1 + \gamma_2 = 1$ .
- ②  $v_2$  is sought from ① and the initial data  $m^l(0)$ ,  $m^l = \frac{1}{2\eta_2^l} \cdot \left\{ \frac{v_2}{v_1} \left(\frac{h}{a}\right)^{-\theta} \cdot \iota - \eta_1 \right\}$
- ③ Using ① and ②,  $v_0$  is sought using a recursive equation.

GDP is calculated as shown below:

$$\begin{aligned}
\text{GDP} &= \sum_j Y_j \\
&= \sum_j F\left((1 - \omega_j^l)H_j, (1 - \psi^l)K_j, (1 - \tau^l)\tilde{T}_j\right) \\
&= \sum_j B_j \{(1 - \omega_j^l)H_j\}^{\alpha_1} \{(1 - \psi^l)K_j\}^{\alpha_2} \{(1 - \tau^l)\tilde{T}_j\}^{\alpha_3} \quad (\text{Eq. 29})
\end{aligned}$$



#### 4.3.4 Graph Rendering

In addition to the GDP and Gini coefficient, the breakdown of capital and consumption for period  $t$  is recorded following the procedures above. By performing this for all measurement periods for the values above, graphs for each case, both with and without DRR, are rendered as shown in Figure 8.

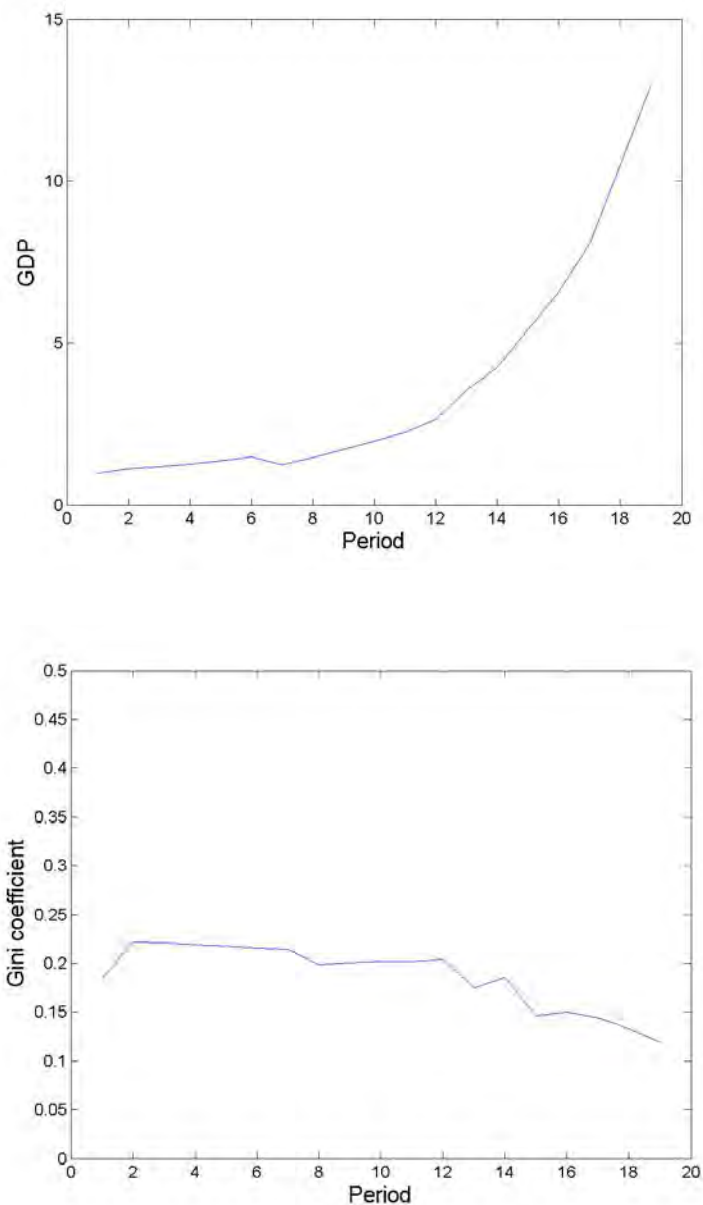


Figure 8. Example results (1 of 2).

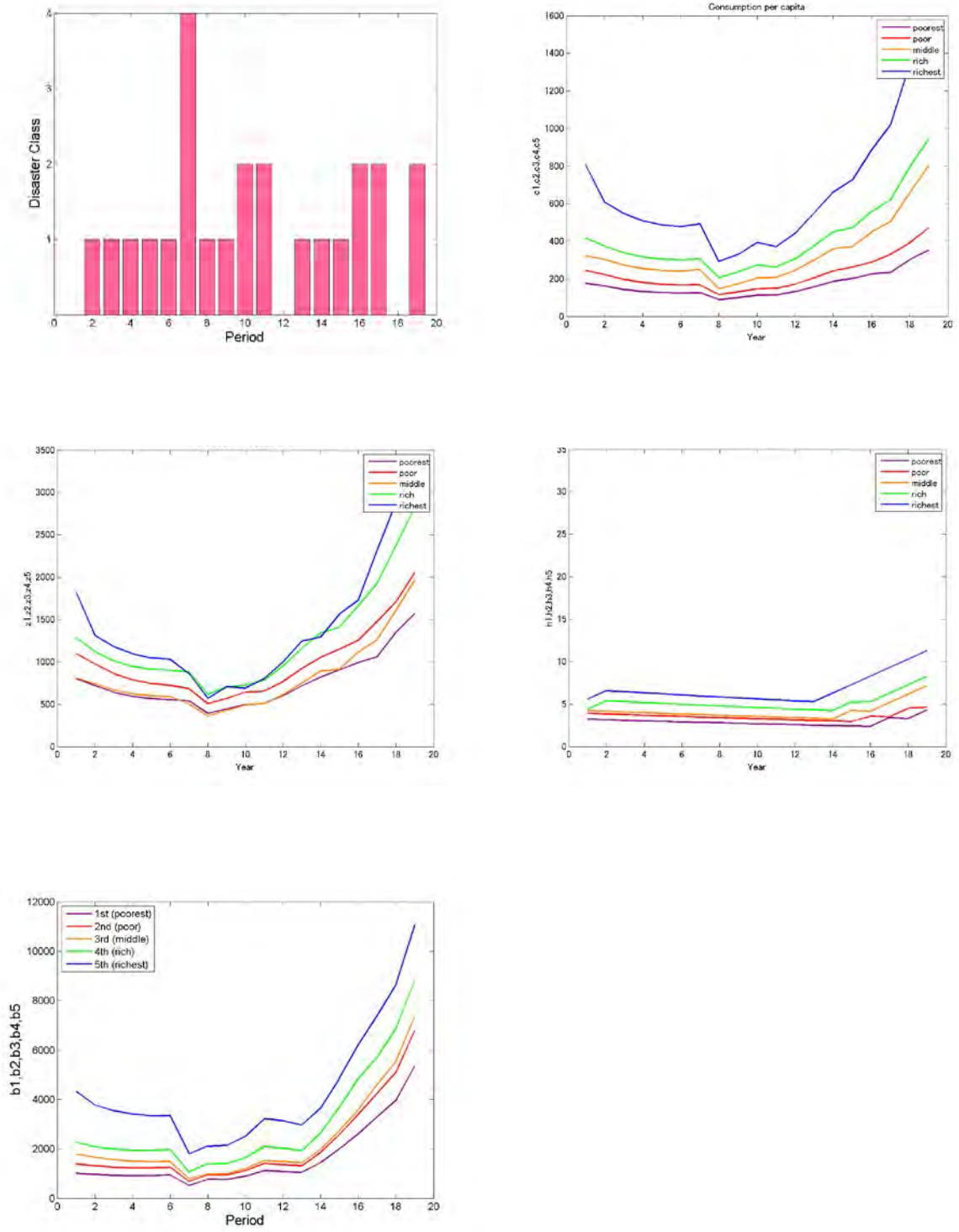


Figure 9. Example results (2 of 2)

### 4.3.5 Calculation of the Effects of DRR

The effects of DRR can be understood as a relative value by looking at the ratio of the value of GDP in the presence or absence of DRR and the value of the Gini coefficient.

$$\text{DRR effect ①} = \frac{\text{GDP}_{\text{DRR (with)}}}{\text{GDP}_{\text{DRR (without)}}$$

$$\text{DRR effect ②} = \frac{\text{Gini coefficient}_{\text{DRR (with)}}}{\text{Gini coefficient}_{\text{DRR (without)}}$$

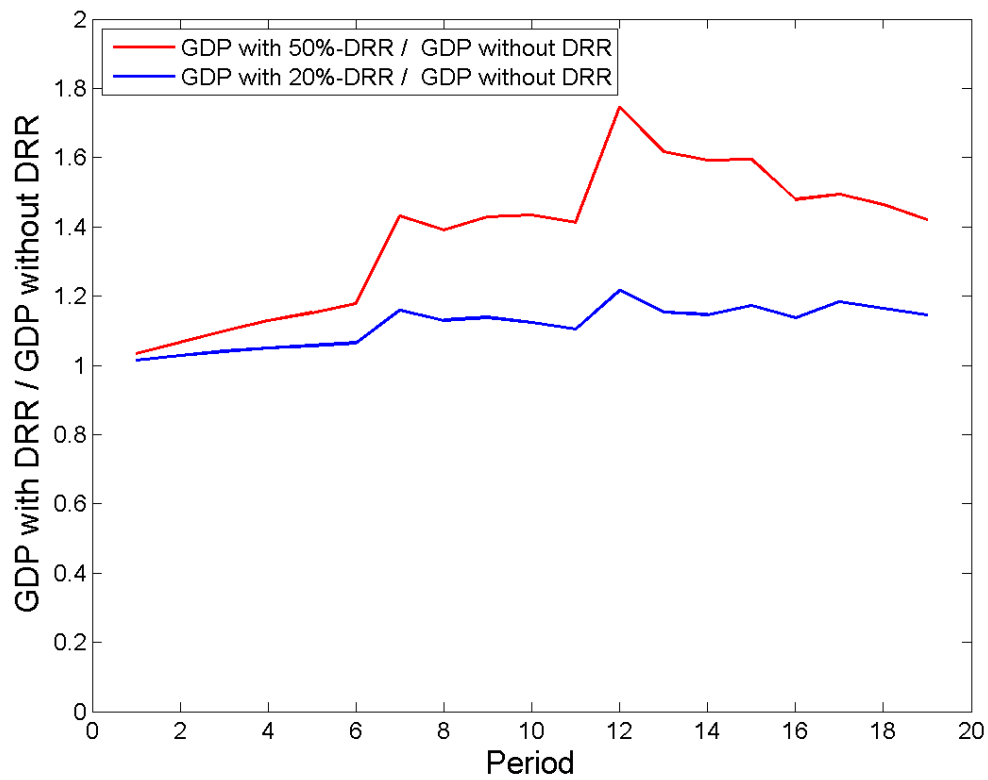


Figure 10. Difference in GDP depending on the presence or absence of DRR (example).

## Part 3 Construction of the DR<sup>2</sup>AD Model Ver1.4 Data Set

### 5 Data Set Construction

In this chapter, the content of the data set necessary for the case study for Ver1.4 and the general method for configuring those data will be explained.

#### 5.1 Assumptions about Data Setting

Data for the case study for Ver1.4 is generally extracted from indicators in the World Bank's data set where data of various countries are abundant. In addition, data for the case study is collected based on the following conditions and assumptions.

- The population could be divided into five income groups: poorest, poor, middle, rich, and wealthiest.
- It is recommended that the population be divided into the quintiles using household survey of each country as a standard method.
- In the benchmark year, large disaster does not occur since the calibration is performed using the first year data in the calculation period.
- It is recommended that, in the past ten or so years in which the statistics were taken, date in the year when disaster occurred to be collected so as to reproduce the GDP of the year concerned.
- For the purpose of reproducing the present situation in keeping with the transition of the GDP, the exogenous growth rate is set so that the model estimated value of GDP in disaster year fits into the actual value.

#### 5.2 Method for Setting Variables Used in the Program

The variables used in the program, the setting method and the variable values set for the Pakistan case study as an example are shown in the below table. Data requiring the estimation and manipulation is explained separately in section 5.3.

Table 11. Method for Setting Variables and Initial Values

Variable	Setting Method	Setting for Pakistan
<b>■Socio-economic Data</b>		
$n_j$	Population	Set from the statistical, population data for each income group. <b>■Total population (2004)</b> 155,151,394 people * Source: World Bank  <b>■Stratified population (2004)</b> ⇒The total population is distributed to each of the five groups, depending on size. *Source: "Poverty Profile of the Islamic Republic of Pakistan," Japan Bank for International Cooperation (2007); Each group: 31,030,279 people (20% of the total population from each group)
$\rho$ rho	Social discount rate	Set based on the actual situation in each country.  0.05
$\delta_z$ delta	Physical assets depreciation rate	Set based on the actual situation in each country.  0.2 Set by a 10%–30% assets write-off rate in Pakistan. *Source: Investment and corporate law, accounting tax, and labor in Bangladesh, Pakistan, Sri Lanka - Kuno Yasunari
$\delta_k$	Production capital depreciation rate	Set based on the actual situation in each country.  0.02
$r_j$	Capital rent	Since it is set from the home and firm equilibrium, it is determined endogenously.  Determined endogenously
$B$	Exogenous growth rate	Set as a correction value based on the production function when predicting the GDP. Exogenous growth is set exogenously when necessary. *Setting method listed in Section 5.3.1(1)  63.0198 ⇒The GDP initial value/ $h(0)^{\alpha_1}K(0)^{\alpha_2}T(0)^{\alpha_3}$ Set for annual growth of $(1 + 0.095)^{t-1}$
$\alpha_i$	Production elasticity's of production function	The production function set from the distribution ratio of human capital, physical capital, and land when using a Cobb–Douglas function. *Setting method listed in Section 5.3.1(2)  $\alpha_1 = 0.52$ $\alpha_2 = 0.40$ $\alpha_3 = 0.08$
<b>■Household Date</b>		
$c_j^l$	Consumption goods (non-durable)	In the optimization calculation, the stock and investment for each period are calculated and determined endogenously. However, the household survey  1 <sup>st</sup> (poorest) : \$176.0 2 <sup>nd</sup> (poor) : \$242.2 3 <sup>rd</sup> (middle) : \$303.8 4 <sup>th</sup> (rich) : \$410.3 5 <sup>th</sup> (richest) : \$815.1

Variable	Setting Method	Setting for Pakistan
	data are used for the initial value. *Setting method listed in Section 5.3.2(1).	*Source: Household Integrated Economic Survey, Pakistan
$z_j$	Physical assets (home, household goods) In the optimization calculation, the stock and investment for each period are calculated. However, the household survey data are used for the initial value. *Setting method listed in Section 5.3.2(1).	1 <sup>st</sup> (poorest) : \$263 2 <sup>nd</sup> (poor) : \$362 3 <sup>rd</sup> (middle) : \$454 4 <sup>th</sup> (rich) : \$613 5 <sup>th</sup> (richest) : \$1218 ⇒Set to an 8.67%–9.99% to 10% past investment rate of Housing (rent & other costs)/Rural from Pakistan's Household Integrated Economic Survey. *Source: Household Integrated Economic Survey, Pakistan
$\theta$	Relative risk aversion Set by existing research data	2 *Reference: Kraay and Raddatz (2007), Poverty traps, aid, and growth, Journal of Development Economics, 82, 315-347.
$\bar{c}$	Minimum consumption amount required for survival Set by existing research data	Assumed to be 0. * David (1998) said that “The least cost requirement for sustaining an individual's minimum dietary needs is approximately \$300 a year (in 1980 dollars).”
$b_j$	Financial assets Set proportionately for each income group based on the data of gross national savings. Determined endogenously by solving the equilibrium problem for each period. However, the household survey data are used as the initial value. *Setting method listed in Section 5.3.2(2)	1 <sup>st</sup> (poorest) : \$1104.3 2 <sup>nd</sup> (poor) : \$1534.4 3 <sup>rd</sup> (middle) : \$1906.4 4 <sup>th</sup> (rich) : \$2487.6 5 <sup>th</sup> (richest) : \$4579.9 *Source: Finance Division, Government of Pakistan, Pakistan Economic Survey. (national savings rate)
$\tilde{t}_j$	Total land area Set while referring to the rank-share of financial assets.	1 <sup>st</sup> (poorest) : 9.5% 2 <sup>nd</sup> (poor) : 13.2% 3 <sup>rd</sup> (middle) : 6.4% 4 <sup>th</sup> (rich) : 21.4% 5 <sup>th</sup> (richest) : 39.4% *Setting method listed in Section 5.3.2(3)
$\xi_{xi}$	Formation of physical assets Is calculated endogenously if physical investment is desired.	Determined endogenously when $z_j$ is determined.
$h_j$	Human capital The accumulation of human capital is set using the average number of schooling years, etc. as a proxy variable. Stratified data for the years of	1 <sup>st</sup> (poorest) : 3.22years 2 <sup>nd</sup> (poor) : 3.92years 3 <sup>rd</sup> (middle) : 4.24years 4 <sup>th</sup> (rich) : 4.39years 5 <sup>th</sup> (richest) : 5.57years

Variable		Setting Method	Setting for Pakistan
		schooling are set from the statistical data of each country *Setting method listed in Section 5.3.2(4)	
$m_j^l$	Hourly human investment	Determined endogenously. *Setting method listed in Section 5.3.2(5)	Determined endogenously.
$\delta_h$ delta	Depreciation rate of human capital	Estimated from the relation between education investment and human capital. *Variable to take into account the depletion of human capital. *Setting method listed in Section 5.3.2(6)	0.075 Estimated from average number of schooling years in Pakistan.
$w_j$	Wage rate (for 1 human capital)	Since it is set from the home and firm equilibrium, it is determined endogenously.	Determined endogenously.
$\eta_i$ eta	Parameters of the human capital cost function	Estimated from the relationship between government and household changes in per capita education investment and human capital. * Parameters of the function for converting time invested in education into a monetary expense. *Setting method listed in Section 5.3.2(6)	$\eta_0$ : 7.98 $\eta_1$ : 44.2  3.30 3.70 $\eta_{21}$ : 4.10 4.50 4.90
$\gamma_i$ gamma	Shared parameters of consumption	The individual value of $\gamma_1 + \gamma_2 = 1$ is determined endogenously.	Determined endogenously
<b>■Disaster Data</b>			
$\omega_j^l$	Damage rate of human capital due to disaster	Set using data from previous disasters. Set stratified when the impact of the damage varies depending on the group. *Setting method listed in Section 5.3.3	0.0000018%–0.000012% ⇒Due to data limitations, the disaster damage rate is currently consistent for each income group.
$\phi_j^l$	Damage rate of physical assets due to disaster	Set using data from previous disasters. Set stratified when the impact of the damage varies depending on the group. *Setting method listed in Section 5.3.3	1 <sup>st</sup> (poorest) : 0.9%–5.4% 2 <sup>nd</sup> (poor) : 0.7%–8.4% 3 <sup>rd</sup> (middle) : 5.5%–22% 4 <sup>th</sup> (rich) : 0.9%–8.2% 5 <sup>th</sup> (richest) : 2.0%–22%
$\psi^l$	Damage rate of financial assets due to disaster	Set using data from previous disasters. Set stratified when the impact of the damage varies depending on the group. *Setting method listed in Section	7.9%~55% Due to data limitations, the disaster damage rate is currently consistent for each income group. Only uses data from Pakistan between 1976 and 2011 (36 years)

Variable	Setting Method	Setting for Pakistan
	5.3.3	
$\tau^l$	Damage rate of land due to disaster Set using data from previous disasters. Set stratified when the impact of the damage varies depending on the group. *Setting method listed in Section 5.3.3(4)	2.1%~15% Due to data limitations, the disaster damage rate is currently consistent for each income group. Only uses data from Pakistan between 1976 and 2011 (36 years)



## 5.3 Method for Setting the Estimated Variable

### 5.3.1 Socio-economic Data

#### (1) Exogenous Growth Coefficient

For the purpose of reproducing the present situation in keeping with the transition of the GDP in more than ten years when statistics useful for considering the disaster risk reduction investment were taken, the exogenous growth coefficient  $B$  is set so that the model estimated value of GDP in disaster year fits into the actual value.

$B$  is a variable based on the production function that is set as a correction value when estimating GDP and it is defined as follows. Initial parameters in the calculation period are used.

$$B(0) = \frac{\text{GDP}}{H(0)^{\alpha_1} K(0)^{\alpha_2} T(0)^{\alpha_3}}. \quad (\text{Eq. 30})$$

It is assumed that  $B$  grows at a constant annual rate in keeping with the growth rate.

$$B(t) = B(0) \cdot (1 + \beta)^{t-1} \quad (\text{Eq.31})$$

#### ● Configuration Example for Case study

In the Pakistan case study,  $B(0)$  is calculated setting the year 2004 as the benchmark year. As a result of calibrating the annual growth rate  $\beta$  so as to fit into with the GDP of 2010, the value is set as follows.

$$\beta = 0.095$$

(2) Production elasticity  $\alpha$  of the Production Function

When Cobb–Douglas function is supposed as a production function, the production elasticity of the production function  $\alpha_i$  is determined by the share of the three production factors: human capital, production capital and land. That share is attained from Input-Output table. The procedure for calculating the production elasticity is shown in the following example.

● Configuration Example for Case study

In the Pakistan case study, information about output which composes the share of labor, capital investment and land is extracted from Input-Output table, and then the production elasticity of the production function is calculated. The procedure is as follows.

Table 12. Procedure for calculating the production elasticity of the Production Function

Field	Ratio	Ratio before Distribution	Ratio after Distribution	Input Value
Labor	0.39	0.39 (labor)	$0.39 + 0.13 = \mathbf{0.52}$	$\alpha_1$
Agriculture Capital	0.09	0.30 (capital investment)	$0.3 + 0.1 = \mathbf{0.4}$	$\alpha_2$
Informal non-agricultural Capital	0.21			
Land	0.06	0.06 (land)	$0.06 + 0.02 = \mathbf{0.08}$	$\alpha_3$
Transfers	0.06	0.25 (other)	0.13	Already allocated to the three factors of production listed above
Others	0.19		0.1	
		0.02		
The rest are sorted, and even further divided proportionately, depending on the ratios (0.39:0.30:0.06) of labor, capital investment, and land.				

Based on the above data, it is set as follows:

$$\alpha \in \{\alpha_1, \alpha_2, \alpha_3\} = \{0.52, 0.40, 0.08\}$$

### 5.3.2 Household Data

#### (1) Consumption and Physical Assets (Durable Goods)

Although physical assets comprised of the house and household assets are normally classified into stocks, here the value of such assets is supposed to be categorized to the durable goods.

Based on the above supposition, the initial values of the consumption and physical assets are calculated using the World Bank’s data as follows. After subtracting saving and cost of human capital from the GDP, the residual is distributed to consumption and physical assets. The value of human capital is set using the data about investment in education in each country as reference. The share of physical assets in expenditure is also determined using the value from Housing (rent & other cost) (refer to the example shown in the below table). Moreover, values of consumption and physical assets in each income level are computed using the data about consumption at each income level. In addition, the value of physical assets is converted into stock. To consider durable years, for example, the value discounted by 10 % could be used when physical assets are amortized in 10 years.

- Configuration Example for Case Study

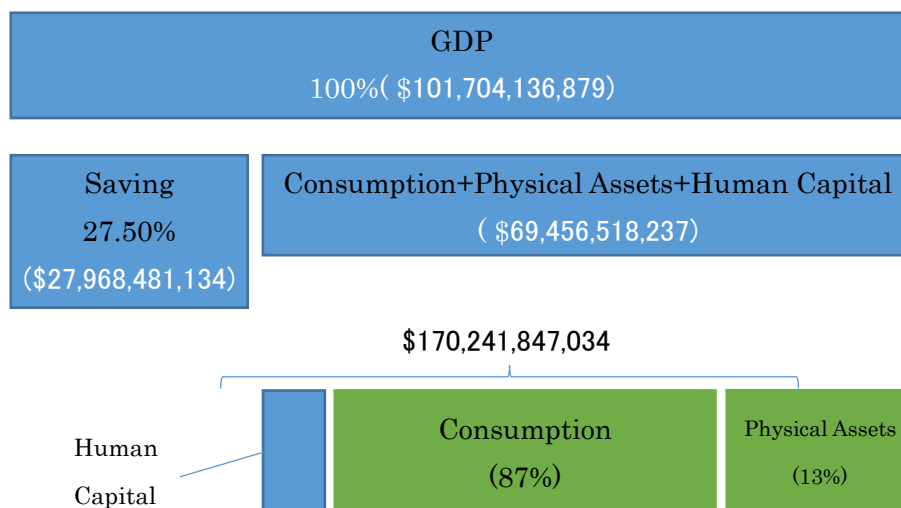


Figure 13. An Example for Estimating the Initial Value of Consumption and Physical Assets

In the Pakistan case study, investment in education per capita is set to \$27.6, and multiplying that value by total population, total investment in education is estimated. The residual obtained by subtracting saving and cost of human capital from the GDP is consumption and physical assets.

Share of consumption and physical assets is set to 13% based on the data in Housing (rent & other costs) in consumption by income class included by household survey, assets is distributed in each income level using household survey, and then consumption and physical assets per capita at each income level is obtained.

In addition, physical assets are discounted by 10% to be converted into stock.

Table 14. The Calculation of the Initial Value of Consumption and Physical Assets

Group	Share in Each Rank (%)	Consumption (USD)	Physical Assets (USD)
Poorest	9.0%	\$176.0	\$263.0
Poor	12.4%	\$242.2	\$361.8
Middle	15.6%	\$303.8	\$453.9
Rich	21.1%	\$410.3	\$613.8
Richest	41.9%	\$815.1	\$1,218.0

(2) Financial Assets

Since financial assets  $b_j$  are considered to be stock, the production capital stock  $K_0$  is distributed on the basis of the ratio of total income distribution. Strictly speaking, the distribution ratio of the stock account balance  $b_j$  and the total income distribution ratio are different; however, since stratified production capital stock data does not exist, the distribution ratio is assumed to be the same in this case.

● Configuration Example for Case Study

In the Pakistan case study, the whole production capital stock in Pakistan in 2004 is \$360,340 (Million USD, (2005 USD)) from the following calculating formula.

$r$  is the discount rate, and  $P$  and  $P_k$  are parameters determined based on the disaster damage rate.

$$K_0 = \frac{\alpha_2 \cdot P \cdot GDP_0}{r \cdot \delta_k \cdot P_k} = \$360,340(\text{Million USD})$$

where  $r = 0.0725$ ,  $P = \sum \mu_l \cdot (1 - \omega_l)^{\alpha_1} \cdot (1 - \omega_l)^{\alpha_2} \cdot (1 - \omega_l)^{\alpha_3} = 0$ .

By dividing this by the population of 33,424,985 in 2004., the per capita average production capital stock can be calculated. The average per capita production capital stock is \$2,322.5(USD).

By prorating this by the total income distribution ratio, financial assets are set as shown in Table 15.

Table 15. Calculation of Financial Assets Using the Income Distribution Ratio

Group	Gross Income Distribution Ratio(%)	Financial Assets(\$)
Poorest	9.5	\$2497.4
Poor	13.2	\$3470.1
Middle	16.4	\$4311.3
Rich	21.4	\$5625.8
Richest	39.4	\$10357.7

### (3) Land Area

The land distribution ratio is assumed to be equivalent to the initial distribution ratio of financial assets. In addition, the land distribution ratio is dependent on the initial value and is assumed to be constant.

Therefore, the land distribution ratio  $T_{share}$  is

$$T_{share} = \frac{b_j(0)}{\sum b_j(0)}. \quad (\text{Eq. 2})$$

Thus, the per capita land ownership percentage becomes

$$T_j(0) = \frac{T_{share}}{n_j}. \quad (\text{Eq. 303})$$

### ● Configuration Example for Case Study

In the Pakistan case study, the land distribution ratio is as follows. The ratio is assumed to be same as the distribution ratio of financial assets.

Table 16. Land Distribution Ratio Assets

Income Group	Land Distribution Ratio (%)
Poorest	9.5
Poor	13.2
Middle	16.4
Rich	21.4
Richest	39.4

#### (4) Human Capital

In this model, the average number of schooling years is used as a proxy variable for human capital.

Therefore, if the average number of schooling years increases, labor productivity is assumed to directly increase. Additionally, it is assumed that the time lag occurs before the improvement in the average number of schooling years is directly connected to the improvement in labor productivity. Some form of representation showing that an increase in average schooling years will lead to the increase in labor productivity in a certain number of years in the future is desirable, but specific data to show how long it takes for the effects actually to appear is not unavailable. It is, therefore, assumed that a rise in the number of schooling years leads to an immediate increase in labor productivity.

The average number of schooling years uses data published by the UNDP. The average number of schooling years is the average for those 25 years old and older.

As the average number of schooling years obtained is used for the regression analysis on investment in education, the average number of schooling years needs to be the continuous time series data. If this is not satisfied, regression analysis compliments that as the following example.

Moreover, if the number of schooling years or school enrollment at each income group is available, the average number of schooling years is calculated using that data. Here, by assuming that the average number of schooling years reflects that of the third group, the net schooling years is set on the assumption that the percentage of school attendance is 100%. Multiplying again that value by the number of schooling years in each group, the average number of schooling at each income level is obtained. When data is in shortage, the average number of schooling years in each income group is supposed to be common.

Table 17. Changes in Schooling Years

Year	1980	1990	2000	2005	2006	2007	2008	2009	2010	2011	2012
Average years of schooling	1.7	2.3	3.3	4.5	4.6	4.7	4.7	4.8	4.9	4.9	4.9

However, since there is no change in the average number of schooling years for each year in the data above, a regression equation is set using the data above. The annual target  $T_{edu}$  uses 1980 as the first year, and it is defined as  $T_{edu} = [1, 2, \dots, 33]$ .

$$h_j = -0.00021393 \cdot T_{edu}^3 + 0.01226631 \cdot T_{edu}^2 - 0.07520949 \cdot T_{edu} + 1.79181699. \quad (\text{Eq. 31})$$

The initial value is the value from 2004. In order to estimate average schooling year by social strata, average school enrollment by social strata is used.

Using average school enrollment, it is assumed that average schooling year of middle class is calculated with “pure estimated schooling year” multiply with average school enrollment of middle class. From this hypothesis, “pure estimated schooling year” is estimated, multiplying the school enrollment by social strata, average schooling year is estimated.

Table18. Calculate the schooling year by social strata

Average schooling year	Average enrollment rate	Pure estimated schooling year	Estimated schooling year by social strata
4.235	41%	7.843 (=4.23/54%)	3.22
	50%		3.92
	54%		4.24
	56%		4.39
	71%		5.57

(5) Hourly Human Investment (time invested in education)

The human capital accumulation of period  $t+1$  requires the human capital accumulation until the previous year and the flow of human capital needed for the next period. Human capital is assumed to depreciate by  $\delta_h$  every year and, if the human investment per unit time is denoted by  $m^l(t)$ , then

$$h(t+1) = (1 - \delta_h) \cdot h(t) + \iota \cdot m^l(t). \quad (\text{Eq. 5})$$

Here, it is assumed that  $\iota = 1$ , and solving for  $m^l(t)$

$$m^l(t) = \delta_h \cdot h(t) + \{h(t+1) - h(t)\}. \quad (\text{Eq.36})$$



Therefore, the human capital in the flow is seen to be formed by two elements: the element to compensate for the depreciation in the period  $t$  including the maintenance of knowledge, the exchange by knowledge obsolescence and the replacement of the workforce, and the element  $h(t+1)-h(t)$  of the improvement of human capital accumulation.

#### (6) Human Capital Cost Function Parameters

Next, the human capital accumulation coefficient in the cost function  $\eta$  is set. If the education investment costs necessary for human capital for each period are  $C_{edu}^l$ , as defined in (5), the human capital cost function  $\eta^l(m^l(t))$  can be formulated by

$$C_{edu}^l = \eta^l(m^l(t)). \quad (\text{Eq.37})$$

Next,  $C_{edu}^l$  is calculated, and then by estimating  $\delta_h$ , which is included in  $F(m^l(t))$ , the equation for the human capital cost function and human capital for each period is derived.

■ Education Investment Cost

$C_{edu}^l$  is the sum value of the government investment in education and the household investment in education for each period.

The government investment in education is calculated on the basis of the education expenditure share of GDP shown by the World Bank and the per capita GDP (in USD for 2005).

The household investment in education is estimated by calculating the education expenditure share of the total expenditure on the basis of the household survey data of each country, due to the lack of the standard database by World Bank with regard to household education investment. In the case there is only data for a limited number of years, an estimate is done as the following example procedure: from the ratio between the average annual education investment by household and the annual education investment by government obtained from the existing date, the average household share of education investment is calculated. This share is applied to the years where only government spending data exists, then  $C_{edu}^l$  is calculated.

● Configuration Example for Case Study

Although calculation is based on household survey, an estimate is done as the following procedure.

- ① The education investment by household is obtained from the breakdown of the total expenditure at each income class from household survey, and the averaging vale of all class is calculated.
- ② For years where both government and household spending data is available, by comparing the expenditure share for the two, the average percentage of household investment in education is calculated. This is applied to the years where only government spending data is exists.

Table 19. Ratio Calculation of Household and Governmental Investment in Education

	2004	2005	2007	2010	Average
Governmental Investment (USD(2005))	12.8	15.6	21.1	17.7	16.8
Household Investment (USD(2005))	9.7	13.4	18.1	25.4	16.7

Total	22.4	30.0	39.2	43.1	33.7
Household Investment Ratio	43%	45%	46%	59%	50%

Based on the above, the education expenditure for households is set as shown Table below.

Table 20. Procedure for Calculating Education Investment

Year	Per capita governmental and household investment in education (constant, USD for 2005)	Per capita governmental investment in education (constant, USD for 2005)	Education investment rate(%)	GDP per capita (constant, USD for 2005)	Household investment in education (constant, USD for 2005)					Average per capita household investment in education (constant, USD for 2005)
					poorest	poor	middle	rich	richest	
1980	12.5	8.4	2.1	396.4						4.1
1981	12.1	8.1	2.0	413.6						4.0
1982	12.7	8.6	2.0	425.9						4.2
1983	13.0	8.8	2.0	439.5						4.3
1984	13.7	9.2	2.1	446.3						4.5
1985	16.8	11.3	2.4	464.2						5.5
1986	18.8	12.7	2.7	473.7						6.2
1987	21.6	14.5	3.0	488.0						7.1
1988	0.0	0.0		508.6						0.0
1989	18.2	12.2	2.4	517.5						5.9
1990	19.6	13.2	2.5	524.9						6.4
1991	20.4	13.8	2.6	536.3						6.7
1992	21.4	14.4	2.6	562.6						7.0
1993	19.9	13.4	2.4	558.0						6.5
1994	21.8	14.7	2.6	564.2						7.1
1995	24.1	16.3	2.8	577.1						7.9
1996	24.6	16.6	2.8	589.3						8.0
1997	26.0	17.5	3.0	579.6						8.5
1998	0.0	0.0		579.0						0.0
1999	22.7	15.3	2.6	585.5						7.4
2000	16.3	11.0	1.8	596.7						5.3
2001	0.0	0.0		596.0						0.0
2002	0.0	0.0		603.5						0.0
2003	18.0	12.1	1.9	621.5						5.9
2004	22.4	12.8	1.9	655.5	4.3	6.1	7.6	10.1	20.1	9.7
2005	29.0	15.6	2.3	693.2	5.9	8.3	10.5	13.8	28.5	13.4
2006		19.0	2.6	722.6	0.0	0.0	0.0	0.0	0.0	0.0
2007	39.2	21.1	2.8	743.5	8.2	11.4	14.4	18.9	37.5	18.1
2008		21.7	2.9	742.2	0.0	0.0	0.0	0.0	0.0	0.0
2009		20.2	2.7	749.4	0.0	0.0	0.0	0.0	0.0	0.0
2010	43.1	17.7	2.4	748.0	12.0	16.5	20.7	26.8	50.9	25.4
2011		0.0		755.7	18.6	25.6	32.2	42.1	82.9	40.3
2012		0.0		772.9						

Estimated by multiplying the governmental per capita investment by 48.5%.



■ Human Capital Cost Function

Next, given the educational investment cost,  $\eta^l(m^l(t))$  is estimated. The educational investment costs are assumed to gradually increase with an increase in the number of schooling years, and it is supposed that the marginal cost also increases at the time of a disaster. In this model, this is approximated using a quadratic equation as follows:

$$\eta^l(m^l(t)) = C_{edu}^l = \eta_{2l}m^l(t)^2 + \eta_{1l}m^l(t) + \eta_{2l} \quad (\text{Eq.38})$$

Since  $C_{edu}^l$ ,  $h(t)$ , and  $h(t + 1) - h(t)$  are given, regression using a quadratic curve was performed while changing  $\delta_h$ .  $\delta_h$  is determined so that  $\eta_{2l}$  is positive value and the correlation coefficient equals to or greater than a certain fixed value.

● Configuration Example for Case Study

In the case of Pakistan case study, using the data below, as a result of regression using a quadratic curve while changing  $\delta_h$ ,  $\delta_h = 0.075$  is set as shown below.

Using this regression equation, the human capital cost function is decided:

$$\eta^l(m^l(t)) = 2.499m^l(t)^2 + 41.145m^l(t) + 8.4308$$

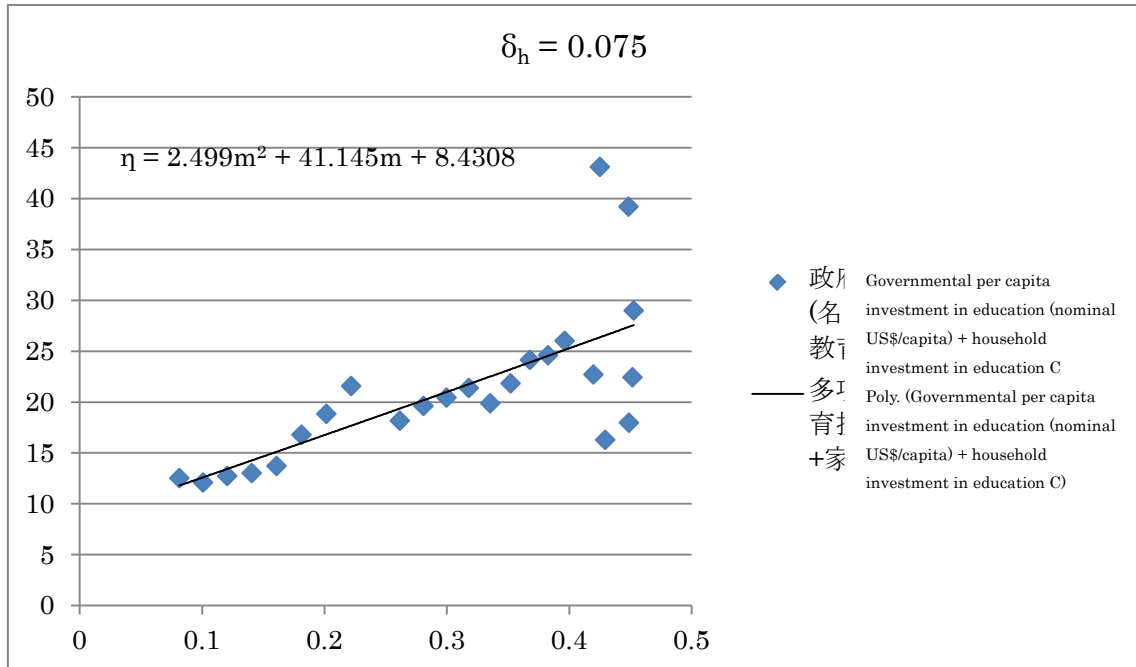


Figure 21. Estimation of the Human Capital Cost Function

### 5.3.3 Disaster Data

When setting the disaster damage rare in the model, the magnitude, frequency and damages of disaster are considered to be used. However disaster data for developing countries published by UNISDR and EM-DAT is short of the statistics on the magnitude and frequency, while that on the damages is sufficient. In this model, therefore, the damage rate is set based on the damages in terms of the availability of disaster data for developing countries,

Although as the way of setting the disaster damage rate, disaster simulations and estimation of the disaster damage rate function based on the past statistical data are considered to be applied, it is likely that available data is restricted.

Therefore, in this model, the existing disaster damage data is stacked in ascending order and divided equally into 5 disaster ranks, and then the damage rate is set for each rank. The data on disaster damage is basically collected from the UNISDR database *desinventar*.

If the data with regard to the disaster frequency, rank is determined taking both the damage rate and frequency into account.

As a representative value of the disaster damage rate at each disaster rank, the average, median, maximum and minimum value of the disaster damage data in each rank are considered to be used. (You need to set a statistical indicator such as the maximum data if the disaster damage rate is too small, or the minimum data if it is too large, considering the present reappearance.)

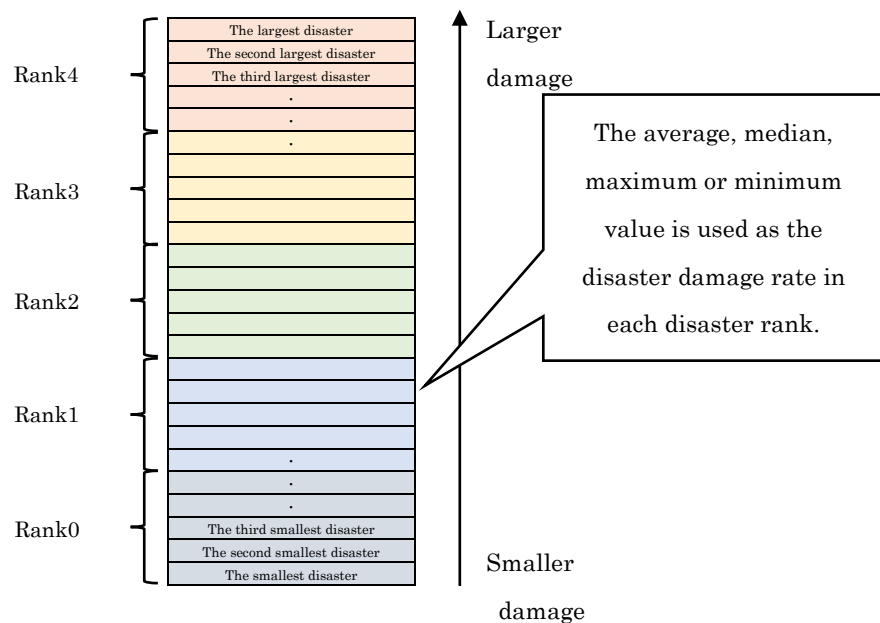


Figure 22. The Image of the Setting of the Damage Rank (the Case of Equal Disaster Frequency at each Ranks)

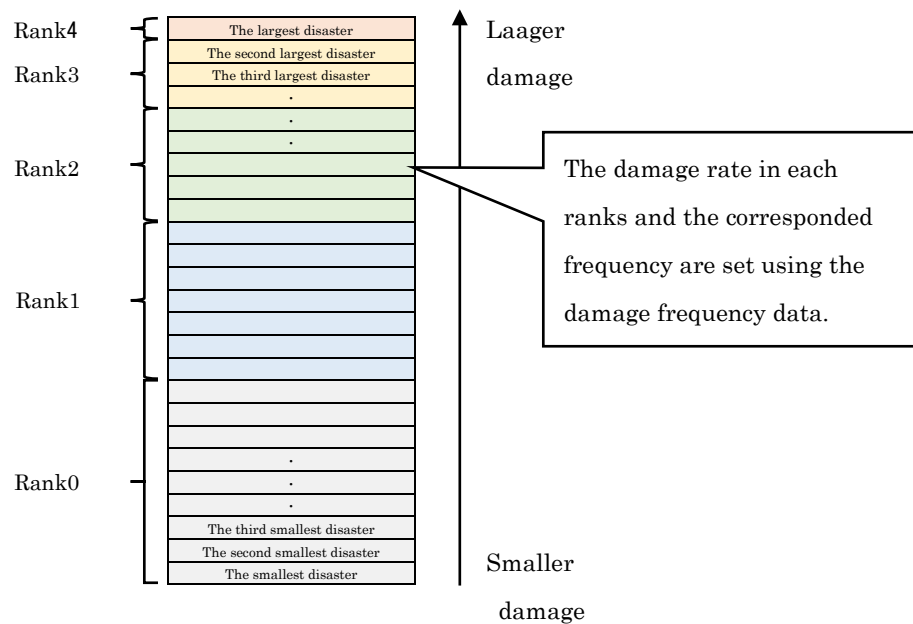


Figure 23. The Image of the Setting of the Damage Rank (the Case of Variable Disaster Frequency at each Ranks)

● Configuration Example for Case Study

In Honduras case study, each disaster damage rate is calculated from the formulas below using the data from UNISDR desinventar and World Bank World Development Indicators. Due to the shortage of the data on the frequency, the damage frequency for each disaster rank is supposed to be the same.

$$\text{Damage rate of human capital} = \text{Damaged population}^{*1} \div \text{Total population}$$

$$\text{Damage rate of land} = \text{The size of damaged crops area} \div \text{The size of cultivated area}$$

$$\text{Damage rate of financial assets} = \text{Damages} \div \text{National savings}$$

$$\text{Damage rate of physical assets}^{*2} = \text{Damage rate of financial assets}$$

\*1 The total number of injured and refugees caused by disaster, excluding the killed.

\*2 Due to the data constraint, damage rate of physical assets is assumed to be equal to that of financial assets.

By using these formulations and following the setting method explained above, the disaster damage rate is divided into five ranks. As the representative value of the damage rate in each rank, the median of the damage rate in each rank is used.

Table 24. Setting of Each Disaster Damage Rate

Disaster rank	Damage rate to human capital	Damage rate of land	Damage rate of financial assets
0	0.00	0.00	0.00
1	0.00	0.00	0.00
2	0.00	0.01	0.01
3	0.00	0.06	0.11
4	0.04	0.16	1.43

\*Each disaster rate is set by the median of the damage rate in each disaster damage rank.

Table 25. The Setting of the Damage Rate of Human Capital and the Disaster Rank in each year (Honduras)

Year	Total population	No damaged	Damage rate to human capital	Cumulative relative frequency	Disaster rank
1974	3,015,607	1,498	0.000	0.351	1
1975	3,107,735	900	0.000	0.324	1
1976	3,204,880	9,995	0.003	0.648	3
1977	3,306,985	0	0.000	0.000	0
1978	3,413,422	2,670	0.001	0.405	2
1979	3,523,279	26,559	0.008	0.729	3
1980	3,635,862	116,044	0.032	0.864	4
1981	3,750,850	1	0.000	0.189	0
1982	3,868,314	0	0.000	0.000	0
1983	3,988,404	2,976	0.001	0.378	1
1984	4,111,424	0	0.000	0.000	0
1985	4,237,518	0	0.000	0.000	0
1986	4,366,493	0	0.000	0.000	0
1987	4,497,954	13,307	0.003	0.567	2
1988	4,631,575	3,740	0.001	0.432	2
1989	4,766,961	18	0.000	0.216	1
1990	4,903,694	50	0.000	0.243	1
1991	5,041,781	53	0.000	0.270	1
1992	5,180,884	741	0.000	0.297	1
1993	5,319,841	10,715	0.002	0.540	2
1994	5,457,189	0	0.000	0.000	0
1995	5,591,935	27,249	0.005	0.675	3
1996	5,723,639	17,018	0.003	0.594	2
1997	5,852,719	0	0.000	0.000	0
1998	5,980,152	518,973	0.087	0.945	4
1999	6,107,385	7,315	0.001	0.486	2
2000	6,235,561	8,935	0.001	0.513	2
2001	6,365,040	91,026	0.014	0.837	4
2002	6,495,801	308,161	0.047	0.918	4
2003	6,628,171	214,540	0.032	0.891	4
2004	6,762,426	82,152	0.012	0.810	4
2005	6,898,825	80,795	0.012	0.783	3
2006	7,037,428	7,478	0.001	0.459	2
2007	7,178,436	76,079	0.011	0.756	3
2008	7,322,368	979,000	0.134	1.000	4
2009	7,469,844	36,860	0.005	0.702	3
2010	7,621,204	800,247	0.105	0.972	4
2011	7,776,669	23,630	0.003	0.621	3

Table 26. The Setting of the Damage Rate of Land and the Disaster Rank in each year (Honduras)

Year	The size of cultivated land(ha)	The size of crops land(ha)	Damage rate of land	Cumulative relative frequency	Disaster rank
1974	1,384,000	22,450	0.016	0.567	2
1975	1,413,000	650	0.000	0.162	0
1976	1,438,000	9,717	0.007	0.378	1
1977	1,503,000	250,000	0.166	0.918	4
1978	1,504,000	283	0.000	0.108	0
1979	1,494,000	19,248	0.013	0.486	2
1980	1,484,000	2,866	0.002	0.216	1
1981	1,481,000	7,431	0.005	0.324	1
1982	1,476,000	572	0.000	0.135	0
1983	1,467,000	22,907	0.016	0.540	2
1984	1,464,000	0	0.000	0.000	0
1985	1,455,000	13,765	0.009	0.459	2
1986	1,451,000	0	0.000	0.000	0
1987	1,441,000	7,004	0.005	0.297	1
1988	1,431,000	28,950	0.020	0.594	2
1989	1,446,000	6,131	0.004	0.270	1
1990	1,462,000	111,812	0.076	0.837	4
1991	1,492,000	380,778	0.255	0.972	4
1992	1,515,000	1,697	0.001	0.189	0
1993	1,683,000	13,494	0.008	0.405	2
1994	1,650,000	0	0.000	0.000	0
1995	1,600,000	14,548	0.009	0.432	2
1996	1,600,000	3,700	0.002	0.243	1
1997	1,520,000	0	0.000	0.000	0
1998	1,520,000	50,072	0.033	0.621	3
1999	1,468,000	77,555	0.053	0.675	3
2000	1,068,000	71,460	0.067	0.783	3
2001	1,068,000	60,182	0.056	0.702	3
2002	1,068,000	577,167	0.540	1.000	4
2003	1,068,000	61,354	0.057	0.756	3
2004	1,050,000	14,084	0.013	0.513	2
2005	1,050,000	165,318	0.157	0.891	4
2006	1,050,000	60,022	0.057	0.729	3
2007	1,050,000	72,977	0.070	0.810	4
2008	1,018,000	216,588	0.213	0.945	4
2009	1,020,000	50,133	0.049	0.648	3
2010	1,020,000	100,732	0.099	0.864	4
2011	1,020,000	5,864	0.006	0.351	1



Table 27. The Setting of the Damage Rate of Financial Assets and the Disaster Rank in each year (Honduras)

Year	National savings	National savings (\$)	Damage rate of financial assets	Cumulative relative frequency	Disaster rank
1974	210,463,187	300,000	0.001	0.324	1
1975	102,666,973	1,550,000	0.015	0.567	2
1976	188,981,072	4,602,240	0.024	0.594	2
1977	352,148,566	13,901,000	0.039	0.648	3
1978	501,444,195	0	0.000	0.000	0
1979	578,858,034	839,465,000	1.450	0.918	4
1980	355,386,361	190,000	0.001	0.243	1
1981	257,853,791	15,300	0.000	0.162	0
1982	4,517,824	121,480,000	26.889	1.000	4
1983	24,220,960	23,634,500	0.976	0.864	4
1984	107,845,698	1,543,000	0.014	0.540	2
1985	374,063,195	0	0.000	0.000	0
1986	313,716,457	500,000	0.002	0.351	1
1987	530,062,541	226,776	0.000	0.216	1
1988	1,148,056,607	42,650,000	0.037	0.621	3
1989	1,031,641,118	121,540,000	0.118	0.702	3
1990	1,744,547,533	461,250,000	0.264	0.810	4
1991	2,006,385,027	10,546,707,025	5.257	0.972	4
1992	2,246,182,360	5,272,000	0.002	0.432	2
1993	3,921,334,456	750,640,000	0.191	0.783	3
1994	6,230,111,593	260,000,000	0.042	0.675	3
1995	7,654,471,834	1,368,662,590	0.179	0.729	3
1996	9,099,981,654	5,000,000	0.001	0.270	1
1997	13,224,417,152	0	0.000	0.000	0
1998	15,388,624,528	72,220,140,095	4.693	0.945	4
1999	18,014,414,609	13,192,536,000	0.732	0.837	4
2000	17,148,825,049	0	0.000	0.000	0
2001	14,596,746,063	0	0.000	0.000	0
2002	16,279,281,348	23,177,147,971	1.424	0.891	4
2003	19,774,168,803	44,000,000	0.002	0.405	2
2004	24,218,904,135	2,500,000	0.000	0.189	0
2005	33,834,487,382	6,078,385,684	0.180	0.756	3
2006	40,173,463,684	70,800,000	0.002	0.378	1
2007	43,410,585,815	30,111,603	0.001	0.297	1
2008	40,172,320,966	175,580,000	0.004	0.459	2
2009	28,952,492,101	1,900	0.000	0.135	0
2010	33,551,267,707	244,068,133	0.007	0.486	2
2011	26,890,061,996	272,454,663	0.010	0.513	2

## 6 Results

As a result, we can obtain the simulation data and figures as follows:

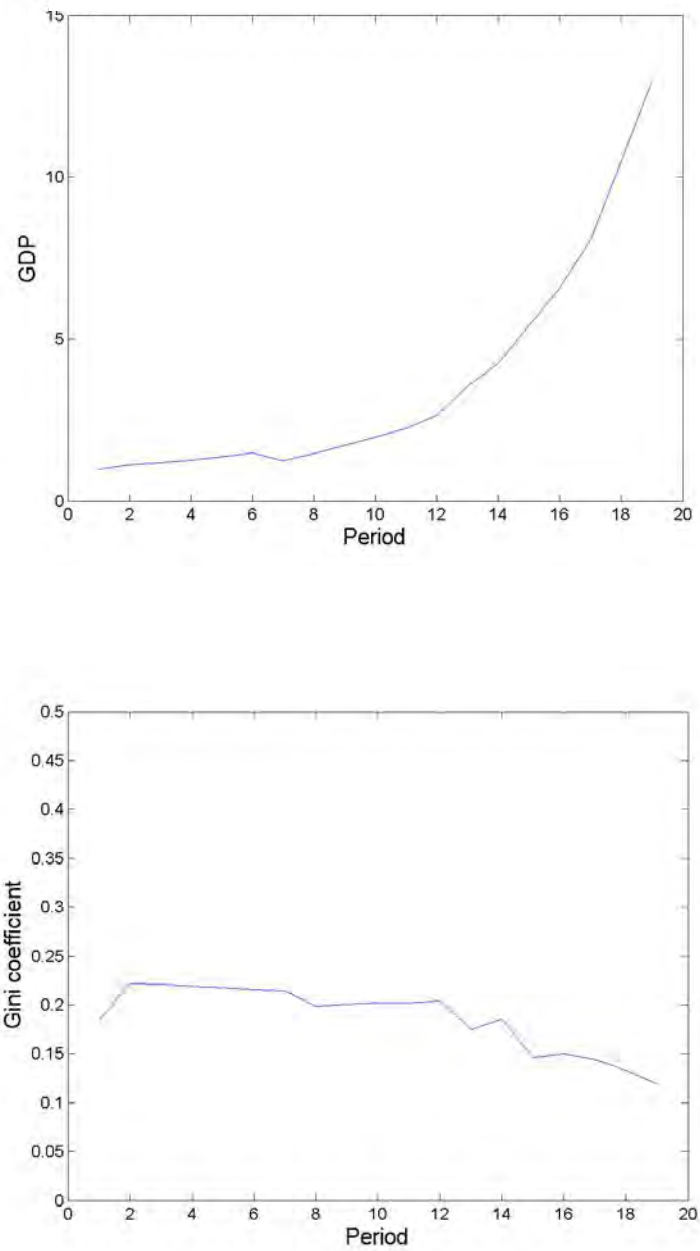
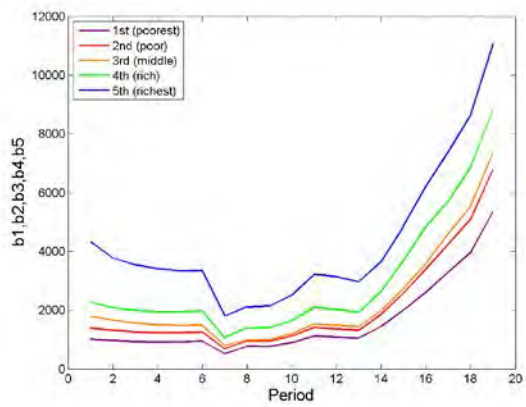
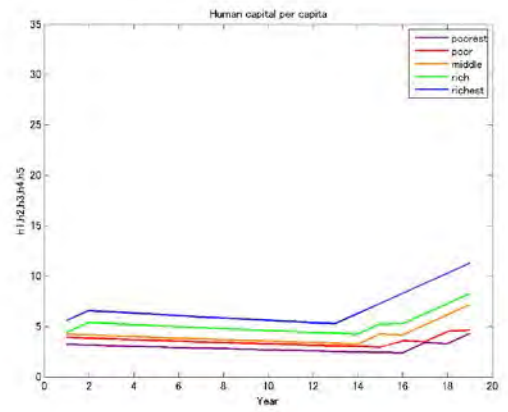
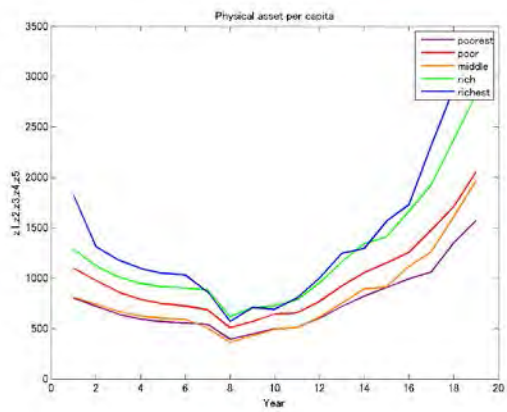
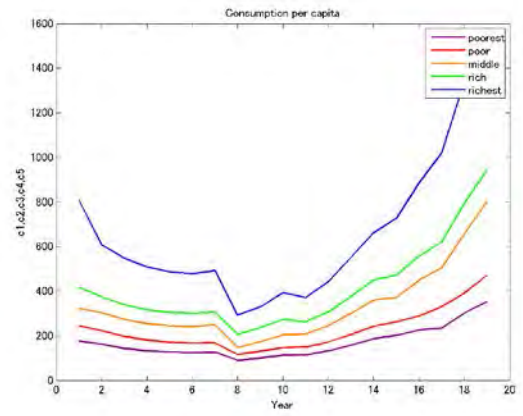
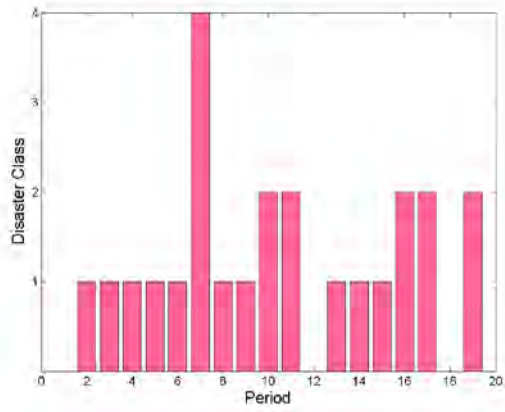
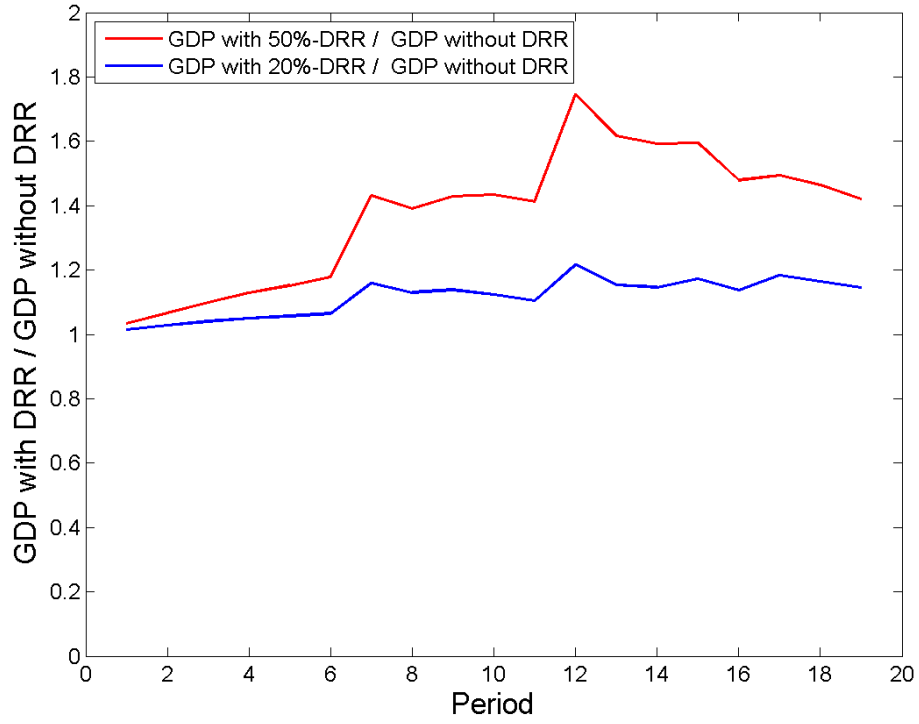
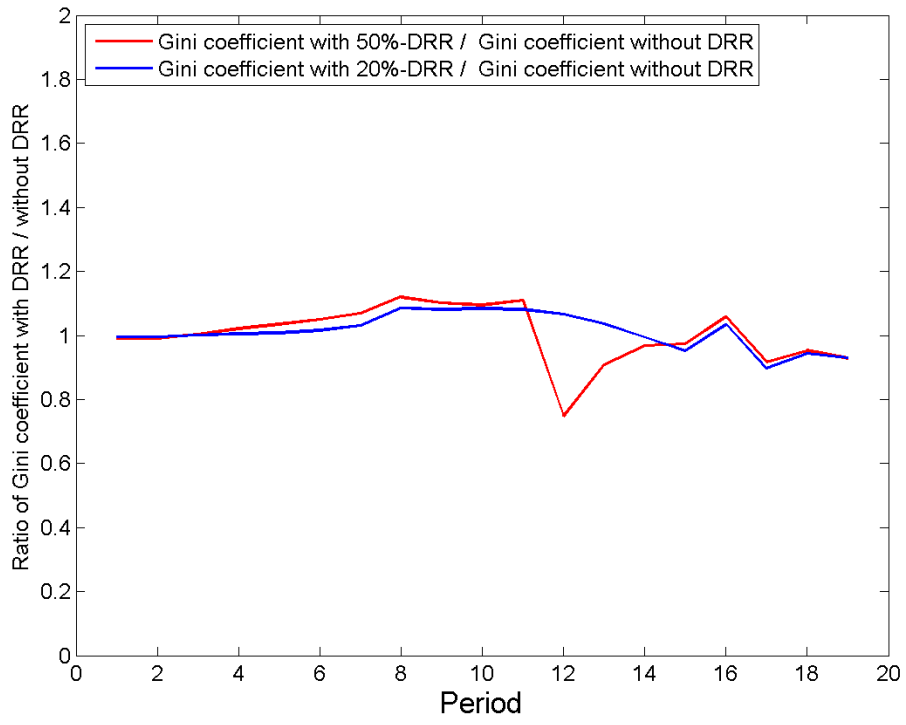


Figure 28. Example Results (1 of 3)



Figures 29. Example Results (2 of 3)





Figures 30. Example Results (3 of 3)

## 7 Future Challenges

In this section, possible improvements and the challenges of constructing Ver1.4 are presented.

### 7.1 Modeling Challenges

#### (1) Exchange between groups

- Exchange between groups for both households and firms is currently not permitted as the model assumes a closed economy; however, in the future, exchange between groups will be carried out.

#### (2) Formation of human capital

- The average number of schooling years is used as a proxy variable for human capital; however, in the future, the time lag between the improvement in the average schooling years and the improvement in labor productivity must be taken into account.
- Poverty and the realities of developing countries, in addition to the average number of schooling years, must also be considered as proxy variables for human capital.

#### (3) Land resource transactions

- Land resources are dependent on the initial value and subsequent transactions are not performed; however, the trading of land resources should also be considered.

### 7.2 Data Challenges

#### (1) Rate of exogenous growth

- The rate of exogenous growth for the Pakistan case study was calibrated to match the actual values of the GDP in 2004 and 2010; however, since the value of the rate of exogenous growth will significantly affect subsequent economic growth, it is preferable to use data from a longer period during which big technological innovations and disasters do not exist.

#### (2) Shared parameters of the production function

- Although the shared parameters of the production function are determined on the basis of inter-industry tables, there are some developing countries that do not create inter-industry tables on a regular basis. In such cases, there is a need to develop a

method that can use an index to replace these tables to determine the parameters.

(3) Initial land distribution ratio

- Since data were not available, the land distribution ratio was treated as equal to the initial distribution ratio of financial assets. However, even though financial assets and land assets are considered to have a correlation, they are separate elements. In the future, it will be necessary to obtain land data that properly reflects the actual situation.

(4) Human capital data

- Currently, only national level data for the average number of schooling years is used as a proxy variable for human capital. However, stratified data exists for the average enrollment rate and this data is used to virtually estimate the stratified average enrollment rate based on the data in the model. Since a clear correlation is not present between the average enrollment rate and the average number of schooling years, it is necessary to use stratified data of the average number of schooling years.

(5) Human investment data

- Since research and data availability on hourly human capital investment is insufficient, the human capital investment level is set in a simple manner using average schooling years and educational expenditure data. However, to more accurately reflect the actual situation, better research and more detailed data must be used. Alternatively, data can be collected through panel surveys.
- To convert time invested in education into a monetary expense, in addition to data limitations for both the governmental and household investment in education, a clear correlation between investment in education and the average number of schooling years has not been established. Future panel surveys may help to identify an appropriate functional form using detailed data for each income group.

(6) Disaster damage data

- In regard to the disaster damage data, a simple damage function using data from the UNISDR-supported DESINVENTAR<sup>8</sup> and EM-DAT(CRED) is fundamental to the model, but when performing sophisticated damage prediction in light of climate change, etc., it is necessary to set the appropriate damage function using geographical

---

<sup>8</sup><http://www.desinventar.org/>

conditions and detailed damage data.

- Flood damage was the only disaster considered in the case study on Pakistan; therefore, to more properly verify the effects of DRR, it is necessary to express numerous types of disasters and treat them as independent events, as well as show multiple disaster scales for each.



## Reference: Calculation Algorithm of the Program

The programs constructed above were performed in accordance with the following calculation algorithms.

The program algorithms are as shown in Figure 21.

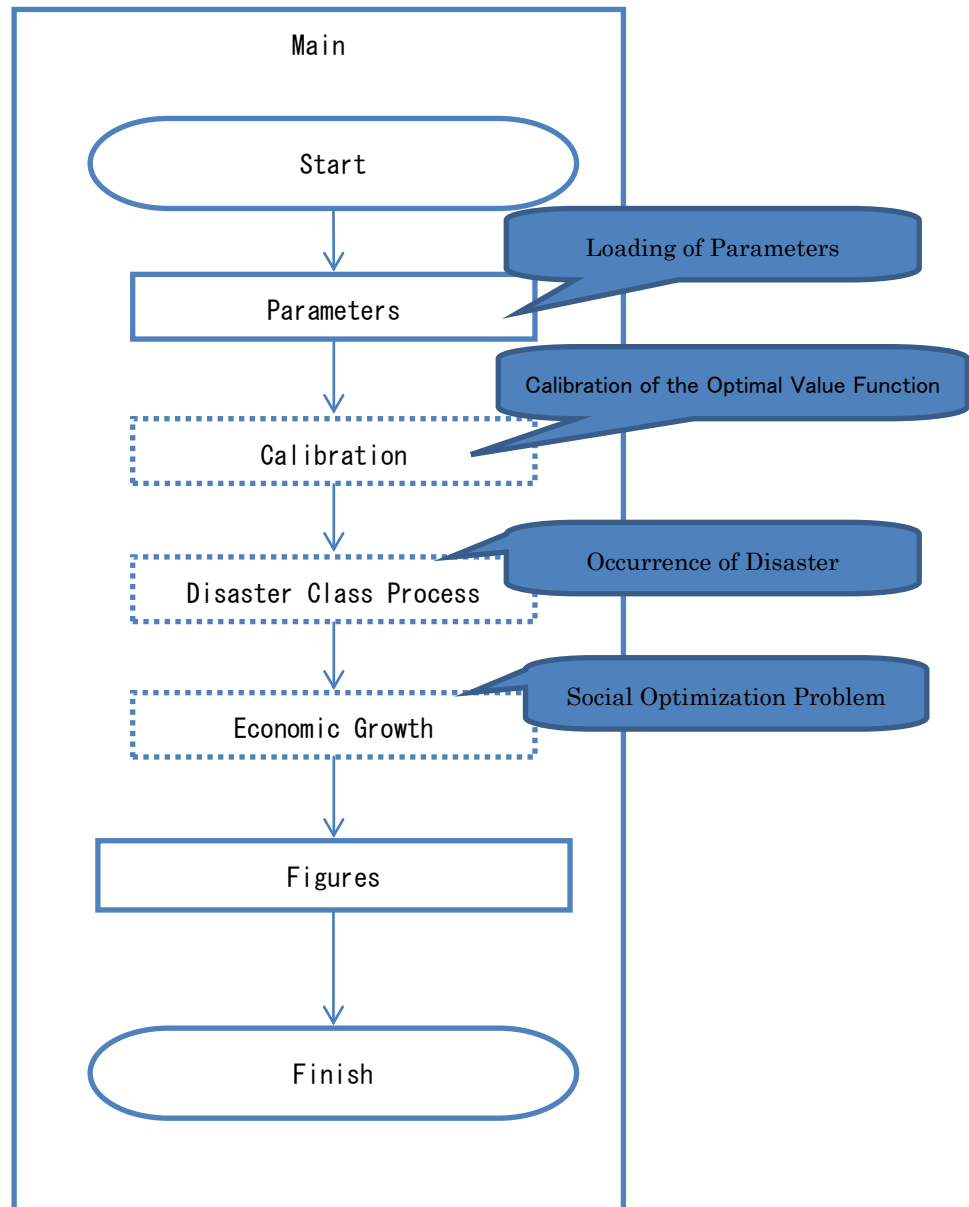


Figure 31. Overall Calculation Algorithm for the Program

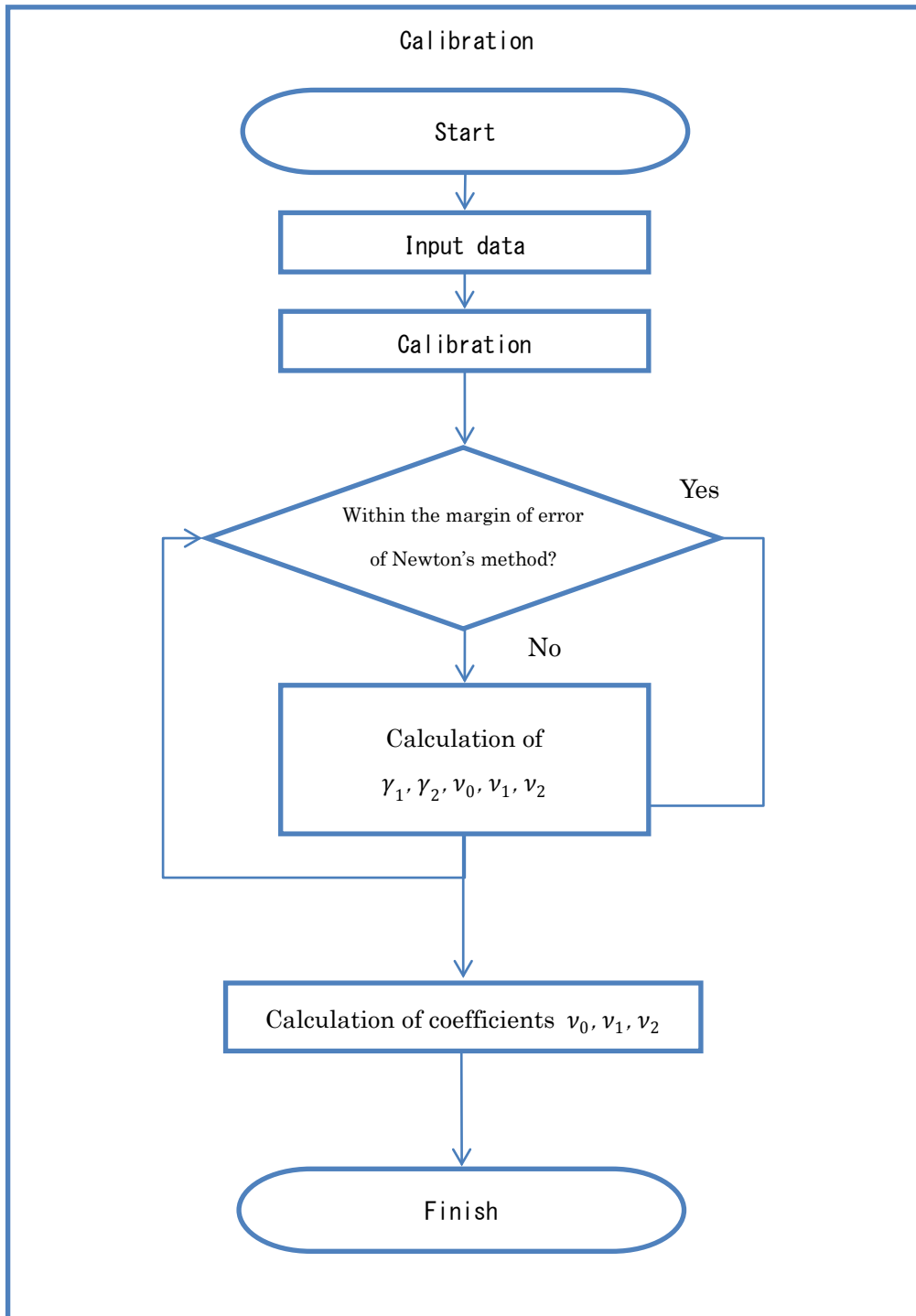


Figure 32. Calibration Calculation Algorithm

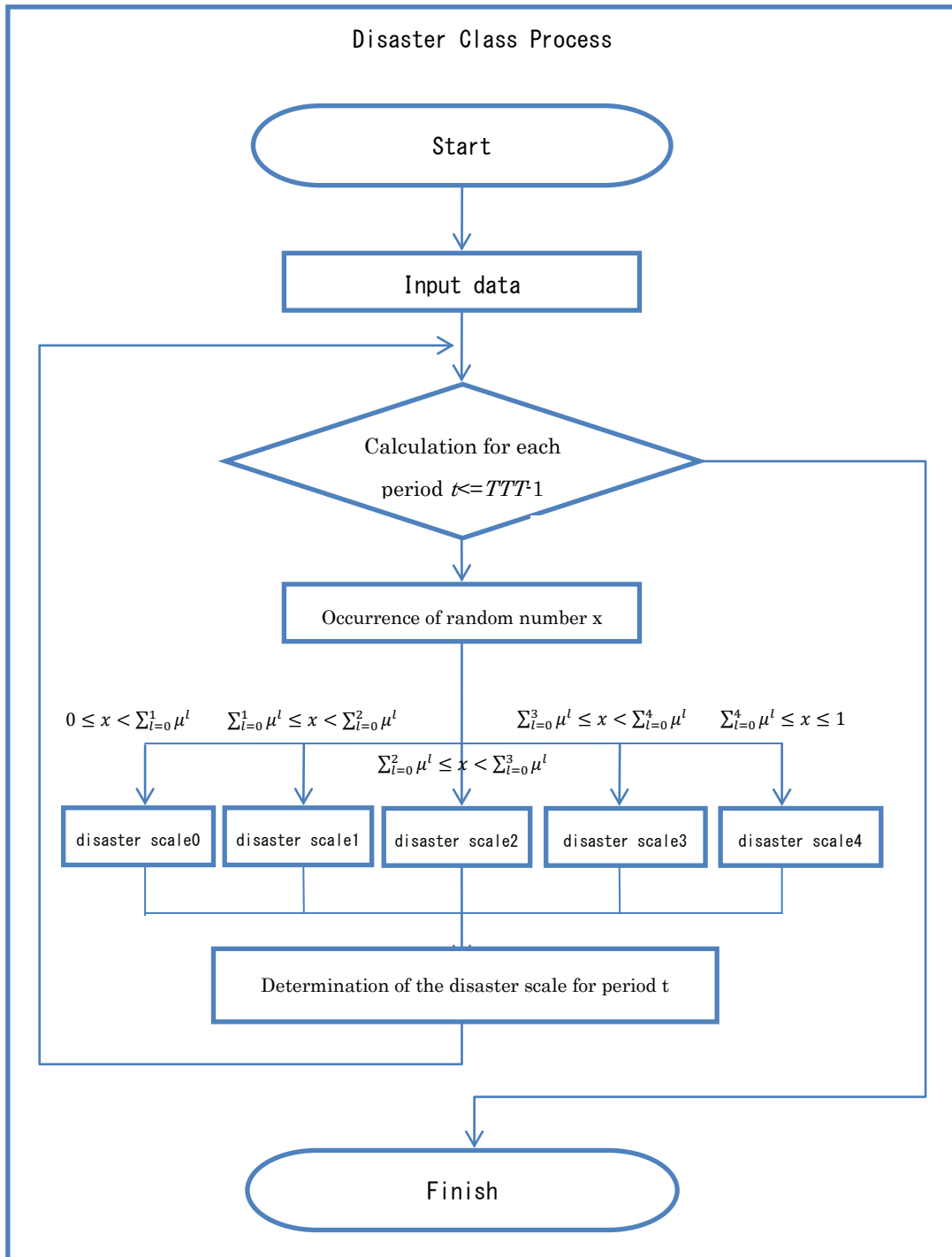


Figure 33. Disaster Class Process Calculation Algorithm

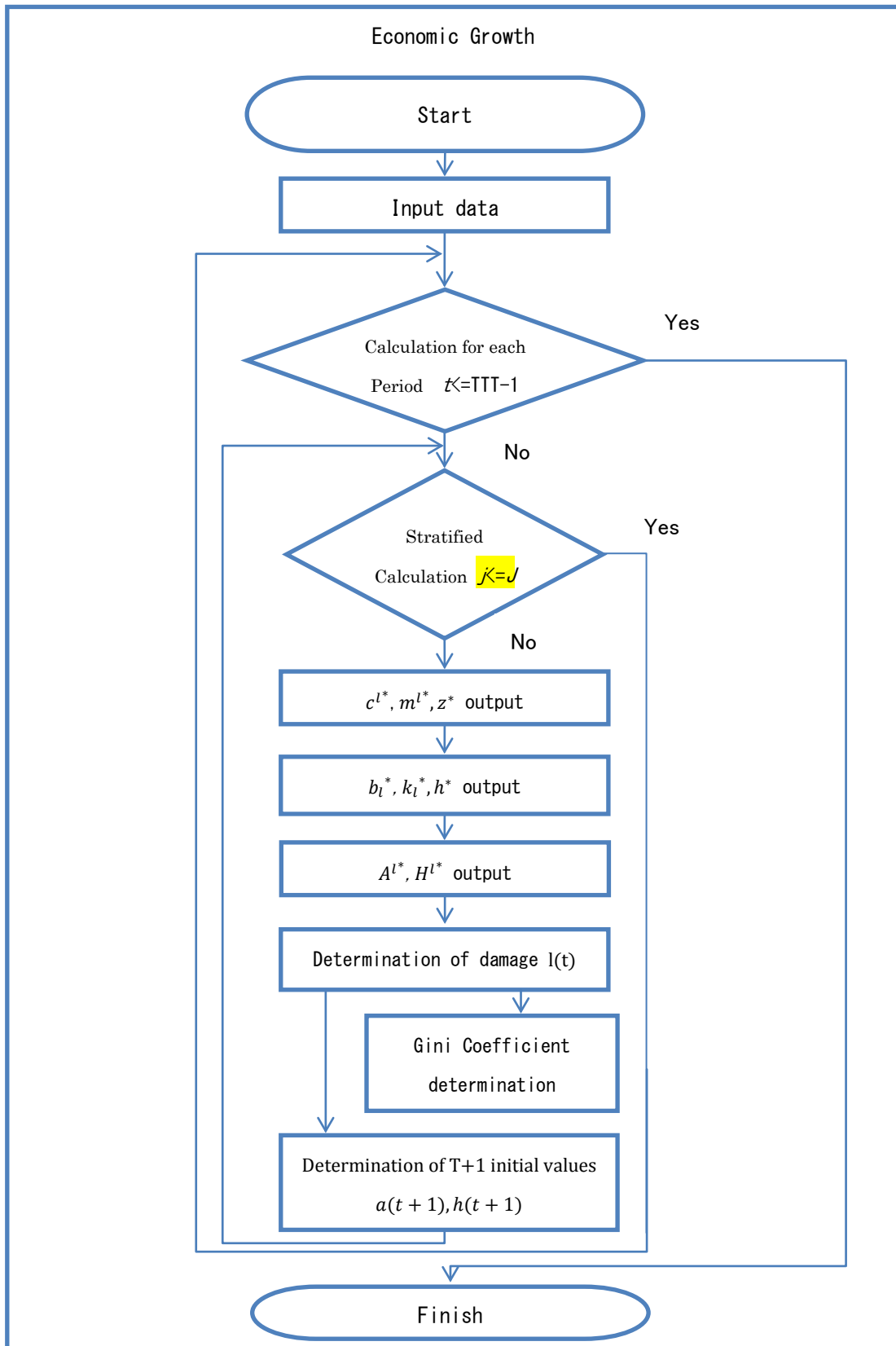


Figure 34. Economic Growth Calculation Algorithm

## Reference: Operating Procedure for MATLAB

In this part operating procedure for MATLAB will be explained. First is how to input parameters and second is how to execute the simulation with MATLAB.

### NOTE:

- DR<sup>2</sup>AD model ver1.4 is a program which used MATLAB, it is necessary to be installed MATLAB in order to execute the program.
- Meanwhile, script files(m file) could be edit as a text files even though MATALB is not installed.
- In case where MATLAB is not installed, first we edit parameters with text file without MATLAB. Then, using other computers where MATLAB is installed, import those parameters into MATLAB and execute the program.

### 1. Input and edit Parameters

Here, it is explained how to edit parameters with text editor.

#### ① Choose parameter file

Select a parameter file (parametersXXX.m) as a right click, then choose “edit”.

\*If needed, input the name of country in XXX.



② Input Parameters

Parameters are then opened as a text file; put the data of each country. The figure below shows an example of without DRR.

Concrete method for editing parameters will be explained as ④.

③ Save parameter files

Not only the case of without DRR, edit parameters of the case of with DRR. (parametersXXXRM(50 and 20).m). Finally, save those text data.

\*Those procedure is also carried directly on the screen of MATLAB if it is installed. (see 2.④)

④ Concrete method for editing parameters.

Followings are editing method for text editors. Blue part is the part where data collected in tables are input. Green part is the part where editors should input the number or data such as initial GDP. Orange part is the part which is demanded to change only for the case of DRR. If the parameter is for without DRR, it should not be touched.

All the other parts, it is not necessary to change.

Note that do not forget all parameters as Blue part and Green part for DRR-50% case and 20% case. Without DRR, DRR-50%, and DRR-20% must be modified as the same.

Following are the example as the case of Pakistan. The number in programs is related to the number in table below.

Table11. Method for Setting Variables and Initial Values

	Variable		EX) Setting for Pakistan
(1)	$n_j$	Population	<p>■Total population (2004) 155,151,394 people * Source: World Bank</p> <p>■Stratified population (2004) ⇒The total population is distributed to each of the five groups, depending on size. *Source: "Poverty Profile of the Islamic Republic of Pakistan," Japan Bank for International Cooperation (2007); Each group: 31,030,279 people (20% of the total population from each group)</p>
(2)	$\rho$ rho	Social discount rate	0.05
(3)	$\delta_z$ delta	Physical assets depreciation rate	0.2 Set by a 10%–30% assets write-off rate in Pakistan. *Source: Investment and corporate law, accounting tax, and labor in Bangladesh, Pakistan, Sri Lanka - Kuno Yasunari
(4)	$\delta_k$	Production capital depreciation rate	0.02
(5)	$r_j$	Capital rent	Determined endogenously
(6)	$B$	Exogenous growth rate	63.0198 ⇒The GDP initial value/ $h(0)^{\alpha_1}K(0)^{\alpha_2}T(0)^{\alpha_3}$ Set for annual growth of $(1 + 0.095)^{t-1}$ *Setting method listed in Section 5.3.1(1)

	Variable		EX) Setting for Pakistan
(7)	$\alpha_i$	Production elasticity's of production function	$\alpha_1 = 0.52$ $\alpha_2 = 0.40$ $\alpha_3 = 0.08$ *Setting method listed in Section 5.3.1(2)
(8)	$c_j^l$	Consumption goods (non-durable)	1 <sup>st</sup> (poorest) : \$176.0 2 <sup>nd</sup> (poor) : \$242.2 3 <sup>rd</sup> (middle) : \$303.8 4 <sup>th</sup> (rich) : \$410.3 5 <sup>th</sup> (richest) : \$815.1 *Source: Household Integrated Economic Survey, Pakistan
(9)	$z_j$	Physical assets (home, household goods)	1 <sup>st</sup> (poorest) : \$26.3 2 <sup>nd</sup> (poor) : \$36.2 3 <sup>rd</sup> (middle) : \$45.4 4 <sup>th</sup> (rich) : \$61.3 5 <sup>th</sup> (richest) : \$121.8 ⇒Set to 8.67%–9.99% to 10% past investment rate of Housing (rent & other costs)/Rural from Pakistan's Household Integrated Economic Survey. *Source: Household Integrated Economic Survey, Pakistan *Setting method listed in Section 5.3.2(1).
(10)	$\theta$	Relative risk aversion	2 *Reference: Kraay and Raddatz (2007), Poverty traps, aid, and growth, Journal of Development Economics, 82, 315-347.
(11)	$\bar{c}$	Minimum consumption amount required for survival	Assumed to be 0. * David (1998) said that “The least cost requirement for sustaining an individual's minimum dietary needs is approximately \$300 a year (in 1980 dollars).”
(12)	$b_j$	Financial assets	1 <sup>st</sup> (poorest) : \$1104.3 2 <sup>nd</sup> (poor) : \$1534.4 3 <sup>rd</sup> (middle) : \$1906.4 4 <sup>th</sup> (rich) : \$2487.6 5 <sup>th</sup> (richest) : \$4579.9 *Source: Finance Division, Government of Pakistan, Pakistan Economic Survey. (national savings rate) *Setting method listed in Section 5.3.2(2)
(13)	$\tilde{T}_j$	Total land area	1 <sup>st</sup> (poorest) : 9.5% 2 <sup>nd</sup> (poor) : 13.2% 3 <sup>rd</sup> (middle) : 6.4% 4 <sup>th</sup> (rich) : 21.4% 5 <sup>th</sup> (richest) : 39.4% *Setting method listed in Section 5.3.2(3)



	Variable		EX) Setting for Pakistan
(14)	$\xi_{xi}$	Formation of physical assets	Determined endogenously when $z_j$ is determined.
(15)	$h_j$	Human capital	1 <sup>st</sup> (poorest) : 3.22years 2 <sup>nd</sup> (poor) : 3.92years 3 <sup>rd</sup> (middle) : 4.24years 4 <sup>th</sup> (rich) : 4.39years 5 <sup>th</sup> (richest) : 5.57years *Setting method listed in Section 5.3.2(4)
(16)	$m_j^l$	Hourly human investment	Determined endogenously. *Setting method listed in Section 5.3.2(5)
(17)	$\delta_h$ delta	Depreciation rate of human capital	0.075 Estimated from average number of schooling years in Pakistan. *Setting method listed in Section 5.3.2(6)
(18)	$w_j$	Wage rate (for 1 human capital)	Determined endogenously.
(19)	$\eta_i$ eta	Parameters of the human capital cost function	$\eta_0$ : 7.98 $\eta_1$ : 44.2 3.30 3.70 $\eta_{2i}$ : 4.10 4.50 4.90 *Setting method listed in Section 5.3.2(6)
(20)	$\gamma_i$ gamma	Shared parameters of consumption	Determined endogenously
(21)	$\omega_j^l$	Damage rate of human capital due to disaster	0.0000018%–0.000012% ⇒Due to data limitations, the disaster damage rate is currently consistent for each income group. *Setting method listed in Section 5.3.3
(22)	$\phi_j^l$	Damage rate of physical assets due to disaster	1 <sup>st</sup> (poorest) : 0.9%–5.4% 2 <sup>nd</sup> (poor) : 0.7%–8.4% 3 <sup>rd</sup> (middle) : 5.5%–22% 4 <sup>th</sup> (rich) : 0.9%–8.2% 5 <sup>th</sup> (richest) : 2.0%–22% *Setting method listed in Section 5.3.3
(23)	$\psi^l$	Damage rate of financial assets due to disaster	7.9%~55% Due to data limitations, the disaster damage rate is currently consistent for each income group. Only uses data from Pakistan between 1976 and 2011 (36 years) *Setting method listed in Section 5.3.3
(24)	$\tau^l$	Damage rate of land due to disaster	2.1%~15% Due to data limitations, the disaster damage rate is currently consistent for each income group. Only uses data from Pakistan between 1976 and 2011 (36 years) *Setting method listed in Section 5.3.3

```

% List of parameters for DR2AD_Ver1-2 and Ver1-4
% Cobb-Douglas production function
% Multiple income class, j=1,...,J
% Multiple disaster class

% Notice!
% In Ver1-4,
% Q3=delzk+Ephsl should be positive !
% deltax-deltak matters, which should be very large!
% Otherwise Q4 gets larger than 1.
% m can easily get negative! -> we need iota to increase the first term of the mj function.

```

```

% Population and the number of income groups
Pop0=155151394 ; % Initial
J=5; % the number of income groups
Pshare=1./J.*ones(J,1); % the population share of each income group
% sigma=0.025; % a birth rate : uniform across income groups
n0=Pop0.*Pshare; % initial population vector
n0bar=Pop0./J;

```

Input Population data (1)

```

TT=20; % length of time horizon
TTT=20; % period for calculation

```

Define the Duration of Calculation.  
Normally, TT=TTT

```

% Initial GDP and Scale parameter

```

```

GDP0=1.01704E+11; % Initial GDP US$ (2004, from World bank HP, 2005US$)
GDP1=1.29517E+11; % 2010 t=7 GDP US$ (from World Bank HP 2005US$)

```

Input Initial GDP(\$USD)

```

gdp0=GDP0./Pop0;

```

```

% Household
rho=0.05; % original discount rate
theta=2.0; % degree of relative risk aversion

```

Input Initial GDP(\$USD)

%cbar0=300 ; % subsistence level of consumption 131.8?

cbar=0;

zbar=0; % subsistence level of household asset

% Disaser risk

% xxM: M means Matrix.

L=4; % the number of dis...ses (not inc

For the Parameters with DRR( 50%  
DRR and 20% DRR),  
Change these parameters into  
50 or 20 for each parameter.

**DRR=0;** % without DRR, DRR=0%%%

mu=[0.360771858133789,0.293157585348079,0.215459211956662,0.110798575192407,  
0.0198127693690624]; % 1\*(L+1)

phiM=(1-DRR).\*[0.00958343142857143, 0.023466625 , 0.03739215, 0.0363373,  
0.0541332 ;

0.00742587, 0.031687765 , 0.03440585, 0.0294299, 0.0835009 ;

0.0550249571428571, 0.072353475 , 0.0607398, 0.0813099, 0.219844 ;

0.0191393014285714, 0.04982087 , 0.05330575, 0.146692, 0.082332 ;

0.0200024714285714, 0.0609288285714286 , 0.13990345, 0.218874, 0.219794 ] ; %

J\*(L+1)

Input Damage rate of physical  
assets matrix.

phiMave=sum(phiM,1)./J; % J\*1

psiM=(1-DRR).\*[0.0791446, 0.139877945 , 0.148394, 0.277004, 0.547603];% 1\*(L+1)

Input Damage rate of financial  
assets.

Epsi=psiM\*(mu. '); % 1\*1

psiTM=(1-DRR).\*[0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565,  
0.1500285];% 1\*(L+1)

Input Damage rate of Land.

EpsiT=psiTM\*(mu. '); % 1\*1

omegaM=(1-DRR).\*[1.72984435628463E-06, 2.93791921393877E-06 ,  
3.51193696218263E-06, 4.37554827071657E-06 , 0.0000121876190692597;

```

1.72984435628463E-06, 2.93791921393877E-06 , 3.51193696218263E-06,
4.37554827071657E-06 , 0.0000121876190692597 ;
1.72984435628463E-06, 2.93791921393877E-06 , 3.51193696218263E-06,
4.37554827071657E-06 , 0.0000121876190692597 ;
1.72984435628463E-06, 2.93791921393877E-06 , 3.51193696218263E-06,
4.37554827071657E-06 , 0.0000121876190692597 ;
1.72984435628463E-06, 2.93791921393877E-06 , 3.51193696218263E-06,
4.37554827071657E-06 , 0.0000121876190692597 ] ; % J*(L+1)

```

Input Damage rate of Human Capital.

```

psiTM55=(1-DRR).*[0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565,
0.1500285 ;
0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565, 0.1500285 ;
0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565, 0.1500285 ;
0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565, 0.1500285];

```

Copy the Damage rate of Land as a matrix

```

psiM55=(1-DRR).*[0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565,
0.1500285;
0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565, 0.1500285;
0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565, 0.1500285;
0.0211531428571429, 0.048810285 , 0.0595332, 0.0902565, 0.1500285] ;

```

Copy the Damage rate of financial assets as a matrix

```
Eomega=omegaM*(mu.');
```

```
omegabarM=sum(omegaM,1)./J; % 1*(L+1)
omegaMave=sum(omegaM,1)./J;
```

% Past Disaster Class Data

PastDC=[ 1, 1, 1, 1, 1, 4]; % Facts From the year (2004) 2005-2010

Input the past disaster rank process

% Discount factor

Ezzeta=zeros(J,1); % For the use of Ver.1-4

Lambda=(1-Ezzeta)./(1+rho); % generalized discount factor (discrete time): % J\*1

Lambdaave=sum(Lambda)./J; % 1\*1

% Initial physical assets per individual:

% Intial physical asset investment as flow variable

xi01=26.30050636;

xi02=36.18460261;

xi03=45.38851173;

xi04=61.31432921;

xi05=121.7971047;

xi0=[xi01; xi02; xi03; xi04; xi05];

Input the physical assets as flow variable. Final physical assets as Stock variable are automatically calculated.

% Initial stock of physical asset:

% NO DATA! We have to estimate from the flow variable, xi0!

deltaz0=0.1; % Special depreciation rate: ad hoc

z0=xi0./deltaz0; % Estimation

z0ave=sum(z0)./J;

Input the depreciation rates

% Depreciation rate

deltak=0.02; % depreciation rate of production capital

deltaz=[0.2;0.2;0.2;0.2;0.2] ; % depreciation rate of household asset

% deltax=[0.15;0.15;0.15;0.15;0.15];

```
% Initial financial assets per individual
```

```
b01=2497.425711;
```

```
b02=3470.107304;
```

```
b03=4311.345438;
```

```
b04=5625.780022;
```

```
b05=10357.74453;
```

```
b0old=[b01;b02;b03;b04;b05];
```

Input the financial assets.

```
totalb=dot(n0,b0old);
```

```
% K2004=878699.12500.*10.^6; data of University of Groningen
```

```
K00= 3.6034e+011;
```

```
% calibrated from  $r_0=0.072575$ (WB),  $K00=\alpha_2 \cdot P \cdot GDP_0 / (0.072575 \cdot \delta \cdot k \cdot P_k)$ 
```

```
b0=b0old.*K00./totalb;
```

Input the total financial assets

```
% Initial capital stock
```

```
k0=b0;
```

```
K0=dot(n0,k0); % Tentative
```

```
% Initial human capital per capita (years of education):
```

```
% Uniform among the classes because of the lack of data
```

```
h01=3.215742; % Poorest class
```

```
h02=3.921636;
```

```
h03=4.23536724;
```

```
h04=4.392233;
```

```
h05=5.568724; % Richest class
```

```
h0=[h01;h02;h03;h04;h05];
```

```
h0ave=sum(h0)./J;
```

Input the human capital

```
H0=dot(n0,h0); % Tentative
```

% Initial consumption per capita: Data of Households' survey 2004

c01=176.011081;

c02=242.1584944;

c03=303.7538862;

c04=410.334357;

c05=815.1037006;

c0=[c01; c02; c03; c04; c05];

avec0=sum(c0)./J;

c0ave=sum(c0)./J;

Input the Consumption

TotalC0=dot(n0,c0);

% Initial total asset

a0=b0+z0; % initial level of total asset

a0ave=sum(a0)./J;

% Initial Land: 資産 b0 のシェアで按分

T00=1;

Tshare=b0./sum(b0); % Share among income classes

T0=T00.\*Tshare./n0; % Initial land per capita

Production

% Production technology: Cobb-Douglas

alpha1=0.52; % share parameter for human capital, h

alpha2=0.40; % share parameter for physical capital, k

alpha3=0.08; % share parameter for land, ld

% Initial level of total factor productivity

B0=GDP0./ (H0.^alpha1 .\* K0.^alpha2 .\* T00.^alpha3 );

```
gb=0.095; % Exogenous technological growth rate
```

```
BProc(1)=B0;
```

```
for t=1:TTT
```

```
    BProc(t)=B0.*(1+gb).^(t-1);
```

```
end
```

Define exogenous growth rate  
B is automatically calculated

```
% Human capital investment
```

```
% Cost of human capital investment= $\eta(m)=\eta_0+\eta_1 \cdot m+\eta_2 \cdot m^2$ 
```

```
% the case of  $\delta_h=0.075$ 
```

```
deltah=0.075; % depreciation rate of human capital
```

```
eta0=8.4307852 ;
```

```
eta1=41.1454326 ;
```

```
eta2M=[2.4990125,2.6990125,2.8990125,3.0990125, 3.2990125] ;
```

```
eta2Mave=sum(eta2M)./J;
```

Input  $\eta_i$  ( $\eta$ ) and depreciation rate of  
human capital

```
m0bar=0.45163377;% data of 2004
```

```
m0=m0bar.*ones(J,1);
```

```
m0ave=sum(m0)./J;
```

Input initial m which is computed when  
you estimate the cost for human capital

```
% mcost0= $\eta_0+\eta_1 \cdot m_0bar+\eta_2M(1) \cdot m_0bar.^2$ ;
```

```
% Parameters in Firm's Expected Profit Maximization problem
```

```
% Ph=sum(mu.*(ones(1,L+1)-zzetabarM).*(ones(1,L+1)-omegabarM)); % scalar
```

```
Pk=sum(mu.*(ones(1,L+1)-psiM)); % scalar
```

```
P=sum(mu.* (ones(1,L+1)).^alpha1.*(ones(1,L+1)- omegabarM).^alpha1 .*  
(ones(1,L+1)-psiM).^alpha2 .* (ones(1,L+1)-psiTM).^alpha3 ); % scalar
```

```
% Dynamic Process of the per-capita variables
```



```
aProc(:,1)=a0;
```

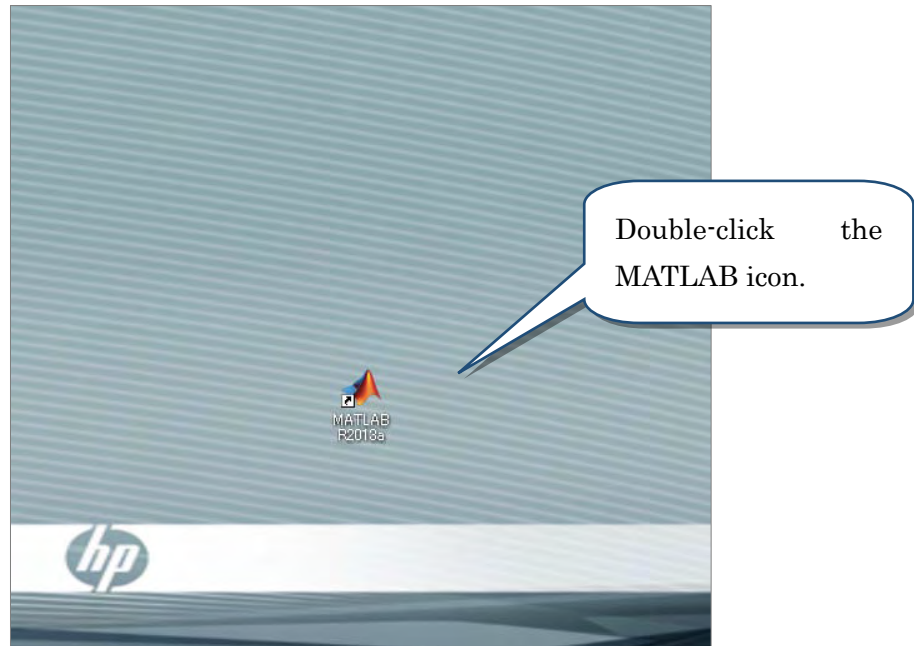
```
hProc(:,1)=h0;
```

```
disp('1-1.All Parameters are loaded. Run Calibration')
```

## 2. Calculation on MATLAB

Next step, the way how to calculate on MATLAB with the parameters set as above will be explained. Note that MATLAB must be installed on your computer. Also, all the program files must be in the same folder.

### ① Start MATLAB.

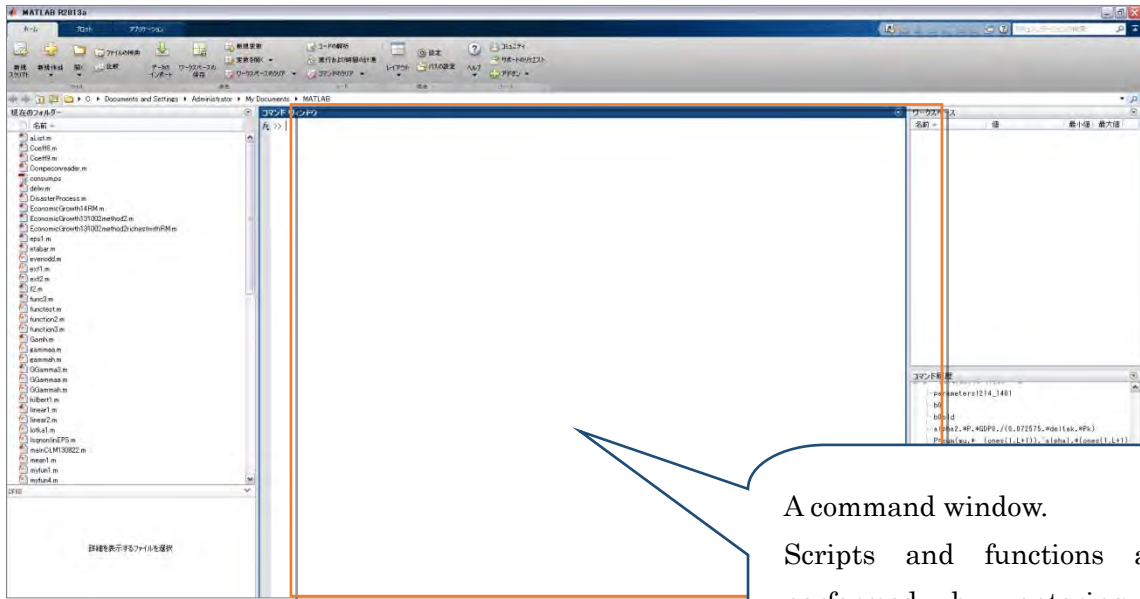


### ② A main window is turned on.

MATLAB performs a variety of scripts (m file) and functions through a command window.

Script file is prepared for the purpose of saving time to keyboard a command.

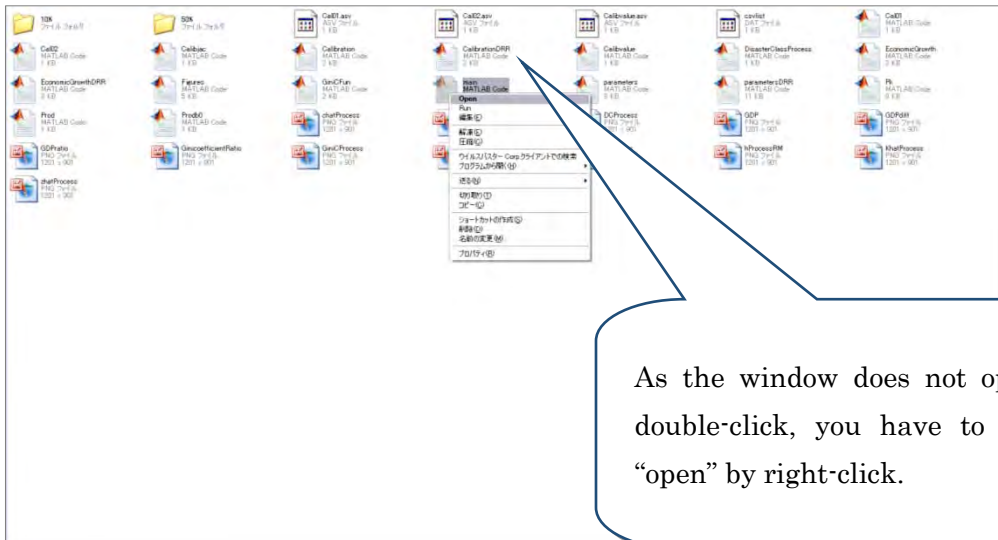
Parameter dataset set the above is one of the scripts.



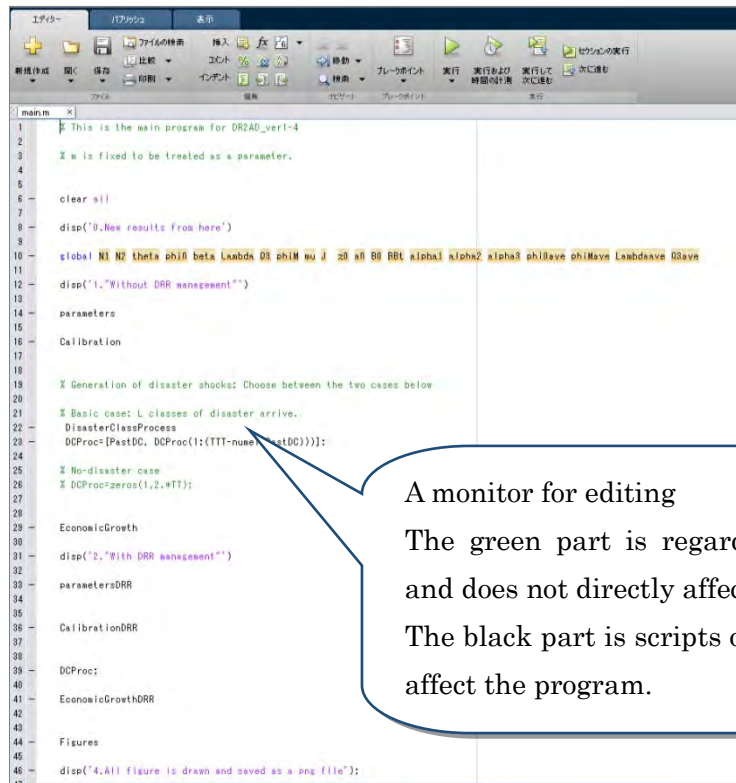
③ Edit scripts.

Scripts are edited through an editor window, which is different from a command window.

Right-click the main program and choose “open”.



An editor like the below is turned on.



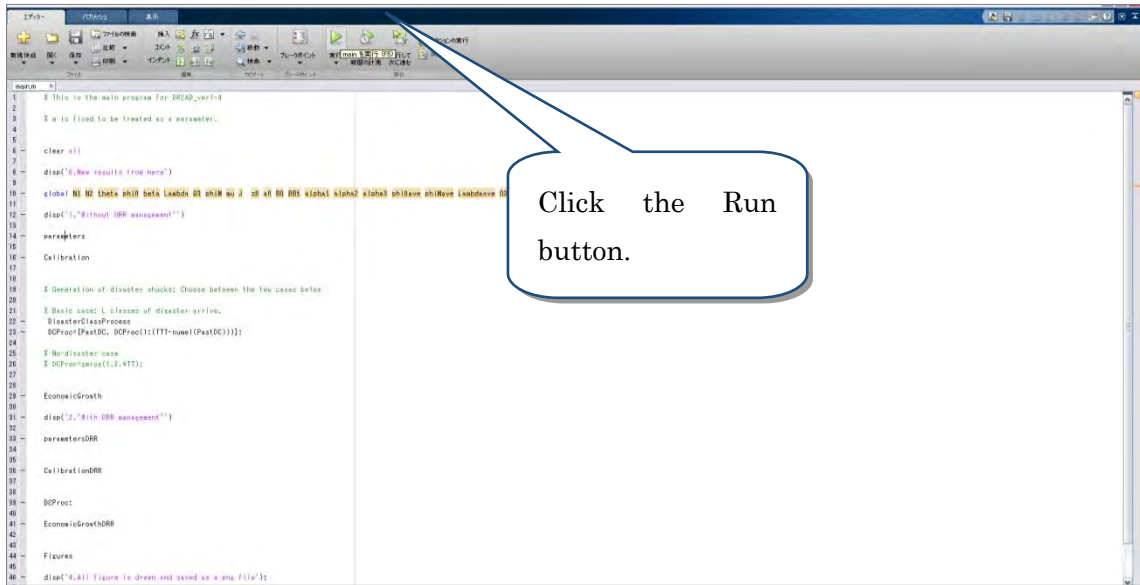
```
1 This is the main program for DR2AD_ver1-4
2
3 % m is fixed to be treated as a parameter.
4
5
6 clear all
7
8 disp('0.New results from here')
9
10 global M1 M2 theta phi1 beta Lambda DR phi1H nu i z0 a1 B1 B2 alpha1 alpha2 alpha3 phi1ave phi1ave Lambdaave G2ave
11
12 disp('1."Without DRR management"')
13
14 parameters
15
16 Calibration
17
18
19 % Generation of disaster shocks: Choose between the two cases below
20
21 % Basic case: L classes of disaster arrive.
22 DisasterClassProcess
23 DCProc=[PastDC, DCProc(1:(TTT-numel(PastDC)))]);
24
25 % No-disaster case
26 % DCProc=zeros(1,2,*TTT);
27
28
29 EconomicGrowth
30
31 disp('2."With DRR management"')
32
33 parametersDRR
34
35 CalibrationDRR
36
37
38 DCProc;
39
40 EconomicGrowthDRR
41
42
43 Figures
44
45 disp('4.All figure is drawn and saved as a png file');
```

A monitor for editing

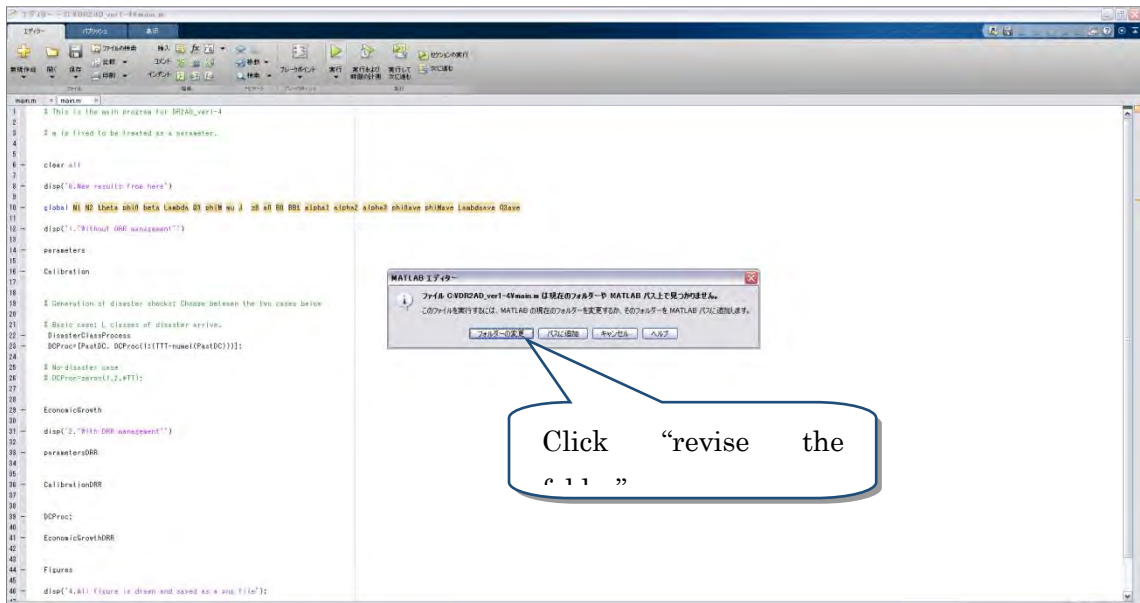
The green part is regarded as comments and does not directly affect the program.

The black part is scripts or commands that affect the program.





MATLAB editor monitor is displayed, and click “revise the folder”. Here the program works, but delete graphs displayed on the monitor. As a result of this, parameters are associated with the main window, and then go to ⑥.



- ⑥ Confirm whether the parameters are updated.  
Confirm if parameters edited by a text editor are updated.

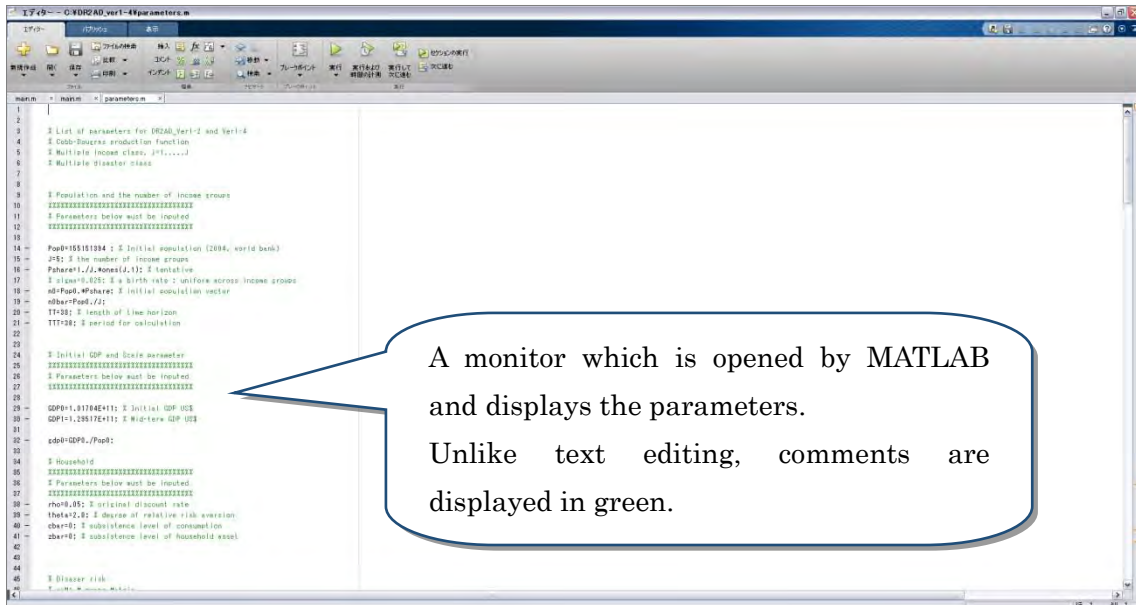
```

mainm K
1  This is the main program for DR2AD_ver1-4
2
3  % w is fixed to be treated as a parameter.
4
5
6  clear all
7
8  disp('0.New results from here')
9
10 jobs1 NI N2 theta phi11 beta Lambda O3 phi111 w1 z1 all B1 BBL alpha1 alpha2 alpha3 phi11ave phi11ave1 Lambdaave O3ave
11
12 disp('1."Without DRB management"')
13
14 parameters
15 Calib
16 % Gen
20 % Bax
22 % DCPri
23 % DCPri
24 % No-
25 % DCP
26 Econo
27 % Econo
30 % Econo
31 % Econo
32 % Econo
33 % Econo
34 % Econo
35 % Econo
36 % Econo
37 % Econo
38 % Econo
39 % Econo
40 % Econo
41 % Econo
42 % Econo
43 % Econo
44 % Econo
45 % Econo
46 disp('4.All figure is drawn and saved as a png file');

```

Open Parameters through a right-click, and then scripts are displayed as well as text editors.

MATLAB regards the green part as comments and the part does not affect directly the program. If the black part is properly revised, that means the parameters has been updated.



In the case of revision of a file, \* is displayed as below. This means that the change has not been yet saved, so click "Save (or ctrl+s)". The disappearance of \* means the change has been saved.



The screenshot shows a text editor window with a file named 'parameters.m\*' open. The file contains a list of parameters for a model, including population, income groups, and GDP. A callout box points to the asterisk in the filename, stating: '\* Means that the file has not been saved yet, so click "save" to reflect the revision.'

```

1
2
3
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```

⑦ Specify the program of the target country

In case if there are several target countries are included in main program, you should specify the target country with the following method.

As below, choose the 3 parameters into black (un-hold %).

- ◆ Parameters
- ◆ Calibration14
- ◆ Economic Growth

And then, repeat the same operations for the case with 50%-DRR and 20%-DRR.

Also, if you need, choose the disaster process pattern.

At last, save those program so as to renewal whole program ( there should be no \* on main program.



```

69 - disp('2-1."With 50% DRR management"')
70
71 - *** INPUT PARAMETERS ***
72 - **Select one of them**
73
74 - % parametersPAKRM50
75 - parametersHONRM50
76 - % parametersIDNRM50
77
78 - *** RUN CALIBRATION ***
79 - **Select one of them**
80
81 - % Calibration14PAKRM
82 - Calibration14HONRM
83 - % Calibration14IDNRM
84
85 - *** RUN ECONOMIC GROWTH ***
86 - **Select one of them**
87
88 - % EconomicGrowthPAKRM
89 - EconomicGrowthHONRM
90 - % EconomicGrowthIDNRM
91
92
93
94 - *** WITHOUT 20% DRR management ****
95
96 - disp('2-2."With 20% DRR management"')
97
98 - *** INPUT PARAMETERS ***
99 - **Select one of them**
100 - % parametersPAKRM20
101 - parametersHONRM20
102 - % parametersIDNRM20
103
104
105 - *** RUN CALIBRATION ***
106 - **Select one of them**
107 - % Calibration14PAKRM2
108 - Calibration14HONRM2
109 - % Calibration14IDNRM2
110
111 - *** RUN ECONOMIC GROWTH ***
112 - **Select one of them**
113 - % EconomicGrowthPAKRM2
114 - EconomicGrowthHONRM2
115 - % EconomicGrowthIDNRM2
116
117 - **** Draw all figures****
118
119 - Figures14
120
121 - disp('4.All figure is drawn and saved as a png file');
122
123 - disp('5.End of Program')
124
125

```

In the same way, in the presence of DRR(50%,20%), remove % from Parameters, Calibration14 and Economic Growth for the case study country (e.g. Honduras). If the letters get into black, that is OK.

⑧ Set the slope eta2M of Human Capital cost function (optional)

Normally, we can calculate the program until point ⑦, however, in some cases, it tends to invest in education at the beginning of the calculation, which is far from real act. In order to be not result in this situation, it should increase the cost for a human capital as its human capital itself increases by changing Human capital cost function. With this restriction, we can mitigate the investments for education in the beginning of the calculation.

Concretely, it is carried by changing the slope eta2M of Human capital cost function in EconomicGrowth program.

As it is generally recognized that human capital cost increases as its educational level, we can change the slope eta2M manually. Generally, we need to increase the eta2M as the human capital is higher. There is however no definitive method to estimate its slope correctly, it still rests as a future challenge.

<In the middle part in EconomicGrowth>

It is assumed that as the educational level changes, human capital cost increases, you can change the slope of human capital cost function manually as below.  
For example, as h increase, we set 4 class of eta2M.

0<h<5  
 5<h<8  
 8<h<11  
 11<h

\*Do the same process for the 50%-DRR and 20%-DRR.

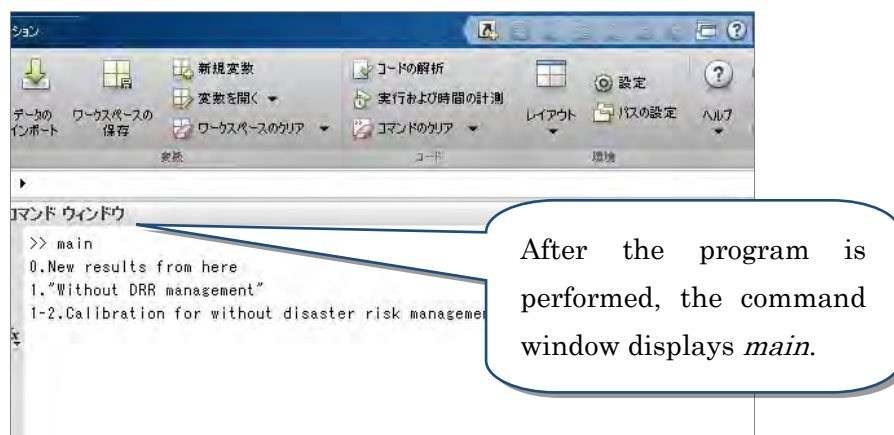
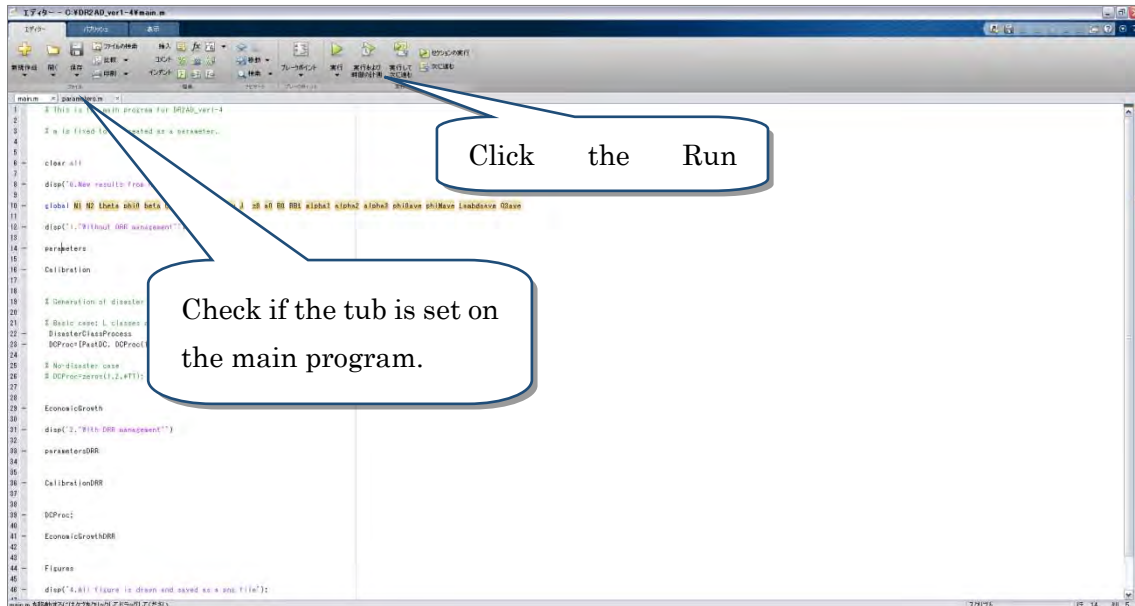
```

37
38
39 % khatProc(j,t)=kk
40 -   if t==1;
41 -       K=(at-z0);
42 -       zj=z0;
43 -   else zj=zj;
44 -   end
45
46
47
48
49 -   for j=1:J
50
51       % Optional Step:Adjust function eta 2M
52
53
54       if (0<ht(j)) && (ht(j)<5);
55           ht(j);
56           eta2M=[2.4990125,2.6990125,2.8990125,3.0990125, 3.2990125] ;
57       elseif (5<ht(j)) && (ht(j)<8);
58           eta2M=[12.4990125,12.6990125,12.8990125,13.0990125, 13.2990125] ;
59       elseif (8<ht(j)) && (ht(j)<11);
60           eta2M=[27.4990125,27.6990125,27.8990125,28.0990125, 28.2990125] ;
61       else
62           eta2M=[50.4990125,50.6990125,50.8990125,51.0990125, 51.2990125] ;
63       end
64       eta2M;
65
66
67
68 % Step 2: First-order conditions
69 %%% solve z by newton method%%
70 -       maxit=100;
    
```

⑨ Perform the program

Save the parameters, and then click the main program.

Click the Run button on the main program, and the program is performed.



The appearance of *End of Program* means that the program has been properly performed. If the program stops the computation, go to ⑩.

```

コマンド ウィンドウ
>> main
0.New results from here
1."Without DRR management"
1-2.Calibration for without disaster risk management case is succeeded! Now calculating dynamic equilibrium
2."With DRR management"
Calibration for with disaster risk management case is succeeded! Now calculating dynamic equilibrium
3.All figure is drawn and saved as a png file
4.End of Program
fx >>

```

When the program is properly performed, 1-4 work.

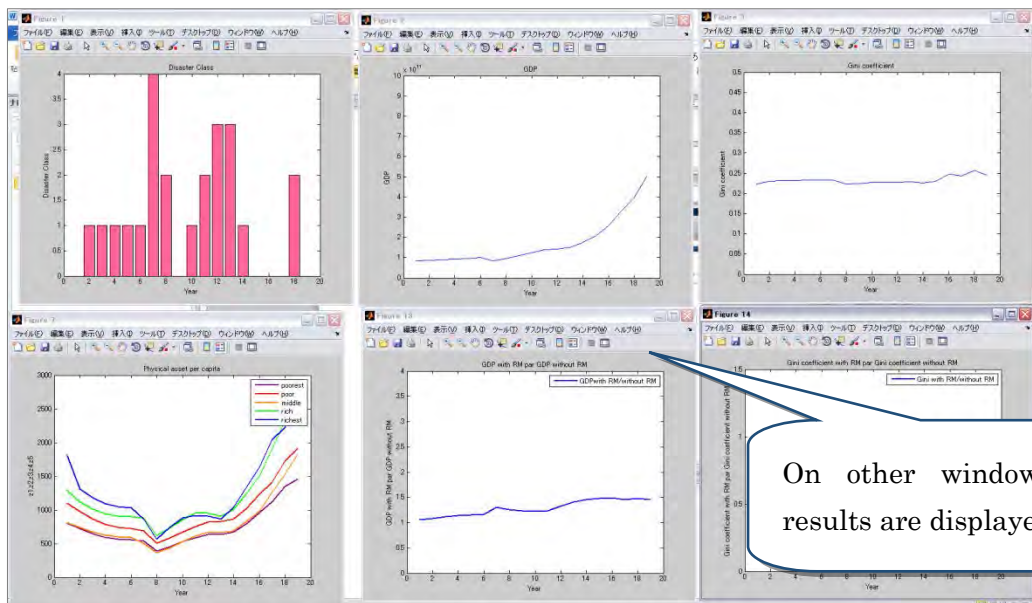
⑩ The program stopping the computation

Stopping of the program in ⑨ means that a combination of input data does not satisfy constraint conditions in the model. In this case, values of input data need to be revised.

By changing input date, revising the parameters again and running the program the computation results could be revised.

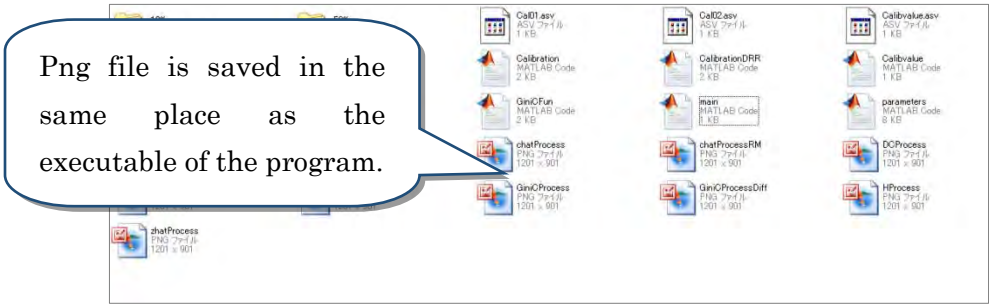
⑪ The results of the program

Windows are displayed as below.



On other windows, the results are displayed.

Png file is saved in the same place as the executable of the program.



After complete the computation, if you input the data from which numerical information you want is derived, you can see how the numerical value actually changes.

An example for the change in GDP

Enter “YhatProc (the value of GDP)” in the command window, the numerical solution is obtained.

```
コマンドウィンドウ
>> main
0.New results from here
1."Without DRR management"
1-2.Calibration for without disaster risk management case is succeeded! Now calculating dynamic equilibrium
2."With DRR management"
Calibration for with disaster risk management case is succeeded! Now calculating dynamic equilibrium
3.All figure is drawn and saved as a png file
4.End of Program
>> YhatProc

YhatProc =
1.0e+11 *

Columns 1 through 15
0.8453 0.8694 0.8862 0.9151 0.9565 1.0108 0.8264 0.9904 1.0320 1.1721 1.3671 1.4208 1.5096 1.7380 2.0458

Columns 16 through 19
2.5783 3.1889 3.8857 5.0137

fx >>
```

Enter a parameter whose value you want to know, then the numerical solution is displayed.