DR²AD Model (Ver. 1.4)

Application Operation Manual

March. 2015

Japan International Cooperation Agency

＜Contents＞

Chapter 1　DR²AD Model Structure

1　DR²AD Model Overview

1.1 DR²AD Model Overview

"Disaster Risk Reduction Investments Accounts for Development (DR²AD)" model is a Ramsey-based macroeconomic simulation model capable of quantitatively evaluating the benefit of disaster risk reduction (DRR) investment from a long-term perspective. Quantitatively comparing the cost of DRR with the expected benefit enables an optimum DRR investment allocation. The DR²AD model serves as a basis and a useful tool in forming policy policies for disaster risk mitigation and sustainable development.

The following list details the main objectives in the development of the DR²AD model.

<u>1. To evaluate the economic impact of DRR investment</u>

・The DR²AD model is a dynamic model used to correlate disasters with household income and consumption as well as corporate production.

<u>2. To evaluate the economic impact of multiple DRR investment policies.</u>

・The DR²AD model can provide feasibility analysis of the optimum mix of direct and indirect measures to configure a DRR investment policy.

<u>3. To evaluate the contribution of DRR investment made toward international goals such as MDG's.</u>

・The DR²AD model can evaluate the effect on disasters per household income levels and per socio-economic level.

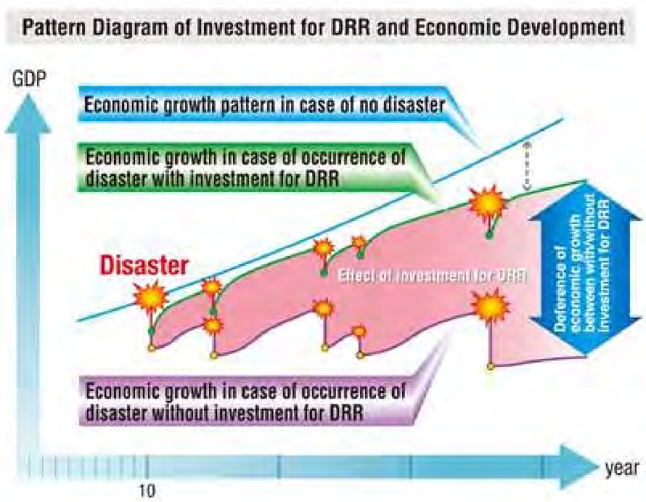


Fig. 1-1　Evaluation of economic growth versus DRR investment

1.2 History behind the development of the DR^{2}AD model

The Third UN World Conference on Disaster Risk Reduction held in Sendai in 2015 resulted in the The Sendai Framework, which aims to achieve the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries over the next 15 years. To accomplish achieve these objectives, 7 targets and 4 priority actions have been set. In particular, the targets require investment to reduce the economic loss in the global GDP caused by disaster, and the priority actions require investment to improve disaster prevention.

Natural disasters occurring in developing countries is likely to have a significant negative impact on national economic development, national stability, and efforts to eliminate poverty. Most of the poor are not protected by insurance or social security programs despite being generally susceptible to the impact of damage caused by disasters.

The United Nations Disaster White Paper in 2015 claims that an investment of 6 billion dollars per year in disaster risk management strategies throughout the world could reduce risk by as much as 360 billion dollars in damage despite such a modest investment representing only 0.1% of new urban infrastructure. In other words, investment that could result in profit and investments to reduce disaster risk could be the determining factor in achieving national and international targets such as eliminating poverty, expanding health care and education programs, and ensuring sustainable and equitable growth.

These circumstances appear to be the result of not having a suitable means of evaluating the benefit of DRR investment beforehand while awareness of the importance of disaster prevention continues to increase. The current extent of information on evaluating the benefit of DRR investment beforehand can be summarized by the statement in the United Nations Development Program (UNDP) that says "Every dollar invested into DRR saves seven dollars in disaster aftermath." In other words, a method has not yet been established that can clearly evaluate levels of DRR investment on a national scale or the benefit of disaster DRR with regard to economic growth and poverty issues.

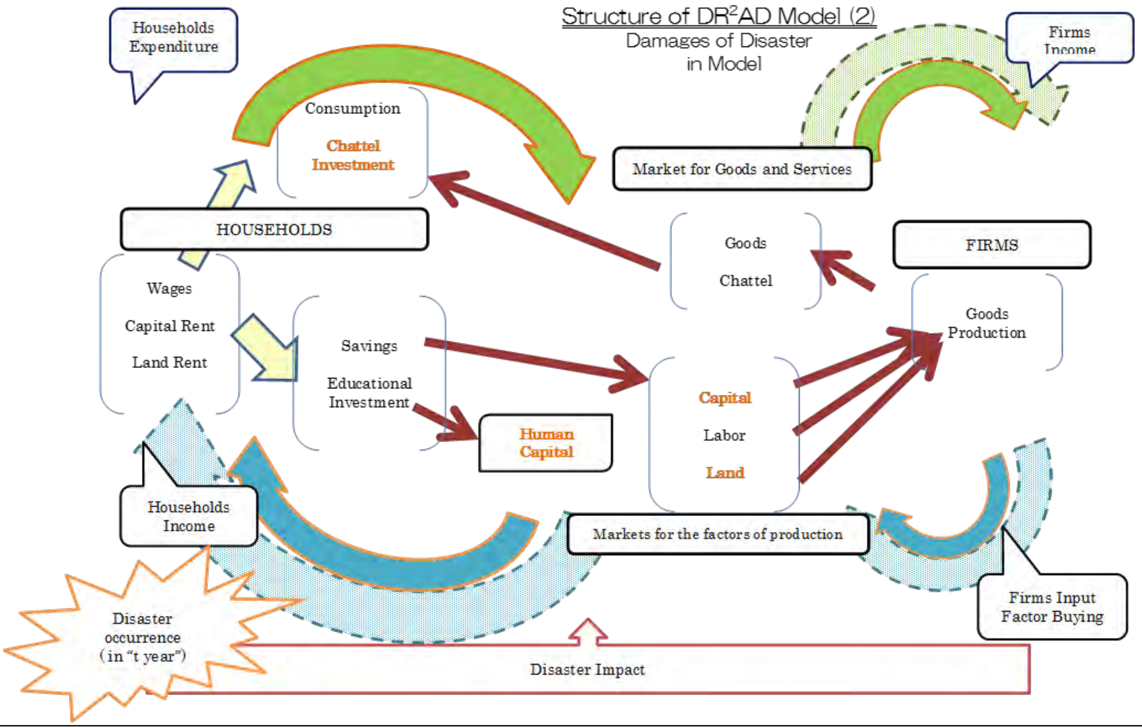
We believe it is vital to develop a method to analyze and illustrate the potential benefit of DRR investment in developing countries. As this leads to actual disaster reduction investment, this will also help the economic development of developing countries as well as resolve poverty issues.

Therefore, through project research conducted by JICA, we developed the Disaster Risk Reduction Investment Accounts for Development (DR^{2}AD Model) as a DRR investment evaluation model capable of evaluating the benefit of DRR investment in developing countries on economic growth, poverty reduction, and others.

2 Basic Structure of the DR²AD Model

2.1 Basic Model Structure

The DR^{2}AD model is a macro-economic model that incorporates DRR investment concepts into a Ramsey-based optimal growth model from neoclassical economic growth theory. The purpose of this model is to be utilized as a policy decision-making tool by displaying the contribution of DRR investment on the economic growth of developing countries. The following figure illustrates the basic structure of this model.



・The natural disaster occurred in period t is defined by the negative impacts on human capital, physical assets, financial assets and land, in terms of the damage rates.
・Through factor market, impact on GDP of period t is considered.

Fig. 2-1 DR^{2}AD Model Structure

The DR^{2}AD model is capable of displaying differences in levels of long-term economic growth quantitatively depending on whether DRR investment is conducted or not. DRR investment improves resiliency against natural disasters and protects human capital investments and physical assets from natural disasters, which results in a positive effect on long-term economic growth. On the other hand, without DRR investment continuous damage to assets from natural disasters will have a negative impact on people's life leading to negative cycles and creating poverty traps.

The following figure are conceptual images representing economic growth versus DRR investment, which can be demonstrated using the DR^{2}AD model.

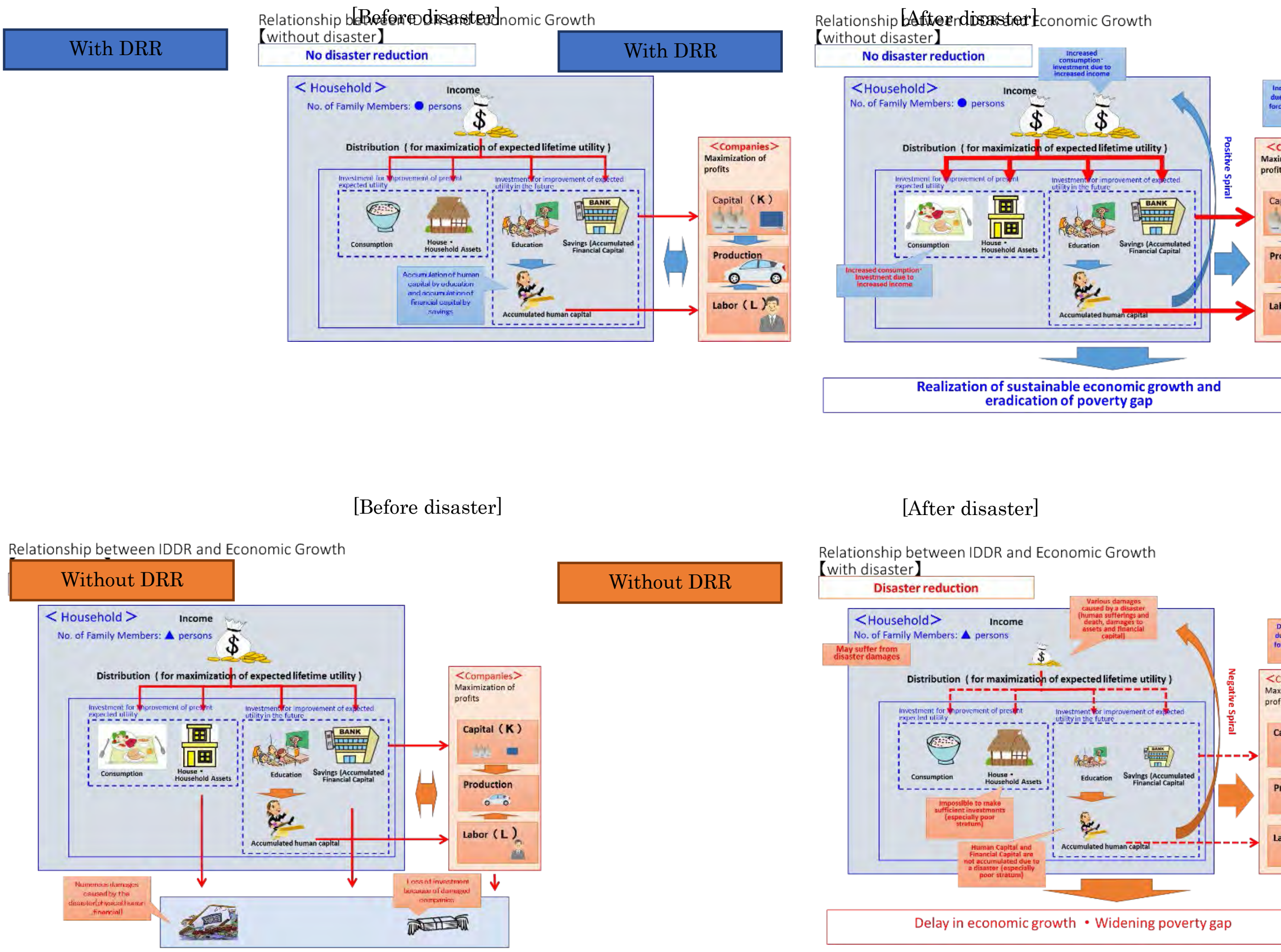


Fig. 2-2 Conceptual image as demonstrated using the DR^{2}AD model of the effect on disasters

2.2 Features of the DR²AD Model (Ver. 1.4)

The following lists describe the main features of the DR²AD model.

2.2.1 Overall Structure

・Evaluates the benefit of DRR investment with regard to economic growth and poverty reduction.

・Simulate closed economies configured with two economic agents: households and firms.

・Households can be classified into five income classes, which enables the evaluation of issues specific to particular classes, such as poverty.

・The economy is closed within each class, which enables equilibrium between households and firms thorough the market to be achieved within each class.

2.2.2 Household

・Five income classes are available for households.

・Household behavior assumes a representative individual in each income group.

・Household behavior is fully reasonable and informative to disaster risk. (That is to say, households decide the level of consumption, investment, and saving so that they can maximize their expected lifetime utility.)

・Households provide production factors (labor, production capital, land) to firms in return for income (labor income, capital income, and land rent).

・A human capital has been incorporated to represent the connection between the accumulation of human capital and the reduction in poverty. This model assumes that education causes growth of human capital, and so reproduces the positive effect of increases in human capital on production efficiency by setting the education index of the mean years of schooling as the proxy variable for human capital.

2.2.3 Firm

・We assume a representative firm in each income class.

・The production technology assumes a constant return to scale.

・Firms are modeled as fully reasonable argents having a myopic perspective toward maximizing the expected profit each term.

・Firms demand production factors (labor, production capital, land) from households and supply these households with the final goods (durable goods and non-durable goods). (Models also assume that household savings are recirculated as production capital for businesses provided through banks.)

・Rapid technological growth due to the transformation of socio-economic structures is not included in this model.

2.2.4 Market equilibrium

・Both good's market and production factor's market are assumed to be perfectly competitive.

2.2.5 Disasters

・Five different disaster scale settings are available, including no occurrence of disasters, for each type of disaster. Every period, the disaster rank (including no disasters) is determined through stochastic process.

・Disasters occur in accordance with an occurrence process independent for each type of disaster.

・Disaster reduction behavior models such as insurance are not included. Reductions in disaster damage ratios can only be generated by DRR investment provided exogenously. However, DRR investment costs are not accounted for in this model.

2.2.6 Output

・The GDP function is a Cobb-Douglas form derived from human capital, production capital, and land.

・Disasters occur in accordance with a stochastic process, and so Monte Carlo simulations are used to analyze average DRR investment benefits.

・As illustrated in the following figure, the occurrence of disasters causes damage to human capital and production factors, which leads to a decrease in production capacity and therefore GDP.

・When DRR investment is conducted, damage can be reduced, which mitigate the decreases in production capacity.

・The DR^2AD model focuses on the DRR investment benefits as the differences in GDP, depending on whether DRR investment is conducted.

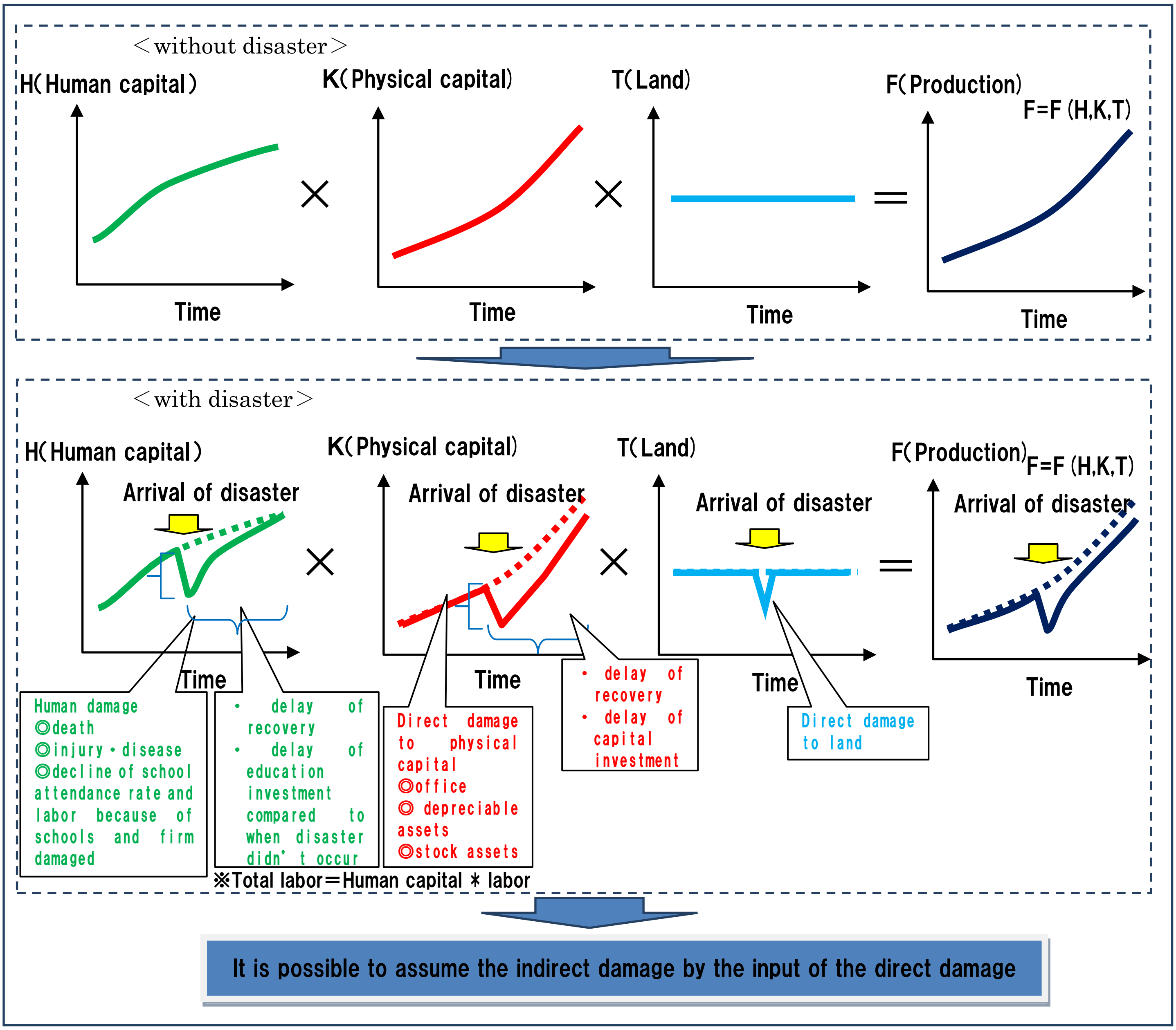


Fig. 2-3　Conceptual images of reduction in GDP when disasters occur

2.3 DR²AD Model (Ver. 1.4) Formulation

2.3.1 List of Endogenous Variables

The following table lists the endogenous variables used in this model.

Number	Name	Symbol	Unit of measure	Definition	Comments
1	Instantaneous utility	u	—	Representative household utility at one period	Assumes the Stone-Geary form.
2	Expected lifetime utility	V	—	Expected lifetime utility for a representative household	
3	Consumption	c^l	$	Amount of consumption of non-durable goods (excluding houses and household goods)	Consumption amount is determined after the occurrence of a rank l disaster.
4	Human capital	h	Year	Mean years of schooling	Uses the mean years of schooling as a proxy variable. Assumes that increases in the mean years of schooling leads to improved labor productivity.
5	Human capital formation (Education time)	m^l	Year	Time invested in education	Education time is determined after the occurrence of a rank l disaster.
6	Amount of human investment cost	$\eta^l(m^l)$	$	Amount of cost invested in education	Amount of cost invested in education is determined after the occurrence of a rank l disaster.
7	Physical assets	z	$	Amount of non-durable assets (houses and household goods)	
8	Physical asset formation	ξ	$	Amount of cost invested in physical assets	
9	Financial assets (Production capital)	b	$	Amount of financial assets (Amount of new savings in each period equals income minus expenditure)	Financial assets is assumed to be completely used as productive capital through banks.
10	Total assets	a	$	Total amount of assets held by households (Sum of physical assets and financial assets)	
11	Wages	w_l	$/year	Wages for one unit of human capital	Wages are determined after the occurrence of a rank l disaster.
12	Interest rate	r_l	—	Interest rate in relation to productive capital (financial assets).	Interest rate is determined after the occurrence of a rank l disaster.
13	Land rent	π_l	$/ha	Land rent in relation to one unit of land available for production	Land rent is determined after the occurrence of a rank l disaster.
14	Income	In	$	Total of wage income, capital income, and land rent	

15	Expenditure	Ex	$	Total of consumption, physical asset formation, and education investment.	
16	Discount factor	Λ	—	Discount factor in relation to future utility	
17	Production (GDP)	Y	$	Gross domestic production (GDP)	Assumes a Cobb-Douglas form.
18	Total factor productivity (TFP)	B	—	Total factor productivity (TFP)	Productivity of factors except for one of labor, capital, and land
19	Amount of human capital investment	H	Year	Sum of human capital per income class	
20	Amount of production capital investment	K	$	Sum of production capital per income class	
21	Total production cost	TC	$	Sum of firm's production cost about labor and capital input	
22	Firm's profit	$\widetilde{\Pi}_l$	$	Firm's profit per income class	Firm's profit is determined after the occurrence of a rank l disaster. Distributed to households as land rent.

2.3.2 Exogenous Variable List

The following table lists the exogenous variables used in this model.

Number	Name	Symbol	Unit of measure	Definition	Comments
1	Population per income class	n	People	Total population per income class	Populations per income class are currently configured to be equal.
2	Subsistence level of consumption	$\bar{c}$	$	Subsistence level of consumption	Variable added for consideration of poverty traps.
3	Time preference rate	ρ	—	Time preference rate in relation to utility	Tendency to focus on current utility as the number increases.
4	Relative risk aversion	θ	—	Household attitude toward risk	Tendency to avoid risk as the number increases.
5	Share parameter of consumption	γ_i	—	Rate of preference for consumption and physical assets	Calculated with production input-output tables or calibration. $i \in \{1,2\}$
6	Human investment coefficient	η_i	—	Function coefficient that represents the relationship between the amounts of education investment and mean years of schooling.	Calculated with calibration. $i \in \{0,1,2\}$
7	Correction coefficient for human capital formation	ς	—	Coefficient used to correct the relationship between the amounts of education investment and mean years of schooling.	Configured to adjust certain parameters (calibration).
8	Total land area in the economic space	$\bar{T}$	ha	Total land area	$\bar{T} = \tilde{T} \times$ Number of income class
9	Total land area per income class	$\tilde{T}$	ha	Total land area per income class	$\tilde{T} = T \times n$
10	Land area held by representative households	T	ha	Land area held by representative households	The land rent allocation is determined in accordance with the land area in possession.
11	Human capital depreciation ratio	δ_h	—	Rate that human capital depreciates each period.	Expresses degradation of knowledge and changing of generations.
12	Physical assets depreciation ratio	δ_z	—	Rate that physical assets depreciate each period.	
13	Production capital depreciation ratio	δ_k	—	Rate that production capital depreciates each period.	
14	Exogenous growth coefficient	B_0	—	Initial total factor productivity	Calculated with calibration.
15	Exogenous growth rate	g_b	—	Degree of technological advancement	Configured with calibration or default values.
16	Share parameter	α_i	—	Rate of input for	$i \in \{1,2,3\}$

Number	Name	Symbol	Unit of measure	Definition	Comments
	for the production function			production factors	
17	Disaster probability	μ^l	—	Probability of occurrence of a rank l disaster.	
18	Physical asset damage ratio	φ^l	—	Ratio of physical assets lost during a disaster	
19	Production capital damage ratio	ψ^l	—	Ratio of production capital (financial savings) lost during a disaster	
20	Human capital damage ratio	ω^l	—	Ratio of human capital affected during a disaster	
21	Land damage ratio	τ^l	—	Ratio of land affected during a disaster	
22	Value function coefficient	ν_i	—		Calculated with calibration. $i \in \{0,1,2\}$
23	Total assets (initial)	$a(0)$	$	Total amount of assets held by initial households (Sum of physical assets and financial savings)	
24	Human capital (initial)	$h(0)$	Year	Initial mean years of schooling	

2.3.3 Basic Constitutive Equations

The following table lists the basic constitutive equations used in this model.

Number	Name	Basic Constitutive Equations
1	Instantaneous utility function	$u\left(c^l(t),(1-\varphi^l)z(t)\right):=\dfrac{[(c^l(t)-\bar{c})^{\gamma_1}\{(1-\varphi^l)\cdot z(t)\}^{\gamma_2}]^{1-\theta}-1}{1-\theta}$
2	Human capital accumulation process	$h(t+1)=(1-\delta_h)\cdot h(t)+\varsigma\cdot m^l(t)$ $=h(t)+H^l(t)$ $H^l(t):=-\delta_h\cdot h(t)+\varsigma\cdot m^l(t)$
3	Human investment cost function	$\eta^l(m^l)=\eta_0+\eta_1\cdot m^l+\eta_2^l\cdot(m^l)^2$
4	Physical assets accumulation process	$z(t+1)=(1-\delta_z)(1-\varphi^l)z(t)+\xi(t),$
5	Income	$\mathrm{In}(t)=r_l(t)(1-\psi^l)\mathrm{b}(t)+w_l(t)\cdot(1-\omega^l)\mathrm{h}(t)+\pi_l(t)\cdot(1-\tau^l)T$
6	Expenditure	$\mathrm{Ex}(t)=c^l(t)+\eta^l\left(m^l(t)\right)+\xi(t)$
7	Financial savings accumulation process	$b(t+1)=(1-\psi^l)b(t)+\mathrm{In}(t)-\mathrm{Ex}(t)$ $=\{1+r_l(t)\}(1-\psi^l)\mathrm{b}(t)+w_l(t)\cdot(1-\omega^l)\mathrm{h}(t)+\pi_l(t)\cdot(1-\tau^l)T-c^l(t)-\eta^l\left(m^l(t)\right)-\xi(t)$
8	Total assets accumulation process	$a(t+1)=a(t)+w_l(t)\cdot(1-\omega^l)h(t)+[r_l(t)-\{1+r_l(t)\}\cdot\psi^l]\cdot a(t)$ $+[(1-\varphi^l)(1-\delta_z)-\{1+r_l(t)\}(1-\psi^l)]z(t)+\pi_l(t)\cdot(1-\tau^l)T-c^l(t)$ $-\eta^l\left(m^l(t)\right)$ $=a(t)+A^l(t),$ $(t)\coloneqq w_l(t)\cdot(1-\omega^l)h(t)+[r_l(t)-\{1+r_l(t)\}\cdot\psi^l]\cdot a(t)$ $+[(1-\varphi^l)(1-\delta_z)-\{1+r_l(t)\}(1-\psi^l)]z(t)+\pi_l(t)\cdot(1-\tau^l)T$ $-c^l(t)-\eta^l\left(m^l(t)\right)$
9	Value function	$\mathrm{V}\left(a(t),h(t),B(t)\right)\cdot\left(\dfrac{1}{1+\rho}\right)^t=\max\ \mathrm{E}\left[\sum_{t'=t}^{\infty}u\left(c^l(t'),(1-\varphi^l)z(t')\right)\cdot\left(\dfrac{1}{1+\rho}\right)^{t'}\right]$
10	Discount factor	$\Lambda=\left(\dfrac{1}{1+\rho}\right)$
11	First-order conditions to maximize expected	$u_c(c^l,(1-\varphi^l)z)=\Lambda\cdot V_a$

Number	Name	Basic Constitutive Equations
	lifetime utility (consumption)	
12	First-order conditions to maximize expected lifetime utility (physical assets)	$\sum_l \mu^l \{u_z(c^l,(1-\varphi^l)z) + \Lambda \cdot V_a \cdot (1-\varphi^l)(1-\delta_z)\} = \Lambda \cdot V_a \sum_l \mu^l \{F_b + (1-\psi^l)(1-\delta_k)\}$
13	First-order conditions to maximize expected lifetime utility (education time)	$V_h \cdot \varsigma = V_a \cdot \eta^{l\prime}(m^l)$
14	Production function (GDP)	$Y(t) = F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big)$ $= B(t)\{(1-\omega^l)H(t)\}^{\alpha1}\{(1-\psi^l)K(t)\}^{\alpha2}\{(1-\tau^l)\tilde{T}\}^{\alpha3}$
15	Total factor productivity	$B(t) = B_0 \cdot (1+g_b)^{t-1}$
16	Amount of human capital	$H(t) = n \cdot h(t)$
17	Amount of production capital	$K(t) = n \cdot b(t)$
18	Total cost function	$C(t) = w_l(t) \cdot (1-\omega^l)H(t) + \{r_l(t)+\delta_k\} \cdot (1-\psi^l)K(t)$
19	Profit function	$\tilde{\Pi}_l(t) = Y(t) - TC(t)$ $= F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big) - w_l(t) \cdot (1-\omega^l)H(t) - \{r_l(t)+\delta_k\}$ $\cdot (1-\psi^l)K(t)$
20	First-order conditions to maximize profit (amount of human capital investment)	$\frac{\partial F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big)}{\partial H} = w_l(t) \cdot (1-\omega^l)$

Number	Name	Basic Constitutive Equations
21	First-order conditions to maximize profit (amount of production capital)	$\frac{\partial F\left(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\right)}{\partial K}=\{r_l(t)+\delta_k\}\cdot(1-\psi^l)$
22	Land rent per unit of productive land	$\pi_l(t)=\frac{\tilde{\Pi}_l(t)}{(1-\tau^l)\tilde{T}}=\frac{\tilde{\Pi}_l(t)}{(1-\tau^l)nT}$

2.3.4 Expanded Description of Basic Constitutive Equations

(1) Household

The representative household behaves in the following manner to maximize the expected lifetime utility. In this case, the representative household behaves in this manner while recognizing disaster risk and allocating income (wage income, interest income, and land rent) and total assets (accumulated equity) per period to consumption, physical investment, human investment, and financial savings.

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

where

E: Expected value operation
u: Instantaneous utility
c^l: Consumption (non-durable goods) (after a rank l disaster)
z: Physical assets (durable goods)
ρ: Time preference rate

The instantaneous utility function is a Stone-Geary type of function that can express the scenario of representative households falling into poverty traps. In other words, when the consumption c^l approaches the subsistence level of consumption, the marginal utility of consumption increases, consumption is given priority, and capital formation such as human capital and financial savings are set aside. As a result, this can express a scenario in which households cannot escape poverty traps. All income classes have the same preference.

$$u\left(c^l(t),(1-\varphi^l)z(t)\right) := \frac{[(c^l(t)-\bar{c})^{\gamma_1}\{(1-\varphi^l)\cdot z(t)\}^{\gamma_2}]^{1-\theta}-1}{1-\theta}, \tag{2}$$

s.t.

$\gamma_1+\gamma_2=1 \quad (0<\gamma_1,\gamma_2<1),$
$\theta>0,$

where

$\bar{c}$: Subsistence level of consumption
γ_i: Consumption share parameter, $i \in \{1,2\}$
θ: Relative risk aversion

The representative household saves money for future consumption. Configuring income per period for the representative household (wage income, interest income, and land rent) to In(t) and expenditure (consumption, human capital, and physical investment) to Ex(t), results in the difference between income and expenditure represented as new financial savings Δb generated per peiod

$$\Delta b(t) = \mathrm{In(t)} - \mathrm{Ex(t)},$$

$$\mathrm{In}(t) = r_l(t)(1-\psi^l)\mathrm{b}(t) + w_l(t)\cdot(1-\omega^l)\mathrm{h}(t) + \pi_l(t)\cdot(1-\tau^l)T,$$
$$\mathrm{Ex}(t) = c^l(t) + \eta^l\left(m^l(t)\right) + \xi(t).$$

(3)

where

h: Human capital
b: Financial assets (production capital)
T: Land area held by a representative household
w_l: Wage rate (after the occurrence of a rank l disaster)
r_l: Interest rate (after the occurrence of a rank l disaster)
n_l: Land rent (after the occurrence of a rank l disaster)
δ_k: Production capital depreciation ratio
ω^l: Human capital damage ratio (rank l disaster)
ψ^l: Production capital damage ratio (rank l disaster)
τ^l: Land damage ratio (rank l disaster)
η^l: Human capital investment costs (after the occurrence of a rank l disaster)
m^l: Human capital formation
ξ: Physical asset formation

Due to a rank l disaster, human capital, financial assets (production capital), and land are all affected by the damage represented by ψ^l, ω^l, τ^l, which causes the income of representative households to decrease as the scale of disaster increases.

Based on this, the accumulation process of financial assets b is expressed as follows.

$$\begin{aligned} b(t+1) &= (1-\psi^l)b(t) + \Delta b(t) \\ &= (1-\psi^l)b(t) + \mathrm{In(t)} - \mathrm{Ex(t)}, \\ &= \{1 + r_l(t)\}(1-\psi^l)\mathrm{b}(t) + w_l(t)\cdot(1-\omega^l)\mathrm{h}(t) + \pi_l(t)\cdot(1-\tau^l)T - c^l(t) - \eta^l\left(m^l(t)\right) - \xi(t), \end{aligned}$$

(4)

Whereas consumption specifies non-durable goods, physical assets specify durable goods. Specifically, this represents the stock of houses and household goods. Physical assets depreciate at the ratio of δ_z and also incur a loss at the ratio of φ^l when a disaster occurs.

The physical assets accumulation process is expressed as follows.

$$z(t+1) = (1-\delta_z)(1-\varphi^l)z(t) + \xi(t),$$

(5)

Human capital is assets related to labor productivity. As human capital increases, more wage income can be obtained. This does not experience loss due to disaster, but the assumption employed that human capital for the period in which a disaster occurs temporarily decreases, which leads to a decrease in labor productivity.

As with physical assets, human capital depreciates at the ratio of δ_h every period. As a result, this expresses a scenario in which knowledge deteriorates if left alone while also reflecting turnover of generations (older generations of human capital dies while younger generations are born) by taking into account depreciation that includes exchanges due to obsolescence of knowledge and turnover of the labor population.

The human capital accumulation process is expressed as follows.

$$h(t+1) = (1-\delta_h)\cdot h(t) + \varsigma \cdot m^l(t)$$
$$= h(t) + H^l(t),$$
$$H^l(t) := -\delta_h \cdot h(t) + \varsigma \cdot m^l(t),$$

(6)

where

δ_h: Human capital depreciation ratio

ς: Correction coefficient for human capital formation

Actual data on labor productivity that represents human capital, the mean years of schooling is used as a proxy variable. Though other possible proxy variables include the average education ratio and the average literacy rate, the mean years of schooling is considered more applicable when handled as a stock (education ratio and literacy rate is either 1 or 0 on the individual level). There are actually gaps in time between human capital growth and labor productivity, but for this application, it is assumed that increases in human capital will immediately lead to increases in labor productivity.

The correction coefficient ς linked to temporal adjustment costs was configured to adjust specific parameters (calibration), which is necessary for case studies. If such adjustment is not necessary, set ς equal to one.

Typical households own a certain amount of land as landlords from the initial point, which generates land rent by renting out all land to companies.

$$T = \frac{\tilde{T}}{n},$$
$$\bar{T} = \sum_j \tilde{T},$$

(7)

where

$\tilde{T}$: Total land area per income class

$\bar{T}$: Total land area in the economic space

n: Population per income class

(2) Firms

Firms produce in accordance with the following Cobb-Douglas function. This assumes that production requires labor, capital, and land. Production is performed after the occurrence of a disaster, and the amount of investment into production factors is affected by the damage from the disaster.

$$Y(t) = F\left(B(t), (1-\omega^l)H(t), (1-\psi^l)K(t), (1-\tau^l)\tilde{T}\right)$$
$$= B(t)\{(1-\omega^l)H(t)\}^{\alpha 1}\{(1-\psi^l)K(t)\}^{\alpha 2}\{(1-\tau^l)\tilde{T}\}^{\alpha 3},$$
$$B(t) = B_0 \cdot (1+g_b)^{t-1},$$
$$H(t) = n \cdot h(t),$$
$$K(t) = n \cdot b(t),$$

(8)

s.t.

$$\alpha_1 + \alpha_2 + \alpha_3 = 1 \quad (0 < \alpha_1, \alpha_2, \alpha_3 < 1),$$

where

Y: Production function

B: Total factor productivity

B_0: Exogenous growth coefficient

g_B: Exogenous growth rate

H: Amount of human capital

K: Amount of production capital

α_i: Share parameter for the production function, $i \in \{1,2,3\}$

The share parameter for the production function α_i represents the distribution ratio for production factors in perfect markets.

Firms pay wages and interest as compensation for labor and production capital provided by households. Production capital stock assumes depreciation at a rate of δ_k every period, and the total cost of which is taken into account.

$$\mathrm{TC(t)} = w_l(t) \cdot (1-\omega^l)H(t) + \{r_l(t) + \delta_k\} \cdot (1-\psi^l)K(t),$$

(9)

where

TC: Total production cost

Based on this, the firm's profit function is configured as follows. Firms behave toward maximizing profit, which is the amount of production minus total production costs. Profit is distributed to each household as land rent.

$$\tilde{\Pi}_l(t) = Y(t) - TC(t)$$
$$= F\left(B(t), (1-\omega^l)H(t), (1-\psi^l)K(t), (1-\tau^l)\tilde{T}\right) - w_l(t) \cdot (1-\omega^l)H(t) - \{r_l(t) + \delta_k\}$$
$$\cdot (1-\psi^l)K(t).$$

(10)

(3) Market Equilibrium

1) Maximization of Utility

Total assets are the total of financial assets and physical assets held by the representative household. Physical capital formation, which is a control variable, can be canceled out by configuring the total assets.

$$a(t) \coloneqq b(t) + z(t), \tag{11}$$

where

a: Total assets

By calculating Expression (11) for the $t+1$ period and using Expression (4) in relation to $b(t+1)$ and Expression (5) in relation to z(t+1):

$$\begin{aligned} a(t+1) &= b(t+1) + z(t+1) \\ &= \{1 + r_l(t)\}(1-\psi^l)\mathrm{b}(t) + w_l(t)\cdot(1-\omega^l)\mathrm{h}(t) + \pi_l(t)\cdot(1-\tau^l)T - c^l(t) - \eta^l\left(m^l(t)\right) - \xi(t) + \\ &\quad (1-\delta_z)(1-\varphi^l)z(t) + \xi(t) \\ &= \{1 + r_l(t)\}(1-\psi^l)\mathrm{b}(t) + w_l(t)\cdot(1-\omega^l)\mathrm{h}(t) + \pi_l(t)\cdot(1-\tau^l)T - c^l(t) - \eta^l\left(m^l(t)\right) + \\ &\quad (1-\delta_z)(1-\varphi^l)z(t) \end{aligned} \tag{12}$$

Here, by substituting b(t) = a(t) – z(t) into Expression (12) and simplifying the right hand side of the expression, the physical assets accumulation process can be expressed as follows.

$$\begin{aligned} a(t+1) &= a(t) + w_l(t)\cdot(1-\omega^l)h(t) + [r_l(t) - \{1 + r_l(t)\}\cdot\psi^l]\cdot a(t) \\ &\quad + [(1-\varphi^l)(1-\delta_z) - \{1 + r_l(t)\}(1-\psi^l)]z(t) + \pi_l(t)\cdot(1-\tau^l)T - c^l(t) \\ &\quad - \eta^l\left(m^l(t)\right) \\ &= a(t) + A^l(t), \end{aligned}$$

$$\begin{aligned} A^l(t) &\coloneqq w_l(t)\cdot(1-\omega^l)h(t) + [r_l(t) - \{1 + r_l(t)\}\cdot\psi^l]\cdot a(t) \\ &\quad + [(1-\varphi^l)(1-\delta_z) - \{1 + r_l(t)\}(1-\psi^l)]z(t) + \pi_l(t)\cdot(1-\tau^l)T - c^l(t) - \eta^l\left(m^l(t)\right). \end{aligned} \tag{13}$$

The optimization problem for representative household is expressed as follows. The value function represents the maximum value of the expected lifetime utility generated as a result of representative household optimizing consumption, human capital, and physical asset formation. The problem of maximizing the expected lifetime utility can be resolved by configuring the value function.

$$\mathrm{V}\left(a(t), h(t), B(t)\right)\cdot\left(\frac{1}{1+\rho}\right)^t = \max\ \mathrm{E}\left[\sum_{t'=t}^{\infty} u\left(c^l(t'), (1-\varphi^l)z(t')\right)\cdot\left(\frac{1}{1+\rho}\right)^{t'}\right], \tag{14}$$

s.t.

$$b(t+1) = \{1 + r_l(t)\}(1-\psi^l)\mathrm{b}(t) + w_l(t)\cdot(1-\omega^l)\mathrm{h}(t) + \pi_l(t)\cdot(1-\tau^l)T - c^l(t)$$
$$- \eta^l\left(m^l(t)\right) - \xi(t),$$
$$z(t+1) = (1-\delta_z)(1-\varphi^l)z(t) + \xi(t),$$
$$h(t+1) = h(t) + H^l(t).$$

(15)

Configuring the total assets as the total of financial assets and physical assets, the conditional expression for the constraints of Expression (15) is expressed using the following two expressions.

$$a(t+1) = a(t) + A^l(t),$$
$$h(t+1) = h(t) + H^l(t).$$

(16)

Afterwards, the section for the time preference rate is configured as follows.

$$\Lambda = \left(\frac{1}{1+\rho}\right).$$

(17)

To obtain the Bellman equation[1] for Expression (14):

$$V\big(a(t), h(t), B(t)\big) = \max E\left[u\left(c^l(t), (1-\varphi^l)z(t)\right) + \Lambda\cdot V\big(a(t+1), h(t+1), B(t+1)\big)\right]$$
$$= \max E\left[u\left(c^l(t), (1-\varphi^l)z(t)\right) + \Lambda\right.$$
$$\left.\cdot V\left(a(t) + A^l(t), h(t) + H^l(t), B(t) + B^{\circ}(t)\right)\right],$$

(18)

where $\boldsymbol{B}^{\circ}(\boldsymbol{t}) = \boldsymbol{B}(\boldsymbol{t}+\mathbf{1}) - \boldsymbol{B}(\boldsymbol{t})$. Approximating the second polynomial on the right side in Expression (18) results in:

$$V\big(a(t), h(t), B(t)\big) = \max\sum_l \mu^l\left[\begin{matrix} u\left(c^l(t), (1-\varphi^l)z(t)\right) \\ +\Lambda\cdot\left\{V + V_a\cdot A^l(t) + V_h\cdot H^l(t) + V_B\cdot B^{\circ}\ (t)\right\}\end{matrix}\right].$$

(19)

$$(1-\Lambda)\cdot V\big(a(t), h(t), B(t)\big)$$
$$= \max\sum_l \mu^l\left[u\left(c^l(t), (1-\varphi^l)z(t)\right) + \Lambda\cdot\{V_a\cdot A^l(t) + V_h\cdot H^l(t) + V_B\cdot B^{\circ}(t)\}\right].$$

(20)

Using the first-order conditions (differential of the objective function using c^l, z, m^l) from Expression (20) to maximize the expected lifetime utility:

$$\frac{\partial V(a,h,B)}{\partial c^l} = 0,$$

$$\frac{\partial V(a,h,B)}{\partial z} = 0,$$

$$\frac{\partial V(a,h,B)}{\partial m^l} = 0.$$

(21)

Using Expression (21), the following three equations are obtained.

$$c^l\ :\ u_c(c^l,(1-\varphi^l)z) = \Lambda \cdot V_a,$$

(22)

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

(23)

$$m^l\ :\ V_h \cdot \varsigma = V_a \cdot \{\eta^l(m^l)\}'.$$

(24)

2）Profit Maximization

Firms behave toward the maximization of the following profit function.

$$\text{Max}\ \ \widetilde{\Pi}_l(t) = Y(t) - TC(t)$$
$$= F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big) - w_l(t)\cdot(1-\omega^l)H(t) - \{r_l(t)+\delta_k\}\cdot(1-\psi^l)K(t)$$

(25)

where

$\widetilde{\Pi}_l$: Firm profit (after the occurrence of a rank l disaster)

Using the first-order conditions (differential of the objective function using H and K) from Expression (25) to maximize profit results in:

$$\frac{\partial\widetilde{\Pi}_l}{\partial H} = 0,$$
$$\frac{\partial\widetilde{\Pi}_l}{\partial K} = 0.$$

(26)

Using Expression (26), the following two equations are obtained.

$$H\ :\ \frac{\partial F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big)}{\partial H} = w_l(t)\cdot(1-\omega^l),$$

(27)

$$K\ :\ \frac{\partial F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big)}{\partial K} = \{r_l(t)+\delta_k\}\cdot(1-\psi^l),$$

(28)

s.t.

$$0 < \mu^l < 1,$$

where

μ^l: Disaster probability (rank l disaster)

The first-order conditions represent that the amount of elemental investment is determined so that the amount of this limited production is equal to the marginal cost regarding labor and production capital.

All firm's profit $\widetilde{\Pi}_l$ is distributed to household as land rent. The amount of distribution is determined in accordance with the ratio of land area owned.

$$\pi_l(t) = \frac{\widetilde{\Pi}_l(t)}{(1-\tau^l)\tilde{T}} = \frac{\widetilde{\Pi}_l(t)}{(1-\tau^l)nT}.$$

(29)

3）Market Equilibrium

The market equilibrium is uniquely determined by simultaneously solving the five equations produced from calculating Expressions (22), (23), and (24), which are the first-order conditions to maximize expected lifetime utility, and Expressions (27) and (28), which are the first-order conditions to maximize profit. Each equation is rewritten here.

$$
\begin{aligned}
c^l &: u_c(c^l,(1-\varphi^l)z) = \Lambda \cdot V_a, \\
z &: \sum_l \mu^l \{u_z(c^l,(1-\varphi^l)z) + \Lambda \cdot V_a \cdot (1-\varphi^l)\cdot(1-\delta_z)\} \\
&\qquad\qquad = \Lambda \cdot V_a \sum_l \mu^l (1-\psi^l)\{r(t)+1\}, \\
m^l &: V_h \cdot \varsigma = V_a \cdot \{\eta^l(m^l)\}', \\
H &: \frac{\partial F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big)}{\partial H} = w_l(t)\cdot(1-\omega^l), \\
K &: \frac{\partial F\big(B(t),(1-\omega^l)H(t),(1-\psi^l)K(t),(1-\tau^l)\tilde{T}\big)}{\partial K} = \{r_l(t)+\delta_k\}\cdot(1-\psi^l).
\end{aligned}
\tag{30}
$$

(4) Social Optimization

Externalities do not exist in this model, and so the market equilibrium equation is equivalent to the social optimization solution. The following equation is used to equalize the amount of production and the amount of distribution.

$$F(B(t),(1-\omega^l)h(t),(1-\psi^l)b(t),(1-\tau^l)T)$$
$$=w_l(t)\cdot(1-\omega^l)h(t)+\{r_l(t)+\delta_k\}\cdot(1-\psi^l)b(t)+\ \pi_l(t)\cdot(1-\tau^l)T.$$

(31)

As with Expression (4), this can be rewritten using Expression (31).

$$b(t+1)=\{1+r_l(t)\}(1-\psi^l)\mathrm{b}(t)+w_l(t)\cdot(1-\omega^l)\mathrm{h}(t)+\pi_l(t)\cdot(1-\tau^l)T-c^l(t)-\eta^l\left(m^l(t)\right)-\xi(t)$$

$$=\{r_l(t)+\delta_k\}(1-\psi^l)\mathrm{b}(t)+w_l(t)\cdot(1-\omega^l)\mathrm{h}(t)+\pi_l(t)\cdot(1-\tau^l)T-c^l(t)-\eta^l\left(m^l(t)\right)-\xi(t)$$
$$+(1-\delta_k)(1-\psi^l)\mathrm{b}(t)$$
$$=F(B(t),(1-\omega^l)h(t),(1-\psi^l)b(t),(1-\tau^l)T)-c^l(t)-\eta^l\left(m^l(t)\right)-\xi(t)$$
$$+(1-\delta_k)(1-\psi^l)\mathrm{b}(t).$$

(32)

As with Expression (31), this can be rewritten using Expression (12).

$$a(t+1)=b(t+1)+z(t+1)$$

$$=\ w_l(t)\cdot(1-\omega^l)\mathrm{h}(t)+\{1+r_l(t)\}(1-\psi^l)\mathrm{b}(t)+\pi_l(t)\cdot(1-\tau^l)T-c^l(t)-\eta^l\left(m^l(t)\right)$$
$$+(1-\delta_z)(1-\varphi^l)z(t)$$
$$=w_l(t)\cdot(1-\omega^l)\mathrm{h}(t)+\{r_l(t)+\delta_k\}(1-\psi^l)\mathrm{b}(t)+\pi_l(t)\cdot(1-\tau^l)T-c^l(t)-\eta^l\left(m^l(t)\right)+$$
$$(1-\delta_z)(1-\varphi^l)z(t)+(1-\delta_k)(1-\psi^l)\mathrm{b}(t)$$
$$=a(t)+w_l(t)\cdot(1-\omega^l)h(t)+\{r_l(t)+\delta_k\}\cdot(1-\psi^l)\mathrm{b}(t)+\ \pi_l(t)\cdot(1-\tau^l)T-\{\delta_k+$$
$$(1-\delta_k)\cdot\psi^l\}a(t)-c^l(t)-\eta^l\left(m^l(t)\right)-\{(1-\psi^l)(1-\delta_k)-(1-\varphi^l)(1-\delta_z)\}z(t)$$
$$=a(t)+F(B(t),(1-\omega^l)h(t),(1-\psi^l)b(t),(1-\tau^l)T)-\{\delta_k+(1-\delta_k)\cdot\psi^l\}a(t)-c^l(t)-$$
$$\eta^l\left(m^l(t)\right)-\{(1-\psi^l)(1-\delta_k)-(1-\varphi^l)(1-\delta_z)\}z(t)$$
$$=a(t)+A^l(t),$$
$$A^l(t)\coloneqq F(B(t),(1-\omega^l)h(t),(1-\psi^l)b(t),(1-\tau^l)T)-\{\delta_k+(1-\delta_k)\cdot\psi^l\}a(t)-c^l(t)-\eta^l\left(m^l(t)\right)$$
$$-\{(1-\psi^l)(1-\delta_k)-(1-\varphi^l)(1-\delta_z)\}z(t).$$

(33)

The social optimization solution has fewer expressions and variables and so is generally easier to calculate than the market equilibrium solution. For this reason, analysis is performed in this model using the social optimization problem. Thus, for the remaining sections, only households are the focus of problem solutions as it is assumed that the economy is managed by responsible social planners trying to maximize the expected lifetime utility for a representative household.

$$\mathrm{V}\big(a(t), h(t), B(t)\big) \cdot \left(\frac{1}{1+\rho}\right)^{t} = \max\ \mathrm{E}\left[\sum_{t'=t}^{\infty} u\left(c^{l}(t'), (1-\varphi^{l})z(t')\right) \cdot \left(\frac{1}{1+\rho}\right)^{t'}\right],$$

(34)

s.t.

$$b(t+1) = F(B(t), (1-\omega^{l})h(t), (1-\psi^{l})b(t), (1-\tau^{l})T) - c^{l}(t) - \eta^{l}\left(m^{l}(t)\right) - \xi(t)$$

$$+ (1-\delta_{k})(1-\psi^{l})\mathrm{b}(t),$$

$$z(t+1) = (1-\delta_{z})(1-\varphi^{l})z(t) + \xi(t),$$

$$h(t+1) = h(t) + H^{l}(t).$$

(35)

Configuring the total assets as the total of financial assets and physical assets, the conditional expression for the constraints of Expression (35) is expressed using the following two expressions.

$$a(t+1) = a(t) + A^{l}(t),$$

$$h(t+1) = h(t) + H^{l}(t).$$

(36)

The section for the time preference rate is configured as follows.

$$\Lambda = \left(\frac{1}{1+\rho}\right).$$

(37)

To obtain the Bellman equation[2] for Expression (34):

$$V\big(a(t), h(t), B(t)\big) = \max E\ \left[u\left(c^{l}(t), (1-\varphi^{l})z(t)\right) + \Lambda \cdot V\big(a(t+1), h(t+1), B(t+1)\big)\right]$$

$$= \max E\ \left[u\left(c^{l}(t), (1-\varphi^{l})z(t)\right) + \Lambda\right.$$

$$\left.\cdot V\left(a(t) + A^{l}(t), h(t) + H^{l}(t), B(t) + B^{\circ}(t)\right)\right],$$

(38)

where $B^{\circ}(t) = B(t+1) - B(t)$. Approximating the second polynomial on the right hand side using the Taylor expansion results in:

$$V\big(a(t), h(t), B(t)\big)$$

$$= \max \sum_{l} \mu^{l}\left[u\left(c^{l}(t), (1-\varphi^{l})z(t)\right) + \Lambda \cdot \left\{V + V_{a} \cdot A^{l}(t) + V_{h} \cdot H^{l}(t) + V_{B} \cdot B^{\circ}\ (t)\right\}\right]$$

(39)

The objective function can be expressed as follows by binding the left side of Expression (39) with V.

$$(1-\Lambda)\cdot V\big(a(t),h(t),B(t)\big)$$
$$= \max \sum_{l} \mu^l \left[u\left(c^l(t),(1-\varphi^l)z(t)\right) + \Lambda\cdot\{V_a\cdot A^l(t) + V_h\cdot H^l(t) + V_B\cdot B^{\circ}(t)\}\right],$$

(40)

Applying the first-order conditions for social optimization to the objective function (40) results in:

$$\frac{\partial V(a,h,B)}{\partial c^l} = 0,$$
$$\frac{\partial V(a,h,B)}{\partial z} = 0,$$
$$\frac{\partial V(a,h,B)}{\partial m^l} = 0.$$

(41)

As a result, the following three equations are obtained.

$$c^l\ :\ u_c(c^l,(1-\varphi^l)z) = \Lambda\cdot V_a,$$

(42)

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

(43)

$$m^l\ :\ V_h\cdot\varsigma = V_a\cdot\{\eta^l(m^l)\}'.$$

(44)

Thus, the social optimization solution is obtained by solving the following equation.

$$c^l \;:\; u_c(c^l,(1-\varphi^l)z)=\Lambda\cdot V_a,$$

$$\boldsymbol{z \;:\; \sum_l \mu^l\left\{u_z\left(c^l,(1-\varphi^l)z\right)+\Lambda\cdot V_a\cdot(1-\varphi^l)(1-\delta_z)\right\}}$$

$$\boldsymbol{=\Lambda\cdot V_a\sum_l \mu^l\left\{F_b+(1-\psi^l)(1-\delta_k)\right\}},$$

$$m^l \;:\; V_h\cdot\varsigma = V_a\cdot\{\eta^l(m^l)\}',$$

$$b \;:\; b(t)=a(t)-z(t),$$

s.t.

$$a(t+1)=a(t)+A^l(t),$$

$$A^l(t)=F(B(t),(1-\omega^l)h(t),(1-\psi^l)b(t),(1-\tau^l)T)-\{\delta_k+(1-\delta_k)\cdot\psi^l\}a(t)-c^l(t)$$

$$-\eta^l\left(m^l(t)\right)-\{(1-\psi^l)(1-\delta_k)-(1-\varphi^l)(1-\delta_z)\}z(t)$$

$$h(t+1)=h(t)+H^l(t),$$

$$H^l(t)=-\delta_h\cdot h(t)+\varsigma\cdot m^l(t).$$

(45)

2.3.5 Formulations to Simplify the Calculations

(1) Configuring the Formation of the Value Function

The formation of the value function is unknown, and so the previously described first-order conditions cannot be solved without modification. For this reason, it is assumed that the marginal utility decreases to arrive at the following formation.

$$V(a, h, B) = \nu_0 + \nu_1 \cdot (Ba)^{1-\theta} + \nu_2 \cdot (Bh)^{1-\theta}. \tag{46}$$

Differentiating expression (46) by the first degree results in the following.

$$V_a = \frac{\partial V(a, h, B)}{\partial a} = (1 - \theta) \cdot \nu_1 B \cdot (Ba)^{-\theta}, \tag{47}$$

$$V_h = \frac{\partial V(a, h, B)}{\partial h} = (1 - \theta) \cdot \nu_2 B \cdot (Bh)^{-\theta}. \tag{48}$$

(2) Configuring the Formation of the Human Investment Cost Function

The cost function related to human investment assumes the following quadratic function as it is assumed that education costs increase as the number of education increases. The coefficient η_2^l as a term in the quadratic m^l is determined by the rank of the disaster.

$$\eta^l(m^l) = \eta_0 + \eta_1 \cdot m^l + \eta_2^l \cdot (m^l)^2. \tag{49}$$

Differentiating expression (49) by the first degree results in the following.

$$\frac{\partial \eta^l(m^l)}{\partial m^l} = \eta_1 + 2\eta_2^l \cdot m^l. \tag{50}$$

Other potential formations of the human investment cost function include logarithmic or logistic types, but these functions cannot be statistically identified due to constraints on data. For this reason, the function has been configured as a quadratic function as the current focus is simplification.

2.3.6 Resulting Basic Constitutive Equations and Their Expansion

First-order conditions can be rewritten as follows by substituting first-order differential equations (47), (48), and (50) with first-order conditional equations (42), (43), and (44).

$$c^l \;:\; u_c(c^l, (1 - \varphi^l)z) = \Lambda \cdot (1 - \theta) \cdot \nu_1 B \cdot (Ba)^{-\theta},$$

(51)

$$\boldsymbol{z}\ :\ \sum_{l} \boldsymbol{\mu}^{l} \{ \boldsymbol{u}_{z}(\boldsymbol{c}^{l}, (\mathbf{1}-\boldsymbol{\varphi}^{l})\boldsymbol{z}) + \boldsymbol{\Lambda} \cdot (\mathbf{1}-\boldsymbol{\theta}) \cdot \boldsymbol{\nu}_{\mathbf{1}} \boldsymbol{B} \cdot (\boldsymbol{B}\boldsymbol{a})^{-\boldsymbol{\theta}} \cdot (\mathbf{1}-\boldsymbol{\varphi}^{l})(\mathbf{1}-\boldsymbol{\delta}_{z}) \}$$

$$= \boldsymbol{\Lambda} \cdot (\mathbf{1}-\boldsymbol{\theta}) \cdot \boldsymbol{\nu}_{\mathbf{1}} \boldsymbol{B} \cdot (\boldsymbol{B}\boldsymbol{a})^{-\boldsymbol{\theta}} \sum_{l} \boldsymbol{\mu}^{l} \{ \boldsymbol{F}_{b} + (\mathbf{1}-\boldsymbol{\psi}^{l})(\mathbf{1}-\boldsymbol{\delta}_{k}) \},$$

(52)

$$m^{l}\ :\ (1-\theta) \cdot \nu_{2} B \cdot (Bh)^{-\theta} \cdot \varsigma = (1-\theta) \cdot \nu_{1} B \cdot (Ba)^{-\theta} \cdot (\eta_{1} + 2\eta_{2}^{l} \cdot m^{l}).$$

(53)

Using Expression (51) for c^{l}:

$$c^{l} - \bar{c} = \Bigg\{ \overbrace{\frac{\gamma_{1}}{\Lambda \cdot (1-\theta) \cdot \nu_{1} \cdot B^{1-\theta}}}^{=\mathrm{Q}_{0}} \Bigg\}^{\overbrace{\frac{1}{1-\gamma_{1}(1-\theta)}}^{=P_{0}}} \cdot (1-\varphi^{l})^{\overbrace{\frac{\gamma_{2}(1-\theta)}{1-\gamma_{1}(1-\theta)}}^{=P_{1}}} \cdot a^{\overbrace{\frac{\theta}{1-\gamma_{1}(1-\theta)}}^{=P_{2}}} \cdot z^{\frac{\gamma_{2}(1-\theta)}{1-\gamma_{1}(1-\theta)}}$$

$$= \mathrm{Q}_{0}{}^{P_{0}} \cdot (1-\varphi^{l})^{P_{1}} \cdot a^{P_{2}} \cdot z^{P_{1}}$$

(54)

Using Expression (52) for z,

$$\sum_{l} \mu^{l} \{ u_{z} + \Lambda \cdot V_{a}(1-\varphi^{l})(1-\delta_{z}) \} = \Lambda \cdot V_{a} \cdot \sum_{l} \mu^{l} \{ F_{b} + (1-\psi^{l})(1-\delta_{k}) \}$$

$$\sum_{l} \mu^{l} [u_{z} - \Lambda \cdot V_{a} \{ (1-\psi^{l})(1-\delta_{k}) - (1-\varphi^{l})(1-\delta_{z}) \}] = \Lambda \cdot V_{a} \cdot \sum_{l} \mu^{l} \cdot F_{b}$$

$$\sum_{l} \mu^{l} [u_{z} - \Lambda \cdot V_{a} \{ \underbrace{(\delta_{z} - \delta_{k})}_{=\delta_{zk}} + \underbrace{\varphi^{l} - \psi^{l} + \psi^{l}\delta_{k} - \varphi^{l}\delta_{z}}_{=\varphi_{s}^{l}} \}] = \Lambda \cdot V_{a} \cdot \sum_{l} \mu^{l} \cdot F_{b}.$$

(55)

Here, obtaining the first derivative related to (2) in the instantaneous utility function, (2) results in:

$$u_z = \gamma_2 \cdot z^{\gamma_2(1-\theta)-1} \cdot \left\{Q_0^{P_0} \cdot (1-\varphi^l)^{P_1} \cdot a^{P_2} \cdot z^{P1}\right\}^{\gamma_1(1-\theta)} \cdot (1-\varphi^l)^{\gamma_2(1-\theta)}$$
$$= \underbrace{\gamma_2 \cdot Q_0^{P_0\gamma_1(1-\theta)}}_{=Q_1} \cdot a^{P_2\gamma_1(1-\theta)} \cdot \{(1-\varphi^l)\cdot z\}^{\gamma_2(1-\theta)-1+P_1\gamma_1(1-\theta)} \cdot (1-\varphi^l).$$

(56)

The degree of $(1-\varphi^l)\cdot z$ is $\gamma_2(1-\theta)-1+P_1\cdot\gamma_1(1-\theta) = -\frac{\theta}{1-\gamma_1(1-\theta)} = -P_2$. So (56) can be written as follows:

$$u_z = Q_1 \cdot a^{P_2\gamma_1(1-\theta)} \cdot (1-\varphi^l)^{-P_2+1} \cdot z^{-P_2}.$$

(57)

Substituting Expression (57) with Expression (55) results in:

$$\sum_l \mu^l \left\{Q_1 \cdot a^{P_2\gamma_1(1-\theta)} \cdot (1-\varphi^l)^{-P_2+1} \cdot z^{-P_2}\right\} = \Lambda \cdot \mathrm{V}_a \Big(\underbrace{\delta_{zk} + \sum_l \mu^l \cdot \varphi_s^l}_{=Q_3} + \sum_l \mu^l \cdot F_b\Big).$$

(58)

$$\sum_l \mu^l F_b = \underbrace{\sum_l \mu^l \cdot \alpha_2 \cdot (1-\omega^l)^{\alpha_1}(1-\psi^l)^{\alpha_2} \cdot (1-\tau^l)^{\alpha_3}} \cdot F(\cdot) \cdot (a-z)^{-1}$$
$$= \frac{S_0 \cdot F(\cdot)}{a-z}.$$

(59)

Thus, substituting Expression (59) with Expression (58) results in:

$$\mathrm{Q}_1 \cdot a^{P_2\gamma_1(1-\theta)} \cdot z^{-P_2} \cdot \underbrace{\sum_l \mu^l \cdot (1-\varphi^l)^{-P_2+1}}_{=Q_2} = \Lambda \cdot (1-\theta) \cdot \nu_1 \cdot B^{1-\theta} \cdot a^{-\theta}\left(Q_3 + \frac{S_0 \cdot F(\cdot)}{a-z}\right).$$

(60)

The degree of a is the result of "$P_2 \cdot \gamma_1(1-\theta)+\theta = P_2$", and so Expression (60) is simplified as follows.

$$\frac{Q_1 \cdot Q_2}{Q_3 \cdot \Lambda(1-\theta)\nu_1 B^{1-\theta}} \cdot a^{P_2} = z^{P_2}\left[1+\underbrace{\frac{S_0}{Q_3}}_{=S_1}\cdot\frac{F(\cdot)}{(a-z)}\right]$$

$$\underbrace{\left(\frac{Q_1 \cdot Q_2}{Q_3 \cdot \Lambda(1-\theta)\cdot \nu_1 \cdot B^{1-\theta}}\right)^{\frac{1}{P_2}}}_{=Q_4} \cdot a = z\left[1+\frac{S_1 \cdot F(\cdot)}{a-z}\right]^{\frac{1}{P_2}}. \tag{61}$$

$$\left[1+\frac{S_1 \cdot F(\cdot)}{a-z}\right]^{\frac{1}{P_2}} \cdot z = Q_4 \cdot a. \tag{62}$$

Using Expression (53) for m^l:

$$\begin{aligned} m^l &= \frac{\varsigma \cdot \nu_2 \cdot a^{\theta} - \nu_1 \cdot \eta_1 \cdot h^{\theta}}{2\nu_1 \cdot \eta_2^l \cdot h^{\theta}} \\ &= \frac{1}{2\eta_2^l}\left\{\frac{\nu_2}{\nu_1}\cdot\left(\frac{h}{a}\right)^{-\theta}\cdot\varsigma - \eta_1\right\}. \end{aligned} \tag{63}$$

Simplifying Expressions (54), (62), and (63) results in the following.

$$\boldsymbol{c^l} \ : \ \mathbf{c}^{\boldsymbol{l}} - \bar{\boldsymbol{c}} = \boldsymbol{Q_0^{P_0}} \cdot \left(\mathbf{1}-\boldsymbol{\varphi^l}\right)^{\boldsymbol{P_1}} \cdot \boldsymbol{a^{P_2}} \cdot \boldsymbol{z^{P_1}}, \tag{64}$$

$$\boldsymbol{z} \ : \ \left[\mathbf{1}+\frac{\boldsymbol{S_1}\cdot \boldsymbol{F}(\cdot)}{\boldsymbol{a}-\boldsymbol{z}}\right]^{\frac{\mathbf{1}}{\boldsymbol{P_2}}} \cdot \boldsymbol{z} = \boldsymbol{Q_4}\cdot\boldsymbol{a}, \tag{65}$$

$$m^l \ : \ m^l = \frac{1}{2\eta_2^l}\left\{\frac{\nu_2}{\nu_1}\cdot\left(\frac{h}{a}\right)^{-\theta}\cdot\varsigma - \eta_1\right\}, \tag{66}$$

where

$$\mathrm{P}_0 = \frac{1}{1-\gamma_1(1-\theta)},$$

$$\mathrm{P}_1 = \frac{\gamma_2(1-\theta)}{1-\gamma_1(1-\theta)},$$

$$\mathrm{P}_2 = \frac{\theta}{1-\gamma_1(1-\theta)},$$

$$\mathrm{Q}_0 = \frac{\gamma_1}{\Lambda \cdot (1-\theta) \cdot \nu_1 \cdot B^{1-\theta}},$$

$$\mathrm{Q}_1 = \gamma_2 \cdot Q_0^{P_0 \gamma_1 (1-\theta)},$$

$$\mathrm{Q}_2 = \sum_l \mu^l (1-\varphi^l)^{-P_2+1},$$

$$\mathrm{Q}_3 = \delta_{zk} + \sum_l \mu^l \cdot \varphi_s^l,$$

$$\mathrm{Q}_4 = \left\{\frac{Q_1 \cdot Q_2}{Q_3 \cdot \Lambda \cdot (1-\theta) \cdot \nu_1 \cdot B^{1-\theta}}\right\}^{\frac{1}{P_2}},$$

$$\delta_{zk} = \delta_z - \delta_k,$$

$$\varphi_s^l = \varphi^l - \psi^l + \psi^l \delta_k - \varphi^l \delta_z,$$

$$\mathrm{S}_0 = \alpha_2 \sum_l \mu^l \,(1-\omega^l)^{\alpha_1} (1-\psi^l)^{\alpha_2} (1-\tau^l)^{\alpha_3},$$

$$\mathrm{S}_1 = \frac{S_0}{Q_3}. \qquad \textbf{(67)}$$

Thus, the basic constitutive equations to be solved by the program are as follows.

$$\boldsymbol{c^l} \;:\; \mathbf{c}^{\boldsymbol{l}} - \bar{\boldsymbol{c}} = \boldsymbol{Q_0^{P_0}} \cdot \left(\mathbf{1} - \boldsymbol{\varphi^l}\right)^{\boldsymbol{P_1}} \cdot \boldsymbol{a^{P_2}} \cdot \boldsymbol{z^{P_1}},$$

$$\boldsymbol{z} \;:\; \left[\mathbf{1} + \frac{\boldsymbol{S_1} \cdot \boldsymbol{F}(\cdot)}{\boldsymbol{a} - \boldsymbol{z}}\right]^{\frac{\mathbf{1}}{\boldsymbol{P_2}}} \cdot \boldsymbol{z} = \boldsymbol{Q_4} \cdot \boldsymbol{a},$$

$$m^l \;:\; m^l = \frac{1}{2\eta_2^l}\left\{\frac{\nu_2}{\nu_1} \cdot \left(\frac{h}{a}\right)^{-\theta} \cdot \varsigma - \eta_1\right\},$$

$$b \;:\; b(t) = a(t) - z(t),$$

s.t.

$$a(t+1) = a(t) + A^l(t),$$

$$A^l(t) = F(B(t), (1-\omega^l)h(t), (1-\psi^l)b(t), (1-\tau^l)T) - \{\delta_k + (1-\delta_k)\cdot\psi^l\}a(t) - c^l(t)$$

$$- \eta^l\left(m^l(t)\right) - \{(1-\psi^l)(1-\delta_k) - (1-\varphi^l)(1-\delta_z)\}z(t),$$

$$h(t+1) = h(t) + H^l(t),$$

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

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

where (The following polynomial variables are given values for exogenous variables, simulation calculations, and configuring constants.)

$$\mathrm{P}_0 = \frac{1}{1-\gamma_1(1-\theta)},$$

$$\mathrm{P}_1 = \frac{\gamma_2(1-\theta)}{1-\gamma_1(1-\theta)},$$

$$\mathrm{P}_2 = \frac{\theta}{1-\gamma_1(1-\theta)},$$

$$\mathrm{Q}_0 = \frac{\gamma_1}{\Lambda\cdot(1-\theta)\cdot\nu_1\cdot B^{1-\theta}},$$

$$\mathrm{Q}_1 = \gamma_2 \cdot Q_0^{P_0\gamma_1(1-\theta)},$$

$$\mathrm{Q}_2 = \sum_l \mu^l (1-\varphi^l)^{-P_2+1},$$

$$\mathrm{Q}_3 = \delta_{zk} + \sum_l \mu^l \cdot \varphi_s^l,$$

$$\mathrm{Q}_4 = \left\{\frac{Q_1\cdot Q_2}{Q_3\cdot\Lambda\cdot(1-\theta)\cdot\nu_1\cdot B^{1-\theta}}\right\}^{\frac{1}{P_2}},$$

$$\delta_{zk} = \delta_z - \delta_k,$$

$$\varphi_s^l = \varphi^l - \psi^l + \psi^l\delta_k - \varphi^l\delta_z,$$

$$\mathrm{S}_0 = \alpha_2 \sum_l \mu^l\,(1-\omega^l)^{\alpha_1}(1-\psi^l)^{\alpha_2}(1-\tau^l)^{\alpha_3},$$

$$\mathrm{S}_1 = \frac{S_0}{Q_3}.$$

(68)

2.3.7 Method of Calculations in the Program

The c^l and m^l first-order conditional equations are explicit functions where as z first-order conditional equations are implicit functions. For this reason, solutions are obtained using the following procedure.

① Substitute (input) the exogenous variables in Expression (68) with initial values.

$$c^l\ :\ \mathrm{c}^l - \bar{c} = Q_0^{P_0} \cdot (1-\varphi^l)^{P_1} \cdot a^{P_2} \cdot z^{P_1},$$

$$\boldsymbol{z}\ :\ \left[\mathbf{1} + \frac{\boldsymbol{S_1} \cdot \boldsymbol{F}(\cdot)}{\boldsymbol{a} - \boldsymbol{z}}\right]^{\frac{1}{P_2}} \cdot \boldsymbol{z} = \boldsymbol{Q_4} \cdot \boldsymbol{a},$$

$$m^l\ :\ m^l = \frac{1}{2\eta_2^l}\left\{\frac{\nu_2}{\nu_1} \cdot \left(\frac{h}{a}\right)^{-\theta} \cdot \varsigma - \eta_1\right\},$$

$$b\ :\ b(t) = a(t) - z(t),$$

s.t.

$$a(t+1) = a(t) + A^l(t),$$

$$A^l(t) = F(B(t), (1-\omega^l)h(t), (1-\psi^l)b(t), (1-\tau^l)T) - \{\delta_k + (1-\delta_k) \cdot \psi^l\}a(t) - c^l(t)$$

$$- \eta^l\left(m^l(t)\right) - \{(1-\psi^l)(1-\delta_k) - (1-\varphi^l)(1-\delta_z)\}z(t),$$

$$h(t+1) = h(t) + H^l(t),$$

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

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

② Apply a(0) and $h(0)$ to Expression (68).

This results in obtaining m^l from the m^l first-order conditional equation (explicit function).

$$m^l\ :\ m^l = \frac{1}{2\eta_2^l}\left\{\frac{\nu_2}{\nu_1} \cdot \left(\frac{h}{a}\right)^{-\theta} \cdot \varsigma - \eta_1\right\}.$$

③ The z first-order conditional equation (implicit function) is solved using Newton's method.

Thus, z is obtained.

$$z\ :\ \left[1 + \frac{S_1 \cdot F(\cdot)}{a - z}\right]^{\frac{1}{P_2}} \cdot z = Q_4 \cdot a.$$

④ Substitute z with the c^l first-order conditional equation (explicit function).

Thus, c^l is obtained.

$$c^l\ :\ \mathrm{c}^l - \bar{c} = Q_0^{P_0} \cdot (1-\varphi^l)^{P_1} \cdot a^{P_2} \cdot z^{P_1}.$$

⑤ Substitute the values of a and z obtained in the preceding step with " $a(t) \coloneqq b(t) + z(t)$"

Thus, b is obtained.

$$b : b(t) = a(t) - z(t).$$

⑥ Substitute the values of m^l obtained in the preceding step with "$\eta^l(m^l) = \eta_0 + \eta_1 \cdot m^l + \eta_2^l \cdot (m^l)^2$". Thus, the value of $\eta^l(m^l)$ is obtained.

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

⑦ Substitute m^l, z, c^l, b, and $\eta^l(m^l)$ obtained by the calculations to A^l and H^l.

$$A^l(t) = F(B(t), (1-\omega^l)h(t), (1-\psi^l)b(t), (1-\tau^l)T) - \{\delta_k + (1-\delta_k)\cdot\psi^l\}a(t) - c^l(t)$$

$$- \eta^l\left(m^l(t)\right) - \{(1-\psi^l)(1-\delta_k) - (1-\varphi^l)(1-\delta_z)\}z(t),$$

$$H^l(t) = -\delta_h \cdot h(t) + \varsigma \cdot m^l(t).$$

⑧ By obtaining A^l and H^l, a and h for the next period is calculated.

$$a(t+1) = a(t) + A^l(t),$$

$$h(t+1) = h(t) + H^l(t).$$

⑨ Apply a(t+1), h(t+1) to Expression (68).

This results in obtaining m^l from the m^l first-order conditional equation (explicit function).

$$m^l \;:\; m^l = \frac{1}{2\eta_2^l}\left\{\frac{\nu_2}{\nu_1}\cdot\left(\frac{h}{a}\right)^{-\theta}\cdot\varsigma - \eta_1\right\}.$$

⑩ Steps 3 through 9 are repeated hereafter (continues until the calculation period ends).

Chapter2　How to use DR²AD model (Ver1. 4) Application

3　DR²AD model (ver1.4) Application Overview

3.1 What can DR²AD model (Ver1.4) do?

This section describes the functions of the DR²AD model (Ver1.4). Application output is generally divided into 2 types: output for policy explanation / policy maker decision making and output for analysis / supervisor decision making. The output for policy explanation / policy maker decision making can be used for macroeconomic indexes and other broad decision making. The output for analysis / supervisor decision making can be used for analysis of social issues such as economic and social disparity using household budget indexes from different socioeconomic levels.

Table-1 Output Types (Overview)

Use		Economic Indexes	Output Type
Policy explanation / Policy maker decision making	Used in broad policy determinations through macroeconomic indexes	GDP, disaster scale, disaster frequency, disaster damage ratios, etc.	Graphs CSV files
Analysis / Supervisor determinations	Detailed analysis of household standards of living through household budget index and income bracket data	GDP per capita (individual income), consumption, physical assets, financial assets, human capital, education time, human investments, etc. by class	CSV files

3.2 Preparation

3.2.1 Operating Environment

Refer to the Mathworks Inc. website for operating environment information.
http:// www.mathworks.com/products/matlab/choosing_hardware.html

■Operating Systems
MATLAB performance is similar on Windows®, Mac OS® X, and Linux®

■32-bit or 64-bit?
On Windows computers, using 64-bit Windows and the 64-bit version of MATLAB is the right choice for most situations, because it can access the larger amounts of memory in modern computers (see Memory section), and support for 32-bit Windows will end in the next couple of years. Refer to the Platform Road Map for more information. Also refer to Adopting 64-bit Windows for a more detailed discussion of migrating to 64-bit Windows.
On Mac and Linux computers, the 64-bit version of MATLAB is the only version available.

■Recommended Specifications (Windows 64 bit)
32-Bit and 64-Bit MATLAB and Simulink Product Families

Operating Systems	Processors	Disk Space	RAM	Graphics
Windows 8.1 **Windows 8** **Windows 7 Service Pack 1** **Windows Vista Service Pack 2** **Windows XP Service Pack 3** **Windows XP x64 Edition Service Pack 2** **Windows Server 2012** **Windows Server 2008 R2 Service Pack 1** **Windows Server 2008 Service Pack 2** **Windows Server 2003 R2 Service Pack 2**	Any Intel or AMD x86 processor supporting SSE2 instruction set*	1 GB for MATLAB only, 3–4 GB for a typical installation	1024 MB (At least 2048 MB recommended)	No specific graphics card is required. Hardware accelerated graphics card supporting OpenGL 3.3 with 1GB GPU memory recommended. Learn moreabout system requirements for MATLAB Graphics

Fig. 3-1　Recommended Specifications (Windows 64 bit)

3.2.2 Program set

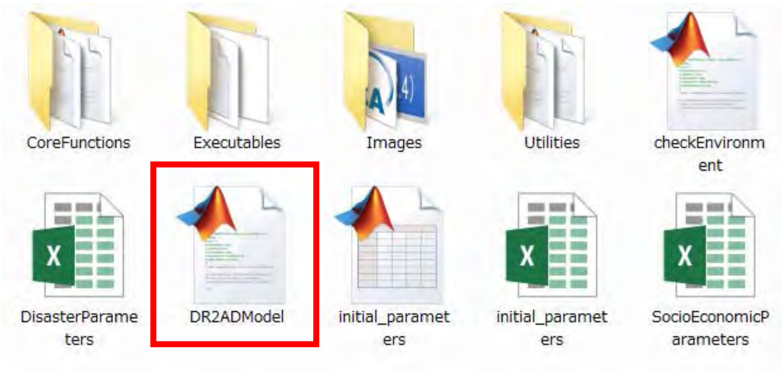
The following items are required in order to run the application.

I. MATLB Runtime program
II. DR^2AD model (ver1.4) program set
III. Sample excel file (for further analysis, excel file prepared by the user)
IV. World bank data catalog
V. Statistic data for target country

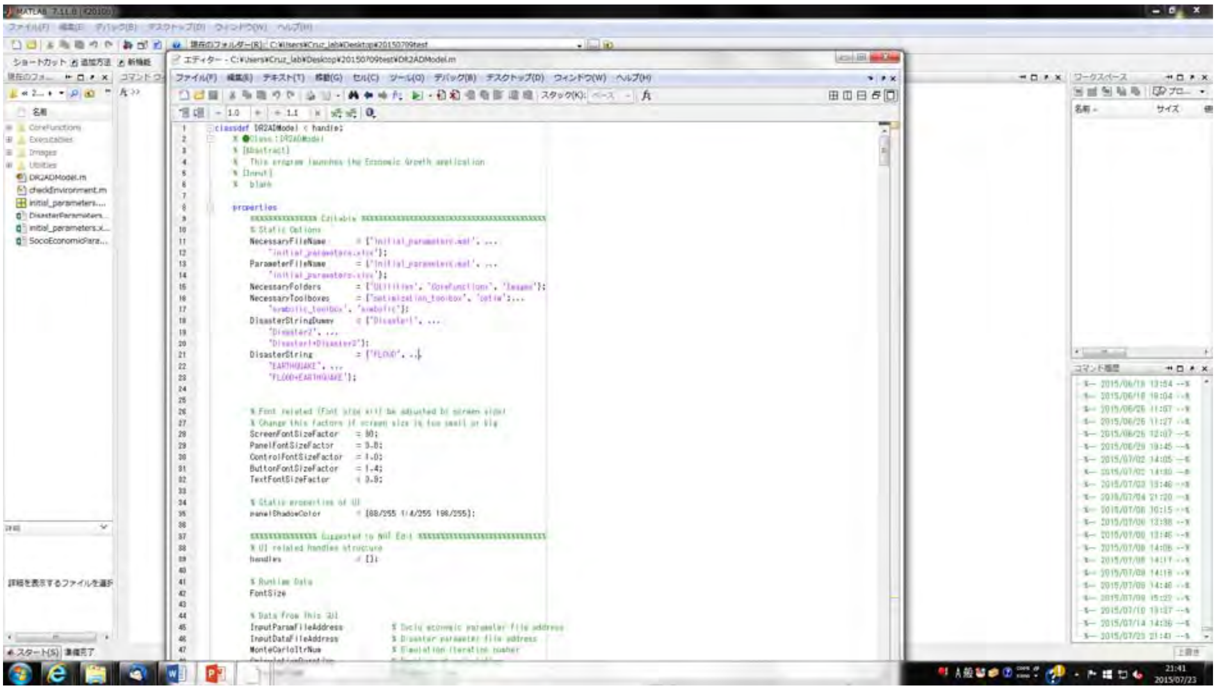
3.2.3 Starting DR^{2}AD model (ver1.4)

The operation procedure to start the DR²AD model (ver1.4) which is the coded version of MATLAB is shown below.

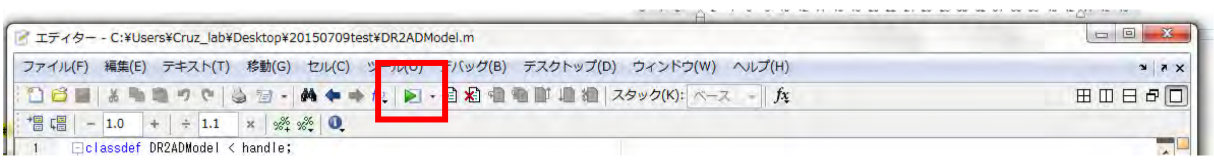
I. Click on the DR2AD_Model file as illustrated in the following figure.



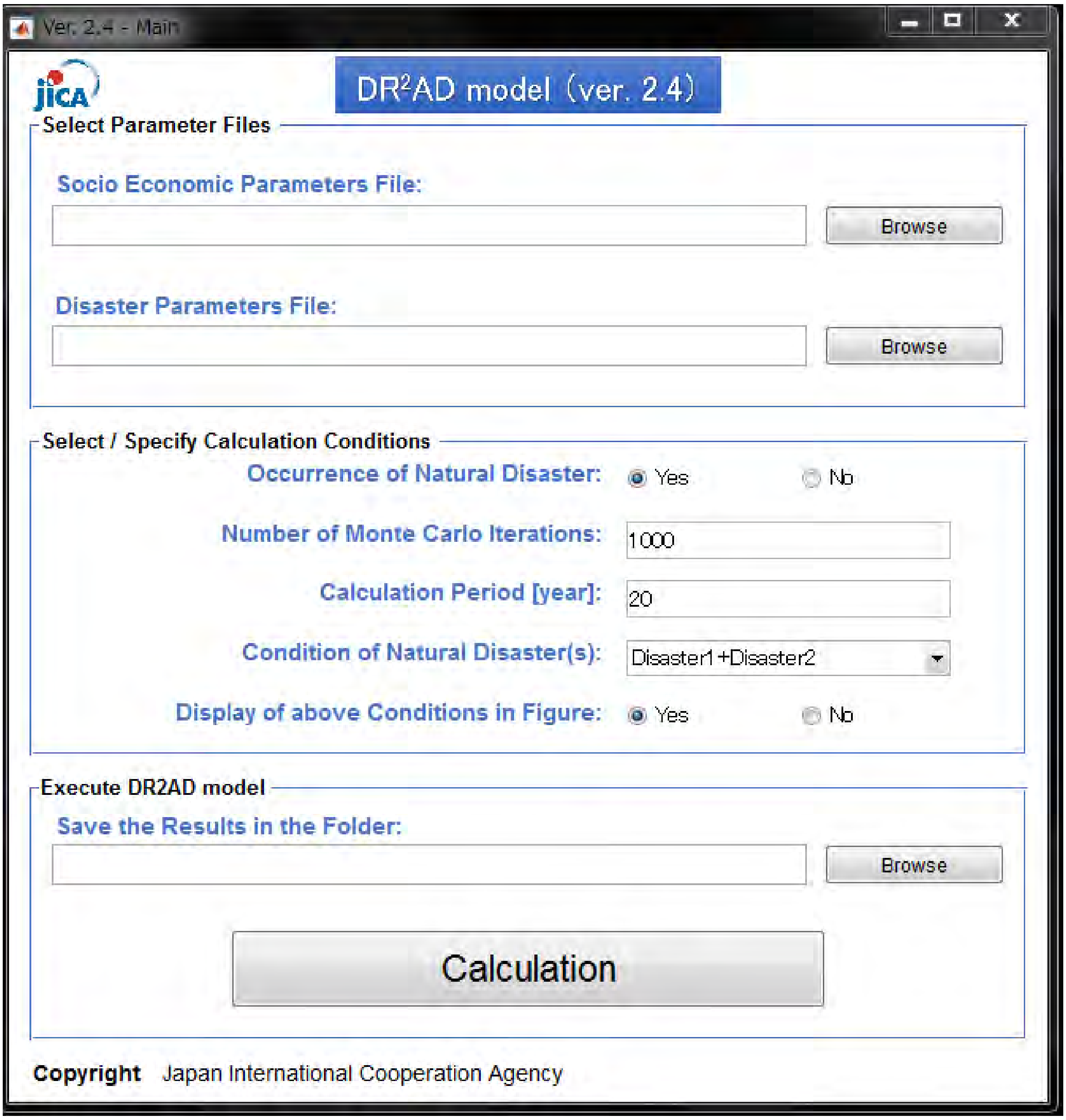
II. The screen shown in the figure below should be displayed.



III. Click run button in editor tab.



IV. The GUI screen as shown below is displayed on the screen.



3.2.4 Compile DR^{2}AD model from ver1.4 to ver.2.4

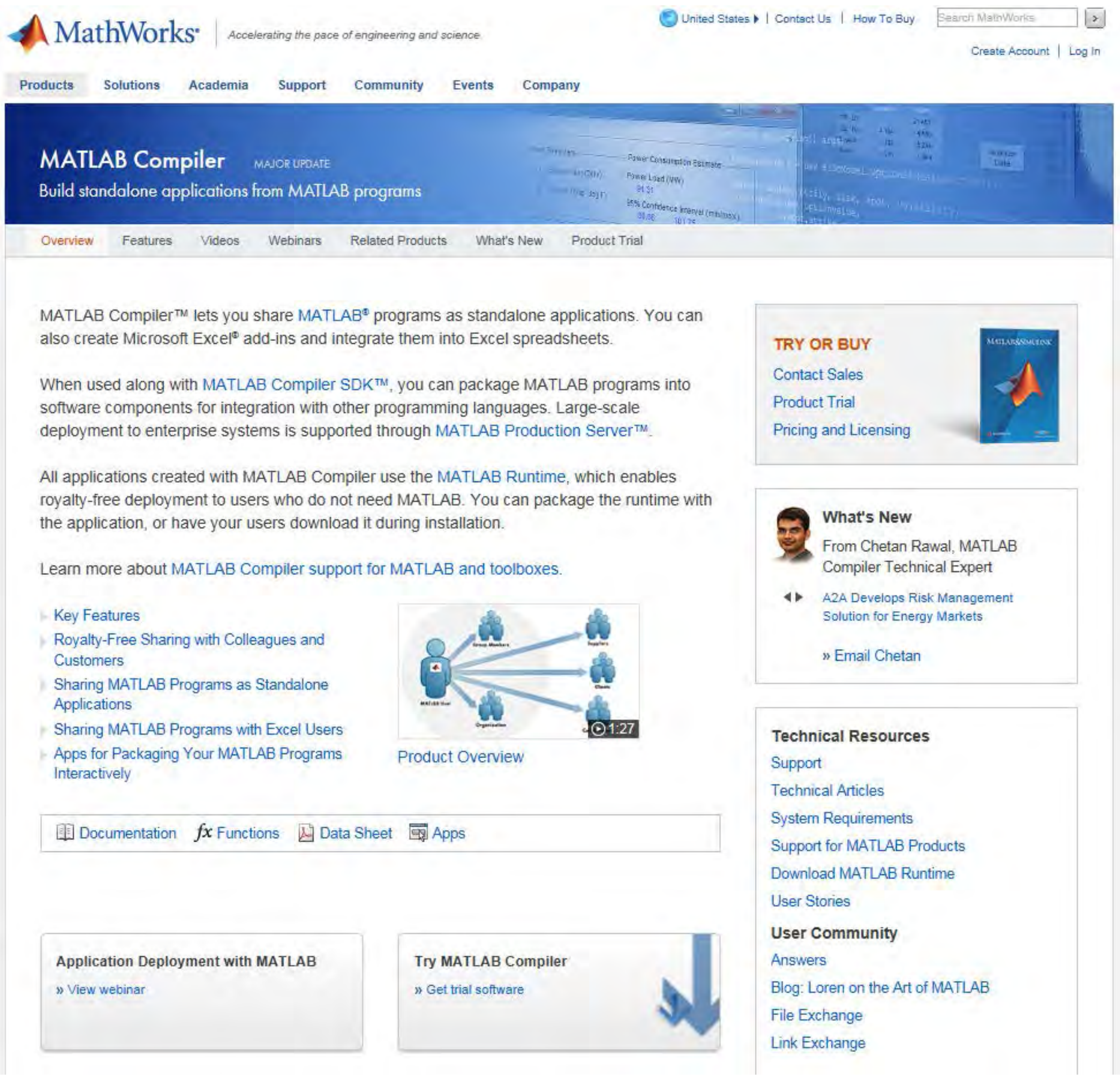
It is necessary to use the MATLAB Compiler of Mathworks to use the DR^{2}AD model (ver1.4) which is the coded version of MATLAB without depending on the operation environment. By compiling the DR^{2}AD model (ver1.4) with MATLAB Compile, it is possible to build the stand-alone type application.

Furthermore, the application version of DR^{2}AD model (ver1.4) is called DR^{2}AD model (ver2.4).

To have detailed information about MATLAB Compiler, refer to the homepage of MathWorks.

<Reference : MATLAB Compiler (MathWorks)>

http://mathworks.com/products/compiler/



4 HOW TO USE APPLICATION

In this chapter, the operation procedure of the application is explained as the scheme shown below.

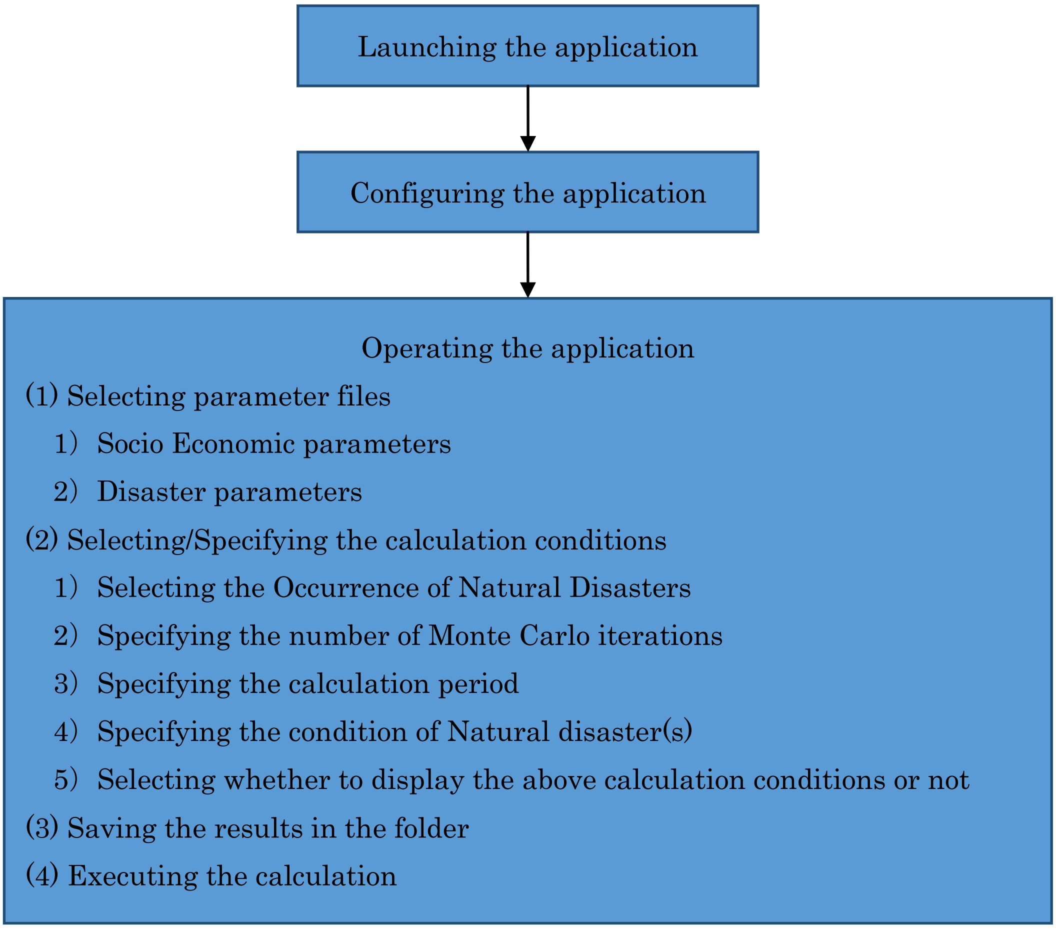


Fig. 4-1 Application Usage Procedure

4.1 Launching the application

Click on the **DR2AD_Model** file as illustrated in the following figure.

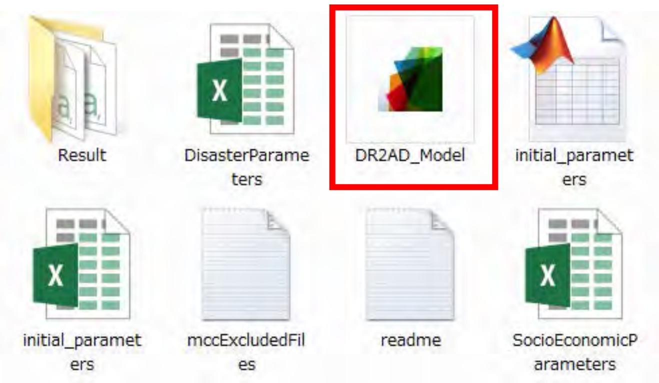


Fig. 4-2　Opening the Application File

The screen shown in the figure below should be displayed.

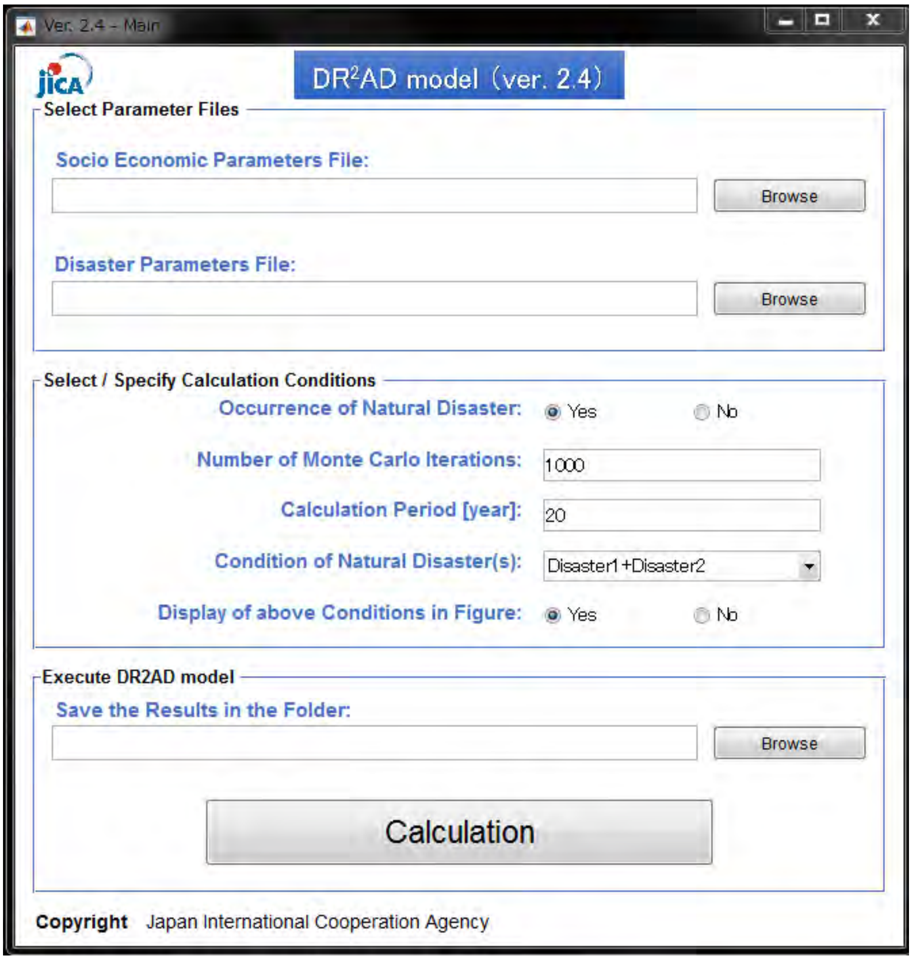


Fig. 4-3　Opening the Application File

4.2 Configuring the Application

Run the program in accordance with the process described below.

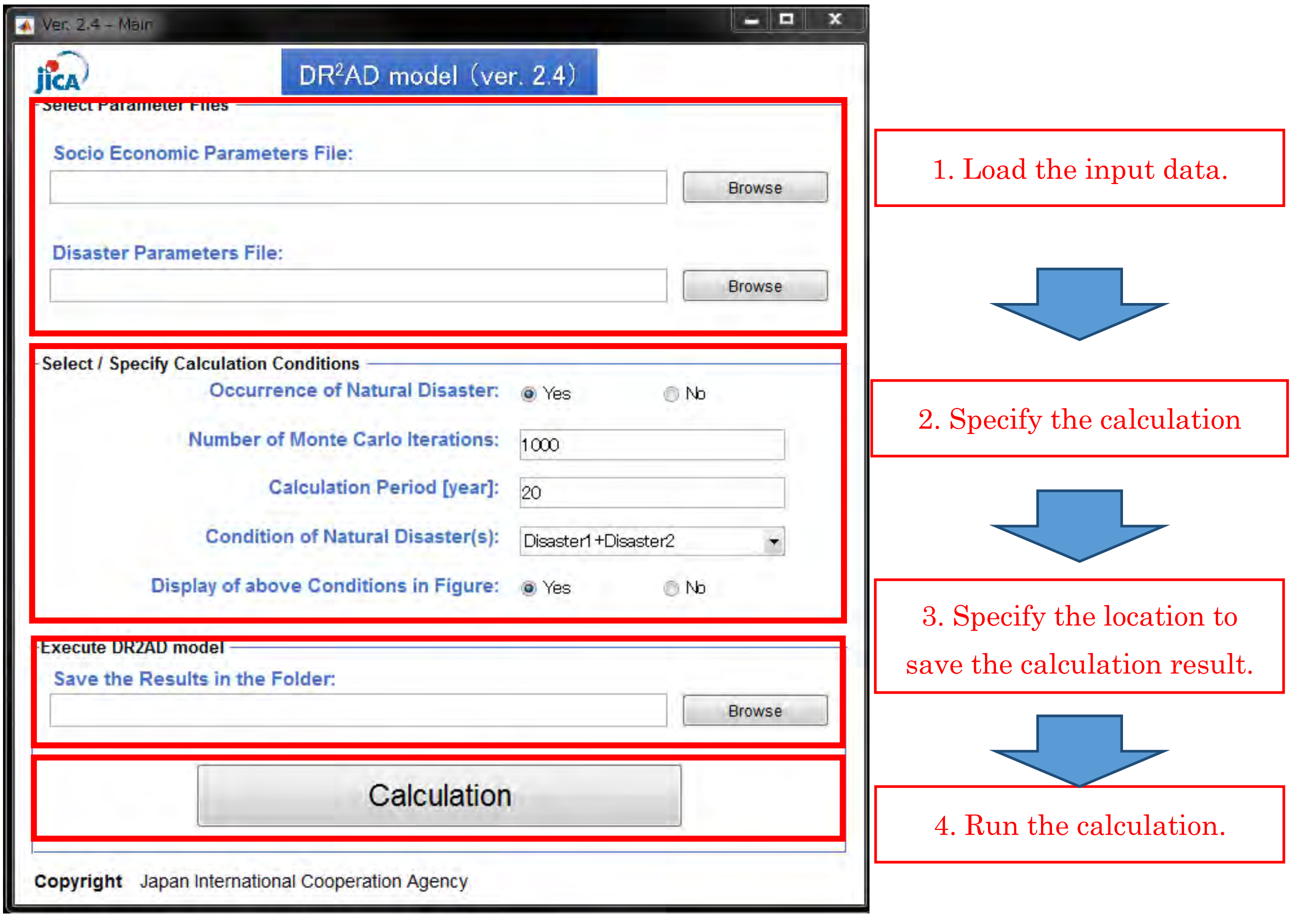


Fig. 4-4 Process to run Ver 2.4 of this application

① Loading the input data

② Specifying the calculation conditions.

(Select whether to include a disaster or not and then specify the number of Monte Carlo simulations, calculation period, the type of disaster, and display of calculation conditions)

③ Specifying the location to save the calculation result

④ Run the calculation

4.3 Operating the Application

This section describes the procedures to operate the application.

4.3.1 Selecting parameter files

This section describes the procedure to configure the input data. Chapter 5 describes the procedure to configure input values for specific data.

The main types of parameters include Socioeconomic and Disaster parameters. Socioeconomic parameters are further divided into Deep parameters for which principle values are not reconfigured and Macroeconomic parameters and Household data used to input data for each country.

Input data created by Excel should be led on the application. Since there are sample data which is filled by the data of Honduras, Pakistan, Peru, Costa Rica and Guatemala. You are able to run application without the setting for the data of the country.

Initial parameters and description are shown in table below.

Table 4-1 Types of input data

Data Type		Examples of Data
Socio Economic parameters	Deep parameters	Relative risk aversion level, time preference rate, etc.
	Macroeconomic data	Population, GDP, etc.
	Household data	Consumption, savings, investment, etc.
Disaster parameters	Disaster data	Human capital damage, physical asset damage, etc.

Table 4-2 Input Data List of Socio Economic parameters

Parameter name	Description	Data source	Sample value
J	The number of income class	<fixed data>	5
L	The number of disaster classes (not including the no-disaster state)	<fixed data>	4
rho	Time preference rate	Recommended value	0.12
theta	Degree of relative risk aversion	Recommended value	2
cbar	The subsistence level of consumption	Recommended value	0
deltaz	Depreciation rate of physical asset	<fixed data>	0.1
deltak	Depreciation rate of production capital	<fixed data>	0.02
gb	Exogenous technological growth rate	Recommended value	0.042
iota	Compensation coefficient between the human capital investment and the years of education.	Those parameters are defined by the assumption. There will be no effect to the model when you use 1.	1
Pop0	Initial population	World Bank data (by Country)	6762426
GDP0	Initial GDP US$ (2004, from World bank HP, 2005US$)	World Bank data (by Country)	9120240790
alpha1	Share parameter for human capital	Social Account Matrix/Input Output Table	0.45
alpha2	Share parameter for physical capital	Social Account Matrix/Input Output Table	0.47
alpha3	Share parameter for land	Social Account Matrix/Input Output Table	0.08
c0	Initial consumption per capita: Data of Households' survey 2004	Household Survey /JICA Poverty Profile	93 243 448 787 2564
h0	Initial human capital per capita (using mean years of schooling as a proxy variable)	UNDP data (Mean years of schooling)/Household Survey /JICA Poverty Profile	3.3 4.2 5.0 6.0 6.9
z0	Initial physical asset investment per capita as flow variable	Household Survey /JICA Poverty Profile	112 293 540 949 3091
b0	Initial financial assets per capita	World Bank data (by Country)	321 842 1554 2732 8899
T0	Initial land per capita	World Bank data (by Country)	0.02 0.05 0.08 0.15 0.48
m0	Initial education time per capita	Household Survey /JICA Poverty Profile	0.33

Parameter name	Description	Data source	Sample value
deltah	Depreciation rate of human capital	World Bank data (by Country)	0.004
eta0	Coefficient of human investment cost function	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank	0
eta1	Coefficient of human investment cost function	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank	0
eta2M	Coefficient of human investment cost function	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank	205.8
eta2Mvector	0<h<=6 6<h<=9 9<h<=11 11<h<=15 15<h<=17 17<h<=20 20<h<=60	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank	205.8 245.3 381.3 1092.6 1504.3 1918.7 5347.2 20000

Table 4-3　Reference of Input Data of Disaster Parameters

Parameter name	Description	Data source
omegaV_DISASTER (1 or 2)	Human capital damage rate due to disaster by rank	Human capital damage: Desinventar / UNISDR population : World Bank data (by Country)
phiV_DISASTER (1 or 2)	Physical assets damage rate due to disaster by rank	Physical assets damage : Desinventar / UNISDR Household: Household Survey / JICA Poverty Profile
psiV_DISASTER (1 or 2)	Production capital damage rate due to disaster by rank	Set following the relationship between Capital damage rate and Physical assets damage rate
tauV_DISASTER (1 or 2)	Damage rate of land due to disaster by rank	There are no disaster in this case study
mu	Probability of disaster occurrence by rank	UNISDR database Desinventar

Table 4-4 Input Data List of sheet1 on Disaster Parameters (Disaster1 =FLOOD)

Parameter name	Sample value				
Disaster Rank	Rank 0	Rank 1	Rank 2	Rank 3	Rank 4
mu	0.500	0.464	0.019	0.011	0.007
DRR	Without				
omegaV_DISASTER1	0	0.110046	0.298150	0.400638	0.475017
phiV_DISASTER1	0	0.000191	0.000488	0.000634	0.000749
psiV_DISASTER1	0	0.000840	0.002149	0.002789	0.003294
tauV_DISASTER1	0	0	0	0	0
DRR	Soft				
omegaV_DISASTER1	0	0	0	0	0
phiV_DISASTER1	0	0.000191	0.000488	0.000634	0.000749
psiV_DISASTER1	0	0.000840	0.002149	0.002789	0.003294
tauV_DISASTER1	0	0	0	0	0
DRR	Hard1				
omegaV_DISASTER1	0	0	0.078125	0.273375	0.402195
phiV_DISASTER1	0	0	0.000153	0.000474	0.000656
psiV_DISASTER1	0	0	0.000671	0.002084	0.002886
tauV_DISASTER1	0	0	0	0	0
DRR	Hard2				
omegaV_DISASTER1	0	0	0	0.099688	0.313246
phiV_DISASTER1	0	0	0	0.000200	0.000541
psiV_DISASTER1	0	0	0	0.000881	0.002380
tauV_DISASTER1	0	0	0	0	0
DRR	Hard1+soft				
omegaV_DISASTER1	0	0	0	0	0
phiV_DISASTER1	0	0	0.000153	0.000474	0.000656
psiV_DISASTER1	0	0	0.000671	0.002084	0.002886
tauV_DISASTER1	0	0	0	0	0
DRR	Hard2+soft				
omegaV_DISASTER1	0	0	0	0	0
phiV_DISASTER1	0	0	0	0.000200	0.000541
psiV_DISASTER1	0	0	0	0.000881	0.002380
tauV_DISASTER1	0	0	0	0	0

Table 4-5 Input Data List of sheet2 on Disaster Parameters (Disaster2 =EARTHQUAKE)

Parameter name	Sample value				
Disaster Rank	**Rank 0**	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**
mu	0.5	0.468048	0.015625	0.009615	0.006711
DRR	Without				
omegaV_DISASTER2	0	0.000300	0.000928	0.001243	0.001485
phiV_DISASTER2	0	0.001339	0.003731	0.005008	0.005959
psiV_DISASTER2	0	0.005893	0.016416	0.022035	0.026222
tauV_DISASTER2	0	0	0	0	0
DRR	Soft				
omegaV_DISASTER2	0	0.000300	0.000928	0.001243	0.001485
phiV_DISASTER2	0	0.001339	0.003731	0.005008	0.005959
psiV_DISASTER2	0	0.005893	0.016416	0.022035	0.026222
tauV_DISASTER2	0	0	0	0	0
DRR	Hard1				
omegaV_DISASTER2	0	0	0.000139	0.000719	0.00116
phiV_DISASTER2	0	0	0.000914	0.003369	0.004995
psiV_DISASTER2	0	0	0.004019	0.014823	0.021976
tauV_DISASTER2	0	0	0	0	0
DRR	Hard2				
omegaV_DISASTER2	0	0	0	0.000175	0.000813
phiV_DISASTER2	0	0	0	0.001179	0.003873
psiV_DISASTER2	0	0	0	0.005188	0.017041
tauV_DISASTER2	0	0	0	0	0
DRR	Hard1+soft				
omegaV_DISASTER2	0	0	0.000139	0.000719	0.00116
phiV_DISASTER2	0	0	0.000914	0.003369	0.004995
psiV_DISASTER2	0	0	0.004019	0.014823	0.021976
tauV_DISASTER2	0	0	0	0	0
DRR	Hard2+soft				
omegaV_DISASTER2	0	0	0	0.000175	0.000813
phiV_DISASTER2	0	0	0	0.001179	0.003873
psiV_DISASTER2	0	0	0	0.005188	0.017041
tauV_DISASTER2	0	0	0	0	0

(3) Socio Economic Parameters

Here you can insert socioeconomic data.

Click **Browse** and select the Excel file to load.

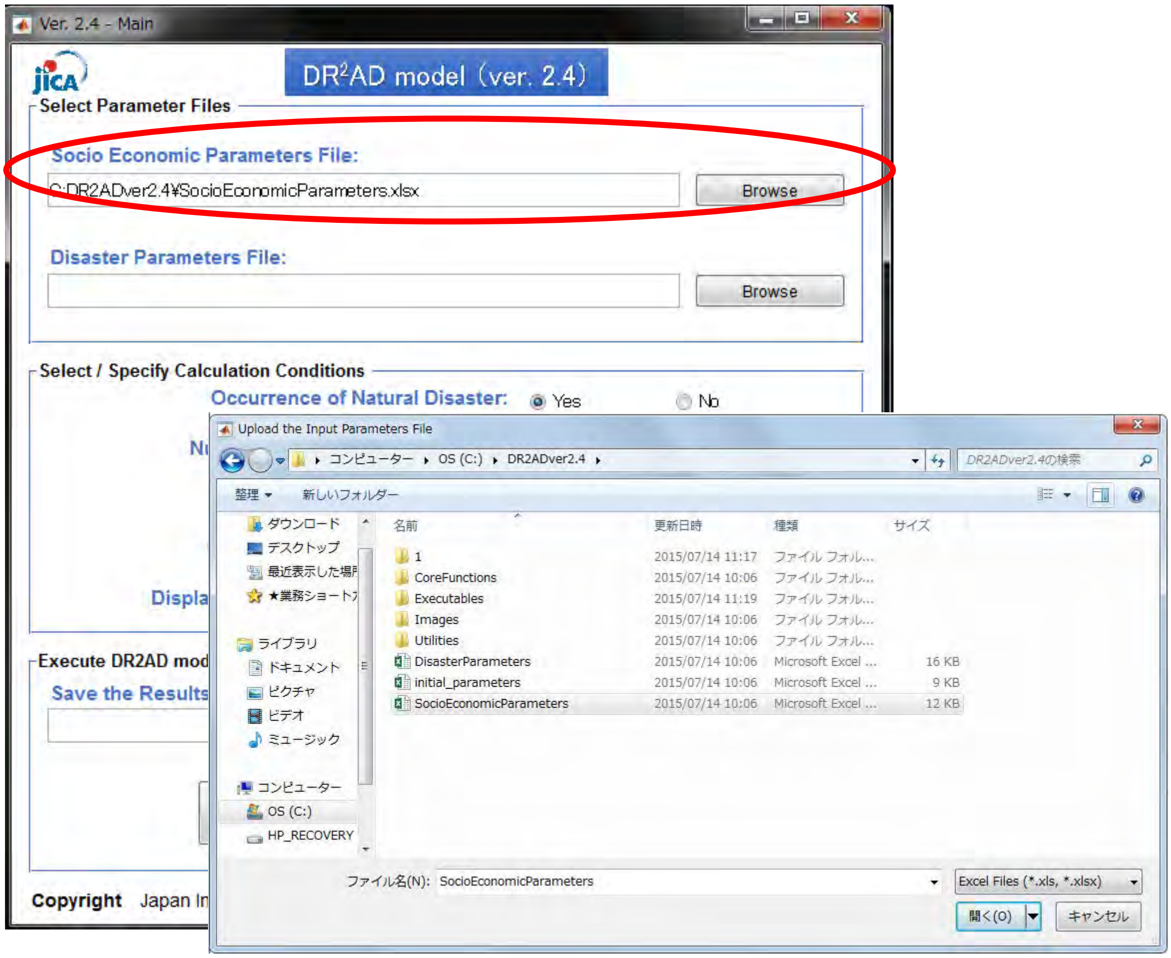


Fig. 4-5 Specifying the Socio Economic parameters file

There are two options to set up Excel file.

First way is to use a sample excel file with already filled with data.

Another way is to create a country's original data.

Option 1	Default value or Sample data
Option 2	Country's original data

<Option 1: Default value or Sample data>

In order to run the application without setting the country's data, you can use 5 country's data below as a sample.

Excel File name	SEPara_Sample HONDURAS	SEPara_Sample PAKISTAN	SEPara_Sample PERU	SEPara_Sample GUATEMALA	SEPara_Sample COSTARICA
J	5	5	5	5	5
L	4	4	4	4	4
rho	0.12	0.12	0.12	0.12	0.12
theta	2	2	2	2	2
cbar	0	0	0	0	0
deltaz	0.1	0.1	0.1	0.1	0.1
deltak	0.02	0.02	0.02	0.02	0.02
gb	0.042	0.042	0.042	0.042	0.042
iota	1	1	1	1	1
Pop0	6762426	155151394	27403845	12367800	4246336
GDP0	9120240790	101704136879	70530831291	26352121441	18855016400
alpha1	0.45	0.52	0.38	0.38	0.45
alpha2	0.47	0.4	0.54	0.54	0.47
alpha3	0.08	0.08	0.08	0.08	0.08
c0	93 243 448 787 2564	208 289 369 480 924	295 583 926 1457 3777	241 545 889 1427 3820	462 1032 1613 2575 6574
h0	3.3 4.2 5.0 6.0 6.9	3.2 3.9 4.2 4.4 5.6	8.4 8.4 8.4 8.4 8.4	3.5 3.5 3.5 3.5 3.5	7.9 7.9 7.9 7.9 7.9
z0	112 293 540 949 3091	186 259 331 429 827	306 605 962 1513 3923	364 825 1345 2158 5779	498 1112 1738 2775 7084
b0	321 842 1554 2732 8899	1297 1801 2306 2992 5765	1101 2176 3458 5440 14104	1277 2892 4713 7564 20256	1793 4005 6259 9993 25513
T0	0.02 0.05 0.08 0.15 0.48	0.06 0.09 0.11 0.15 0.28	0.03 0.05 0.09 0.14 0.35	0.02 0.05 0.08 0.13 0.36	0.01 0.02 0.03 0.05 0.13
m0	0.33	0.18	0.31	0.31	0.26
deltah	0.004	0.005	0.005	0.005	0.005
eta0	0	0	0	0	0
eta1	0	0	0	0	0
eta2M	205.8	100.9	632	310	1001.9
eta2Mvector	205.8 245.3 381.3 1092.6 1504.3 1918.7 5347.2 20000	100.9 120.3 187.3 536.4 651.4 820.0 2064.6 20000	555.4 632.0 665.4 1164.8 1412.9 1679.8 3860.1 20000	310.0 369.8 575.6 1653.3 2275.5 2904.4 8097.9 20000	880.3 1001.9 1056.8 1858.0 2256.9 2685.6 6183.3 20000

<Option 2：Country's original data>

Socioeconomic data is organized as Excel data as shown in the following figure. Open the excel file named "Socioeconomic Parameters" and fill the yellow columns.

To calculate events separately for different countries, in Excel, enter data in cells highlighted in yellow, as shown in the following figure. Refer to the table on the previous page for more information on each parameter.

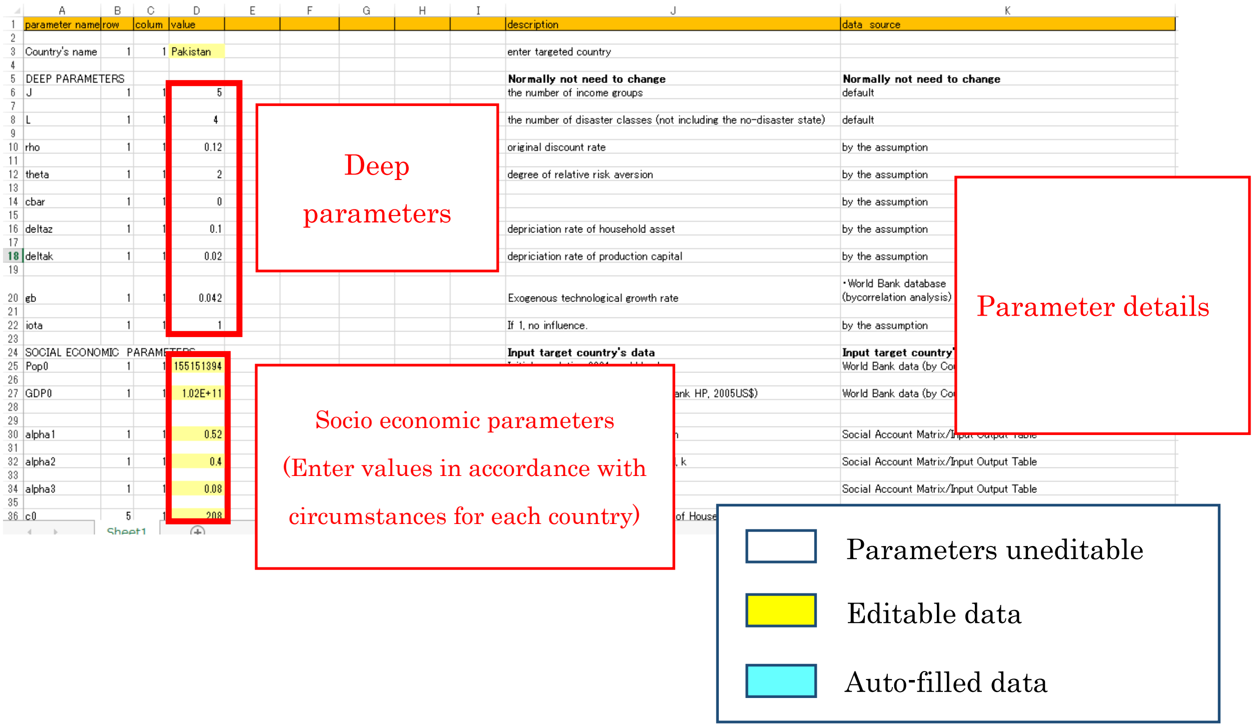


Fig. 4-6 Enter Socioeconomic parameters file

(4) Disaster Parameters

Here, you can insert disaster damage data.

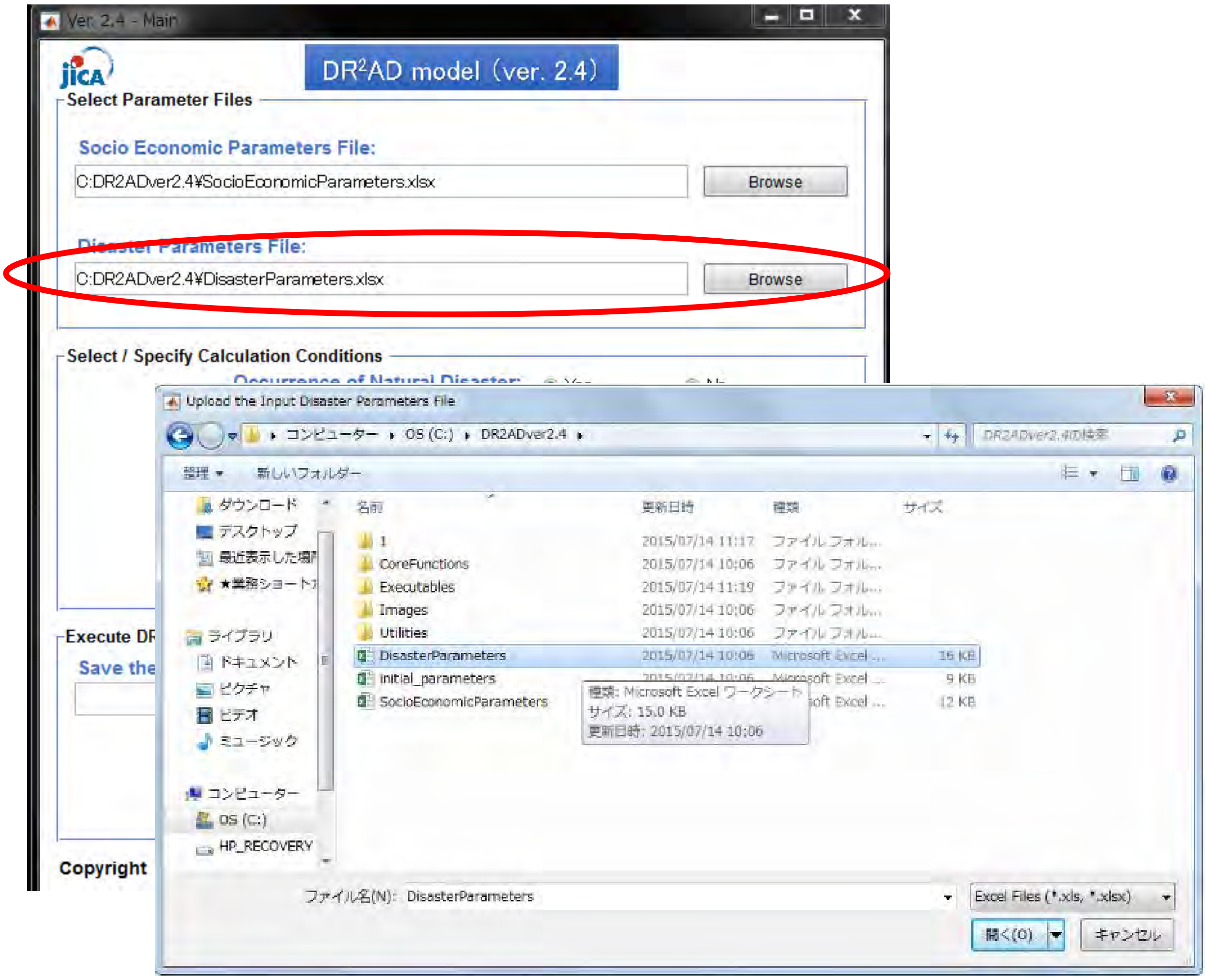


Fig. 4-7 Specifying the Disaster Parameters

There are also two options to set up Excel file.
The first way is to use a sample excel file with already filled data.
You can create a country's original data with Option 2

Option 1	Default value or Sample data
Option 2	Country's original data

<Option 1: Default value or Sample data>

In order to run the application without setting the country's data, you can use 5 country's data below.

Table 4-6 Sample Input Data Lists of 5 countries of disaster 1 in Disaster parameters

Country(Disaster)	Rank	rate	Proba.	Damege rate of human capital				damage rate of physical asstes				Damage rate of financial assets			
				without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2
GUATE MALA (FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	43.0%	1/2～1/23	1.44%	0.00%	0.00%	0.00%	0.89%	0.89%	0.00%	0.00%	3.93%	3.93%	0.00%	0.00%
	2	4.3%	1/23～1/56	2.82%	0.00%	1.83%	0.00%	1.62%	1.62%	1.18%	0.00%	7.13%	7.13%	5.20%	0.00%
	3	1.8%	1/56～1/112	3.61%	0.00%	3.30%	2.32%	2.09%	2.09%	1.94%	1.46%	9.20%	9.20%	8.55%	6.43%
	4	0.9%	1/112～1/200	4.26%	0.00%	4.11%	3.81%	2.51%	2.51%	2.45%	2.28%	11.05%	11.05%	10.76%	10.03%
COSTA RICA (FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.5%	1/2～1/56	0.15%	0.00%	0.00%	0.00%	0.03%	0.03%	0.00%	0.00%	0.13%	0.13%	0.00%	0.00%
	2	1.8%	1/56～1/96	0.41%	0.00%	0.09%	0.00%	0.08%	0.08%	0.02%	0.00%	0.36%	0.36%	0.08%	0.00%
	3	1.0%	1/96～1/143	0.55%	0.00%	0.37%	0.12%	0.11%	0.11%	0.07%	0.02%	0.49%	0.49%	0.32%	0.11%
	4	0.7%	1/143～1/200	0.65%	0.00%	0.55%	0.42%	0.13%	0.13%	0.11%	0.08%	0.58%	0.58%	0.48%	0.37%
PAKISTAN(FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.6%	1/2～1/60	0.23%	0.00%	0.00%	0.00%	0.16%	0.16%	0.00%	0.00%	0.72%	0.72%	0.00%	0.00%
	2	1.7%	1/60～1/100	0.68%	0.00%	0.13%	0.00%	0.32%	0.32%	0.21%	0.00%	1.43%	1.43%	0.92%	0.00%
	3	1.0%	1/100～1/146	0.92%	0.00%	0.57%	0.17%	0.42%	0.42%	0.38%	0.27%	1.84%	1.84%	1.67%	1.17%
	4	0.7%	1/146～1/200	1.11%	0.00%	0.89%	0.65%	0.49%	0.49%	0.47%	0.44%	2.15%	2.15%	2.08%	1.93%
PERU(FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.0%	1/2～1/48	0.19%	0.00%	0.00%	0.00%	0.03%	0.03%	0.00%	0.00%	0.15%	0.15%	0.00%	0.00%
	2	2.1%	1/48～1/87	0.49%	0.00%	0.16%	0.00%	0.07%	0.07%	0.04%	0.00%	0.30%	0.30%	0.19%	0.00%
	3	1.1%	1/87～1/136	0.64%	0.00%	0.48%	0.21%	0.09%	0.09%	0.08%	0.05%	0.38%	0.38%	0.35%	0.24%
	4	0.7%	1/136～1/200	0.75%	0.00%	0.66%	0.55%	0.10%	0.10%	0.10%	0.09%	0.46%	0.46%	0.44%	0.40%
HONDURAS(FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.4%	1/2～1/54	11.00%	0.00%	0.00%	0.00%	0.02%	0.02%	0.00%	0.00%	0.08%	0.08%	0.00%	0.00%
	2	1.9%	1/54～1/94	29.82%	0.00%	7.81%	0.00%	0.05%	0.05%	0.02%	0.00%	0.21%	0.21%	0.07%	0.00%
	3	1.1%	1/94～1/142	40.06%	0.00%	27.34%	9.97%	0.06%	0.06%	0.05%	0.02%	0.28%	0.28%	0.21%	0.09%
	4	0.7%	1/142～1/200	47.50%	0.00%	40.22%	31.32%	0.07%	0.07%	0.07%	0.05%	0.33%	0.33%	0.29%	0.24%

Table 4-7 Sample Input Data Lists of 5 countries of disaster 2 in Disaster parameters

Country(Disaster)	Rank	rate	Proba.	Damege rate of human capital				damage rate of physical asstes				Damage rate of financial assets			
				without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2
GUATE MALA (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	45.7%	1/2～1/43	0.19%	0.19%	0.00%	0.00%	0.31%	0.31%	0.00%	0.00%	1.35%	1.35%	0.00%	0.00%
	2	2.3%	1/43～1/82	0.48%	0.48%	0.18%	0.00%	0.78%	0.78%	0.25%	0.00%	3.43%	3.43%	1.09%	0.00%
	3	1.2%	1/82～1/133	0.63%	0.63%	0.50%	0.24%	1.03%	1.03%	0.75%	0.32%	4.51%	4.51%	3.32%	1.41%
	4	0.8%	1/133～1/200	0.75%	0.75%	0.67%	0.57%	1.21%	1.21%	1.06%	0.87%	5.33%	5.33%	4.67%	3.82%
COSTA RICA (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.4%	1/2～1/54	0.46%	0.46%	0.00%	0.00%	0.44%	0.44%	0.00%	0.00%	1.95%	1.95%	0.00%	0.00%
	2	1.9%	1/54～1/95	1.29%	1.29%	0.33%	0.00%	1.18%	1.18%	0.34%	0.00%	5.20%	5.20%	1.51%	0.00%
	3	1.1%	1/95～1/142	1.72%	1.72%	1.18%	0.40%	1.58%	1.58%	1.13%	0.44%	6.95%	6.95%	4.96%	1.95%
	4	0.7%	1/142～1/200	2.05%	2.05%	1.72%	1.33%	1.87%	1.87%	1.61%	1.29%	8.21%	8.21%	7.10%	5.67%
PAKISTAN (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.7%	1/2～1/61	0.03%	0.03%	0.00%	0.00%	0.53%	0.53%	0.00%	0.00%	2.34%	2.34%	0.00%	0.00%
	2	1.6%	1/61～1/101	0.10%	0.10%	0.02%	0.00%	1.41%	1.41%	0.41%	0.00%	6.20%	6.20%	1.82%	0.00%
	3	1.0%	1/101～1/146	0.14%	0.14%	0.08%	0.02%	1.87%	1.87%	1.34%	0.53%	8.24%	8.24%	5.92%	2.34%
	4	0.7%	1/146～1/200	0.16%	0.16%	0.13%	0.10%	2.23%	2.23%	1.91%	1.53%	9.79%	9.79%	8.42%	6.75%
PERU (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	45.4%	1/2～1/39	0.54%	0.54%	0.00%	0.00%	0.63%	0.63%	0.00%	0.00%	2.79%	2.79%	0.00%	0.00%
	2	2.6%	1/39～1/77	1.32%	1.32%	0.55%	0.00%	1.60%	1.60%	0.51%	0.00%	7.03%	7.03%	2.22%	0.00%
	3	1.3%	1/77～1/128	1.75%	1.75%	1.40%	0.71%	2.06%	2.06%	1.56%	0.69%	9.04%	9.04%	6.87%	3.05%
	4	0.8%	1/128～1/200	1.99%	1.99%	1.86%	1.64%	2.42%	2.42%	2.14%	1.80%	10.63%	10.63%	9.40%	7.90%
HONDURAS (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.8%	1/2～1/64	0.03%	0.03%	0.00%	0.00%	0.13%	0.13%	0.00%	0.00%	0.59%	0.59%	0.00%	0.00%
	2	1.6%	1/64～1/104	0.09%	0.09%	0.01%	0.00%	0.37%	0.37%	0.09%	0.00%	1.64%	1.64%	0.40%	0.00%
	3	1.0%	1/104～1/149	0.12%	0.12%	0.07%	0.02%	0.50%	0.50%	0.34%	0.12%	2.20%	2.20%	1.48%	0.52%
	4	0.7%	1/149～1/200	0.15%	0.15%	0.12%	0.08%	0.60%	0.60%	0.50%	0.39%	2.62%	2.62%	2.20%	1.70%

<Option 2: Country's original data>

Disaster damage data is organized as Excel data as shown in the following figure.

To calculate events separately for different countries, in Excel, enter data in cells highlighted in yellow, as shown in the following figur. Blue areas are automatically calculated. You do not need to input any data here.

You can specify different types of disasters for Disaster Type 1 and Disaster Type 2. You can then calculate a compound disaster by entering the probability and damage ratio for each disaster. Refer to the table on the previous page for more information on each parameter.

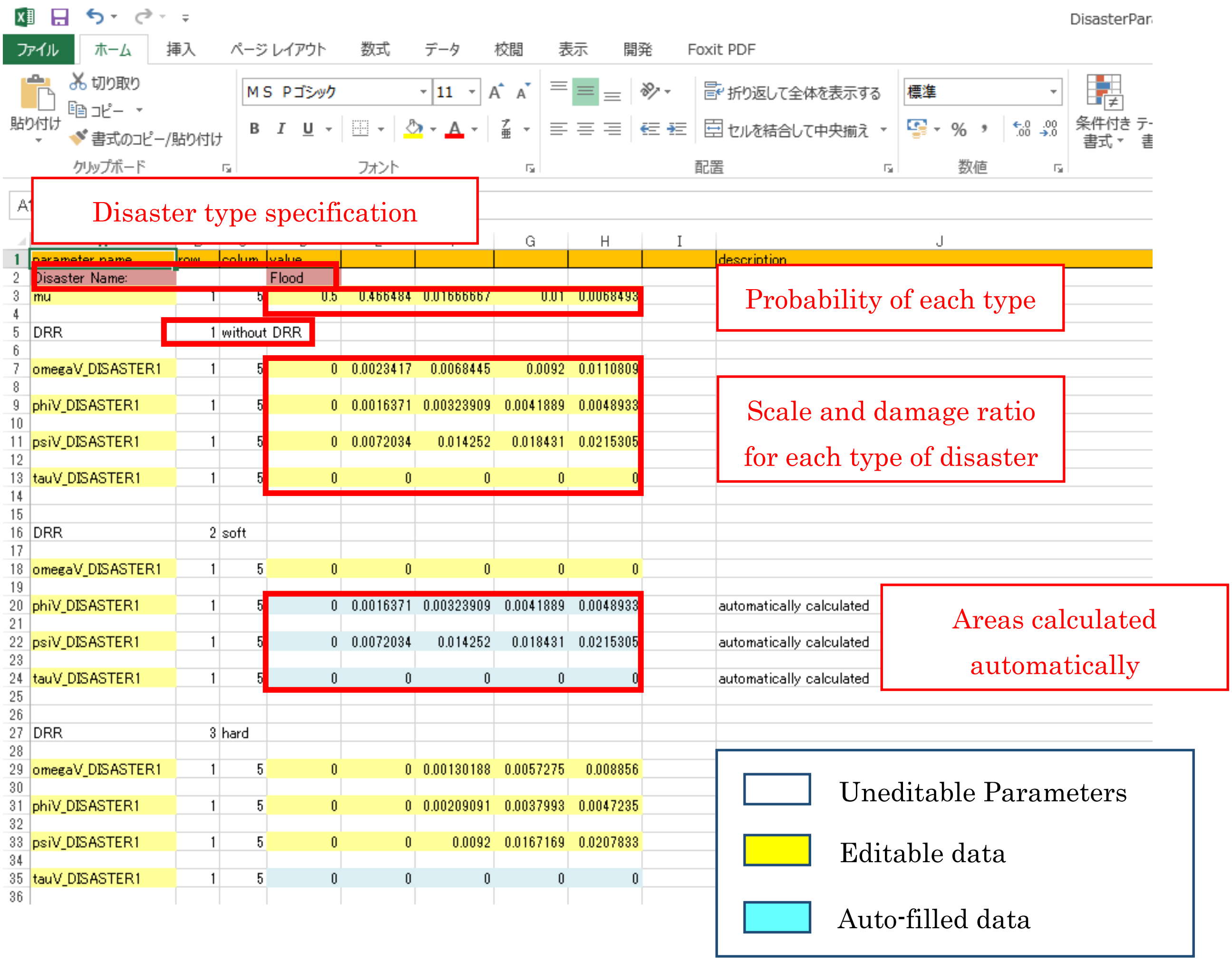


Fig. 4-8 Entering Socio Economic parameters into the Excel sheet1

4.3.2 Selecting / Specifying the calculation conditions

The following section describes the procedure to configure the calculation conditions of the Excel data.

(1) Selecting the Occurrence of Natural Disasters

You can select the occurrence of Natural disaster by choosing “Yes” or “No”. The default value is "Yes". If you need to verify the process of GDP is theoretical or not in case of no occurrence of Natural disaster, you can choose "No".

(2) Specifying the number of Monte Carlo iterations

You can specify the number of desired Monte Carlo iterations.
The default value is 1000 iterations.

(3) Specifying the calculation period

You can specify the desired calculation period in the program.
The default value is 20 years.
To ensure stability of the model calculations, the first 3 years is set as the setup period of the model to reconcile any differences. If you need to view the whole period of results, you can refer to csv files.

(4) Specifying the condition of Natural disaster(s)

You can specify the condition of Natural disaster(s) up to two types of disasters. You can also specify single disaster or compound disasters. The default value is "compound disasters"

(5) Displaying the condition of Above Conditions in Figure

You can represent the above conditions such as calculation date, target country, disaster type and number of Monte Calro iteration in figures and csv files. The default value is "Yes".

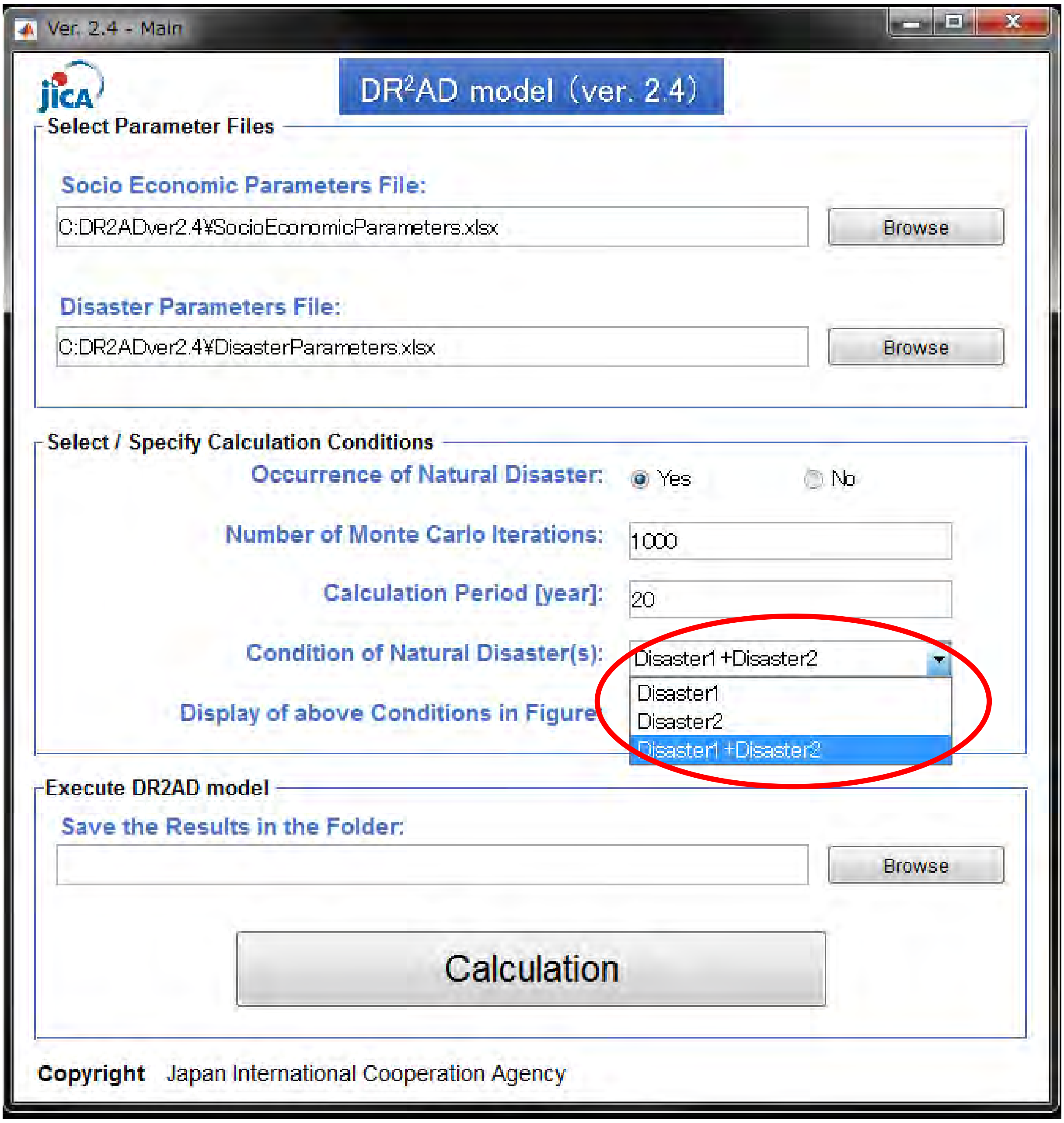


Fig. 4-9 Selecting the Disaster Type

(6) Selecting whether to display the above calculation conditions or not

You can select whether to display the above calculation conditions or not on the graph. The default value is “Yes”.

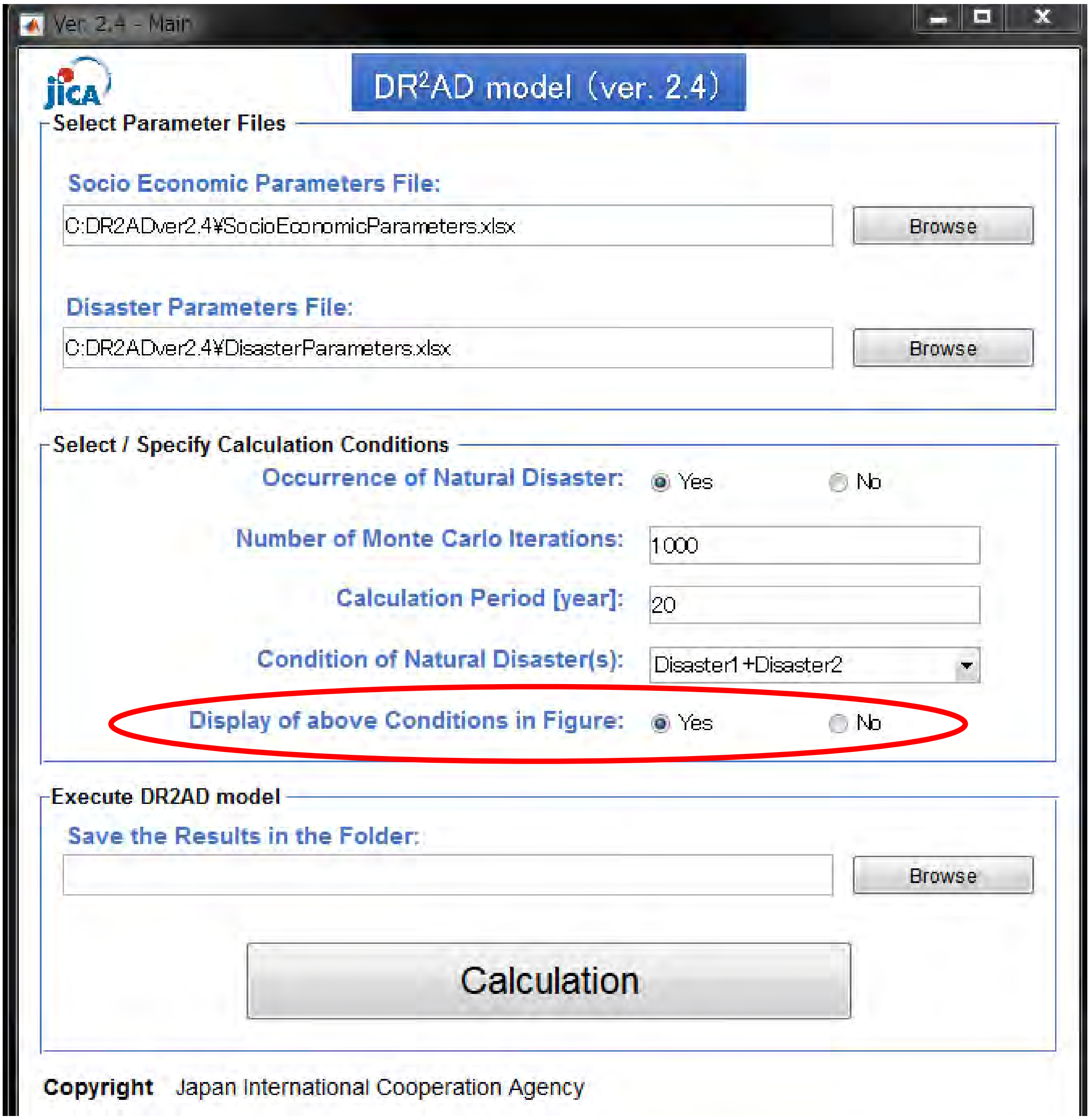


Fig. 4-10 Selecting the display of above conditions in figure

4.3.3 Saving the results in the folder

You can select the location to save the results in the folder. Images and calculations results (csv files) will be saved here. In the figure below, the targeted folder is named “test” in folder DR^2AD (ver2.4).

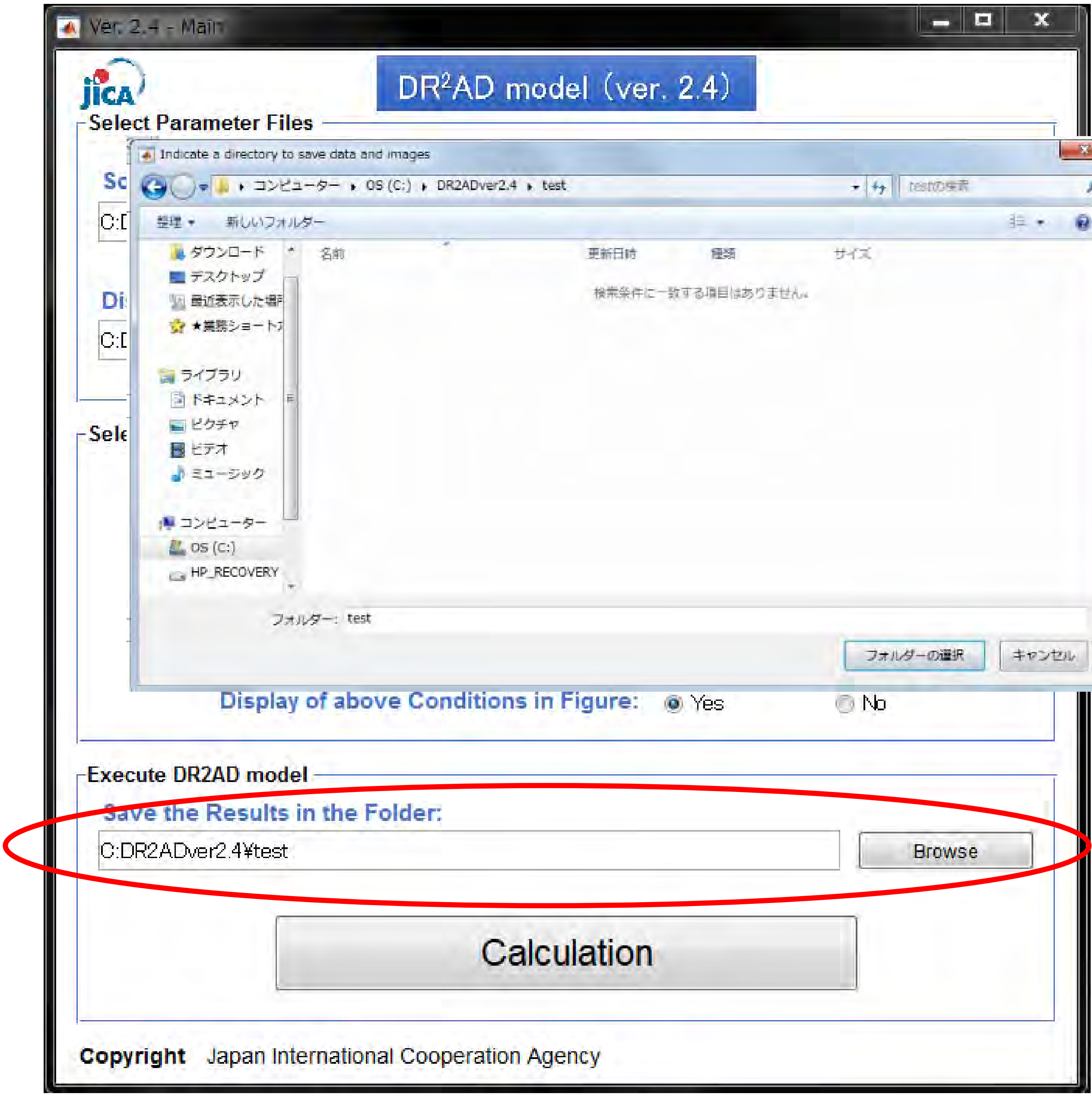


Fig. 4-11　Specifying the Save Location

4.3.4 Executing the calculation

Click the Run **Calculation** button to perform the automatic calculations and save the result in the specified folder.

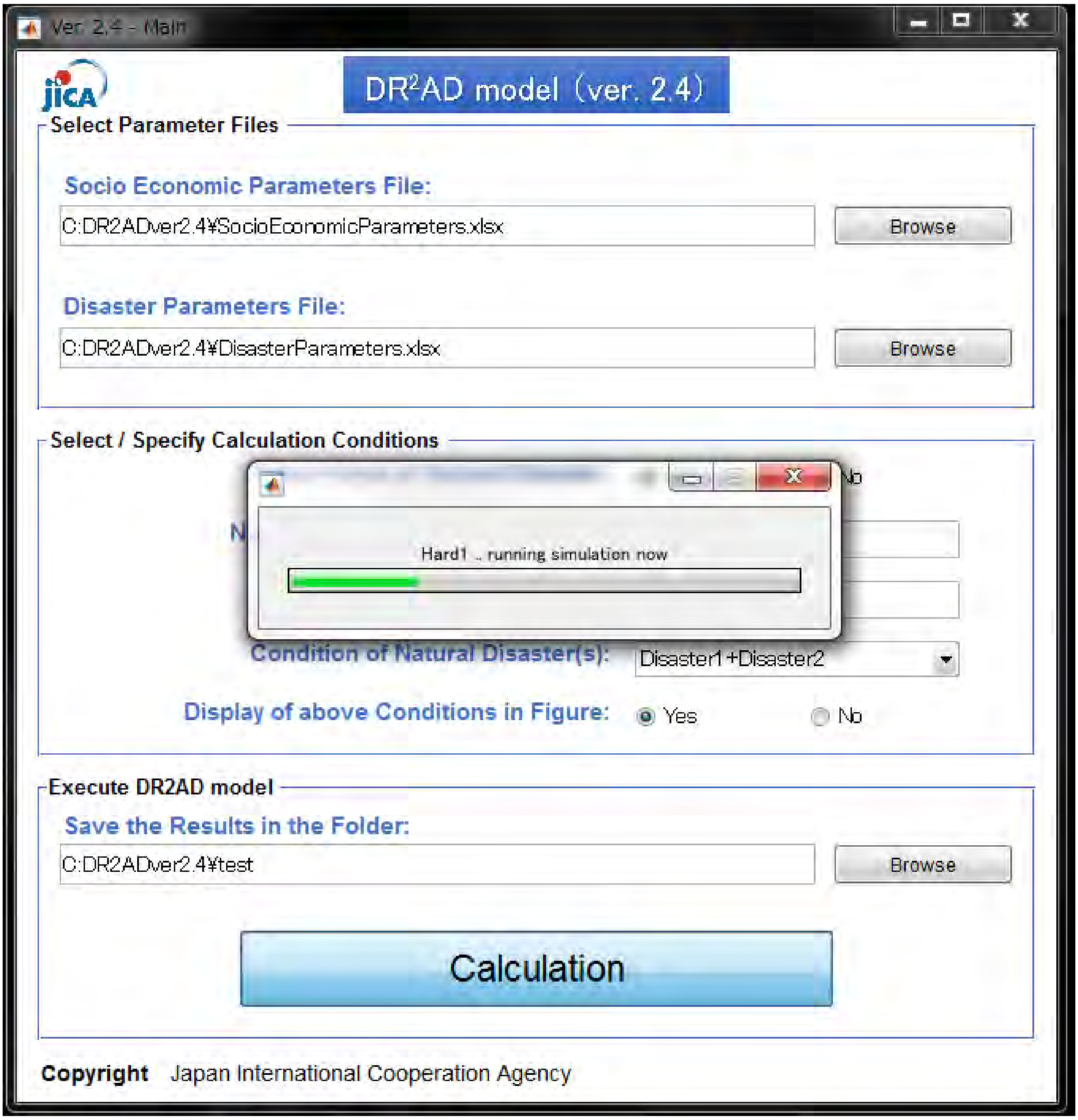


Fig. 4-12 Running the Calculation Screen on the Application

5 Output

This chapter describes the different types of output from the DR²AD model (Ver 2.4). Output is mainly divided into two categories: Policy Description / Policy-making and Analysis / Practical decision-making. The policy description / policy-making output is used to aid large-scale decision-making on the basis of macro-economic indicators. The analysis / practical decision-making output is used to analyze social issues such as social disparity using household economic indicators by income class.

Table 5-1 Output Classification (Outline) (reproduction of Table 5)

Purpose		Economic indicator	Output method
Policy description /Policy-making	Used to aid large-scale decision-making on the basis of macroeconomic indicators	GDP, disaster scale, disaster frequency, disaster damage ratio, etc.	Graph CSV file
Analysis/Practical decision-making	Detailed analysis of household standard of living based on household indicators and data by income class	GDP by capita (individual income), consumption, physical asset, financial assets, human capital, education time, human investment, etc. by class	CSV file

*The next section describes how to read CSV file output.

■How to read CSV output file

The following table describes how to read CSV output file.

This section of data represents dates, country name, disaster type, and number of Monte Carlo iterations.

Table 4 - How to read CSV file output

Data Legend
(In this example, the data in row 1 represents the following parameters in the order listed: Period, Without DRR policy, Soft measures, Hard measures 1, Hard measures 2, Hard measures 1 + Soft, Hard measures 2 + soft, scenario A, and scenario B.)

<File>	GDP_DRR.csv			<Date>	2015/7/14		<Country>	Pakistan		<Disaster	Type>	Flood+Earthquake		<MonteCar	lo(times)>	100	
[From	above]	Period (year)		Without		Soft		Hard1		Hard2		Hard1+Soft		Hard2+Soft		*GDP (average)	
-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9.92E+10	1.06E+11	1.14E+11	1.22E+11	1.31E+11	1.40E+11	1.51E+11	1.62E+11	1.75E+11	1.88E+11	2.04E+11	2.20E+11	2.38E+11	2.58E+11	2.80E+11	3.04E+11	3.31E+11	3.60E+11
9.93E+10	1.07E+11	1.14E+11	1.22E+11	1.31E+11	1.40E+11	1.51E+11	1.62E+11	1.75E+11	1.89E+11	2.04E+11	2.20E+11	2.38E+11	2.58E+11	2.81E+11	3.05E+11	3.31E+11	3.61E+11
1.00E+11	1.08E+11	1.17E+11	1.25E+11	1.35E+11	1.46E+11	1.58E+11	1.70E+11	1.84E+11	1.99E+11	2.16E+11	2.34E+11	2.55E+11	2.77E+11	3.01E+11	3.28E+11	3.57E+11	3.89E+11
1.00E+11	1.08E+11	1.17E+11	1.26E+11	1.35E+11	1.46E+11	1.58E+11	1.70E+11	1.85E+11	2.00E+11	2.17E+11	2.35E+11	2.56E+11	2.78E+11	3.03E+11	3.29E+11	3.58E+11	3.90E+11
1.00E+11	1.08E+11	1.17E+11	1.25E+11	1.35E+11	1.46E+11	1.58E+11	1.70E+11	1.84E+11	1.99E+11	2.16E+11	2.34E+11	2.55E+11	2.77E+11	3.01E+11	3.28E+11	3.57E+11	3.89E+11
1.00E+11	1.08E+11	1.17E+11	1.26E+11	1.35E+11	1.46E+11	1.58E+11	1.70E+11	1.85E+11	2.00E+11	2.17E+11	2.35E+11	2.56E+11	2.78E+11	3.03E+11	3.29E+11	3.58E+11	3.90E+11

Startup period (3 years)
(This data is not used)

Calculation period
(This data is used)

*The startup period data is output in the CSV file, but this data is not used.

Table 5-2 Types of Output (Details)

Details of output from the DR2AD Model Ver. 2.4

Legend
◎ Save images + csv files ○ Save images ● Save csv files

Usage application	Name of graph	Outline	対策別								by class
			Without DRR	Soft	Hard 1	Hard 2	Hard1+Soft	Hard2+Soft	ScenarioA (Without DRR − Hard 1)	ScenarioB (Without DRR − Hard 1 − Hard 2)	
Policy description/Policy-making	GDP_DRR.png	GDP trends per measure	◎	◎	◎	◎	◎	◎			
	GDP_DRR_ratio.png	GDP trends per measures (no-policy standard)	◎	◎	◎	◎	◎	◎			
	GDP_Scenario.png	GDP scenario analysis	◎	◎	◎	◎			◎	◎	
	GDP_Scenario_ratio.png	GDP scenario analysis (no-policy standard)	◎	◎	◎	◎			◎	◎	
	DisasterClass.png	Frequency of flood and earthquake occurrence	◎	◎	◎	◎	◎	◎	◎	◎	
	DisasterClass_Histogram	Histogram of frequency of flood and earthquake	◎	◎	◎	◎	◎	◎	◎	◎	
	DisasterRate_human	Disaster damage ratio (human capital)	◎	◎	◎	◎	◎	◎			
	DisasterRate_Phisical	Disaster damage ratio (physical capital)	◎	◎	◎	◎	◎	◎			
	DisasterRate_Financial	Disaster damage ratio (financial capital)	◎	◎	◎	◎	◎	◎			
	DisasterRate_Land	Disaster damage ratio (land)	◎	◎	◎	◎	◎	◎			
Analysis/Practical decision-making	GDP_capita_y.png	GDP trends per capita	●	●	●	●	●	●	●	●	●
	Consumption_c.png	Consumptions trends per group	●	●	●	●	●	●	●	●	●
	EducationTime_m.png	Education investment time trends per group	●	●	●	●	●	●	●	●	●
	FinancialAsset_b.png	Financial asset trends per group	●	●	●	●	●	●	●	●	●
	HumanCapital_h.png	Human capital trends per group	●	●	●	●	●	●	●	●	●
	HumanInvestmentCost_eta.png	Human investment costs trends per group	●	●	●	●	●	●	●	●	●
	PhysicalAsset_z.png	Physical asset trends per group	●	●	●	●	●	●	●	●	●
Other remarks	GDP_mean.png	GDP trends (average)	○								
	GDP_monte.png	GDP trends (Monte Carlo simulation)	○								

5.1 Details of Output for Policy Description / Policy-making

This chapter describes examples of output. The case are as follows

Target country	HONDURAS
Target Disaster	FLOOD

5.1.1 GDP by DRR Measure

You can analyze long-term GDP growth by DRR measure. This analysis assumes the following six types of DRR measures.

①	No policy
②	Soft measures
③	Hard measures 1
④	Hard measures 2
⑤	Hard measures 1 + Soft measures
⑥	Hard measures 2 + Soft measures

This analysis is useful in determining the best combination of strategies as the value of soft measures and hard measures differs depending on the type of disaster (floods, earthquakes, etc.).

Table 5-3 Example Output of GDP by DRR Measure (Graph)

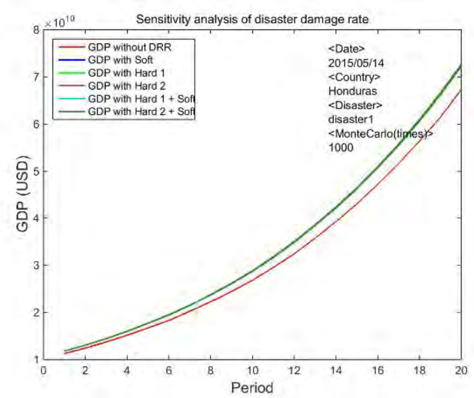
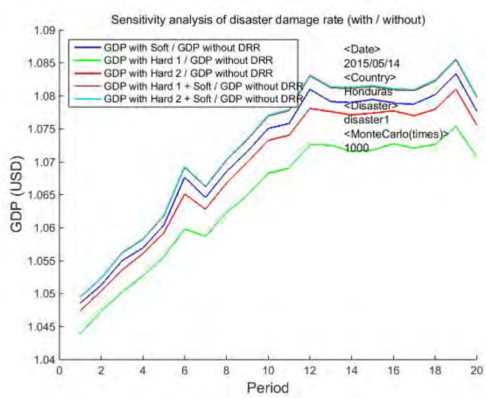
GDP by DRR Measure（measured value）	GDP by DRR Measure（With / Without ratio）
	
You can find the difference in the GDP growth between hard measures and soft measures. The GDP difference between hard measures and soft measures increase by both hard measure and soft measure over time.	

Table 12 - Example Output of GDP by DRR Measure (With/Without Comparison) (CSV file)

<File>	GDP_DRR_ratio.csv			<Date>	2015/7/14		<Country>	Pakistan		<Disaster	Type>	Flood+Earthquake		<MonteCar	lo(times)>	100						
[From	above]	Period (year)		Soft/Without		Hard1/Without		Hard2/Without		(Hard1+Soft)/Without		(Hard2+Soft)/Without		*GDP ratio (with/without)								
−2	−1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.0007	1.0007	1.0007	1.001	1.001	1.001	1.0011	1.0011	1.0012	1.0012	1.0012	1.0014	1.0014	1.0014	1.0015	1.0015	1.0016	1.0014	1.0014	1.0015	1.0016	1.0017	1.0016
1.0112	1.0172	1.0229	1.0299	1.0355	1.0403	1.0458	1.0495	1.054	1.0582	1.0613	1.065	1.0691	1.0721	1.0751	1.0774	1.0779	1.0793	1.082	1.0838	1.085	1.0876	1.0882
1.0121	1.0182	1.0243	1.0316	1.0375	1.0423	1.0478	1.0522	1.0569	1.0615	1.065	1.0692	1.0736	1.0771	1.08	1.082	1.0826	1.0841	1.0868	1.0886	1.09	1.093	1.0931
1.0112	1.0173	1.0231	1.03	1.0356	1.0403	1.0458	1.0496	1.0541	1.0584	1.0614	1.0652	1.0692	1.0723	1.0752	1.0775	1.078	1.0794	1.0821	1.0839	1.0853	1.0878	1.0883
1.0121	1.0182	1.0243	1.0316	1.0375	1.0424	1.0479	1.0523	1.057	1.0616	1.065	1.0693	1.0737	1.0771	1.08	1.082	1.0827	1.0842	1.0868	1.0886	1.0901	1.0931	1.0931

*The periods -2 through 0 in the CSV file represents the model setup period (3 years).

5.1.2 GDP by Scenario

You can analyze long-term GDP growth by scenario. This analysis assumes the following five types of scenarios.

① Implementation of soft measures from the standard year ② Implementation of hard measures 1 from the standard year ③ Implementation of hard measures 2 from the standard year ④ No implementation of DRR measures for the standard year. Implementation of hard measures 1 from the sixth year (scenario A) ⑤ No implementation of DRR measures for the standard year. Implementation of hard measures 1 from the sixth year and hard measures 2 from the eleventh year (scenario B)

You can determine the proper timing and scale of DRR investment by analyzing the growth of GDP by scenario.

Table 5-4 Example Output of GDP by Scenario (Graph)

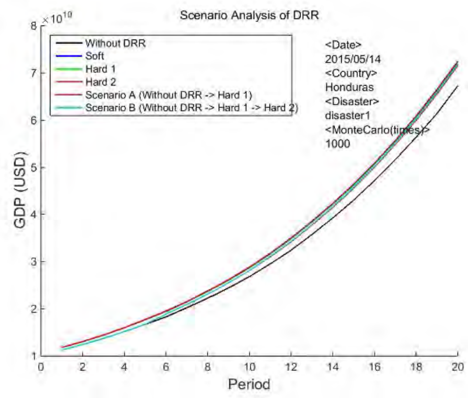
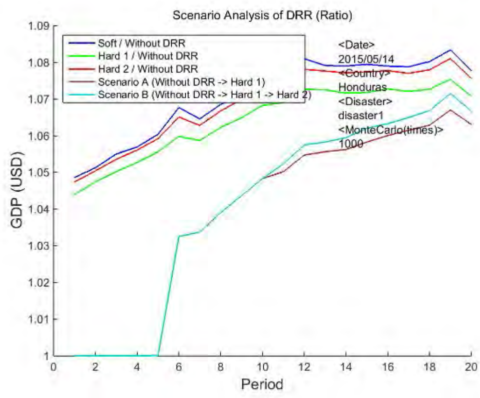
GDP by Scenario（measured value）	GDP by Scenario（With / Without ratio）
	
From large rate of human damage we can understand that soft measure is the most effective, since it can mitigate the human damage rate to the lower level. Besides, we can understand that hard measures are also effective. By comparing each DRR measure and DRR scenario, we can see that the sooner the timing of DRR investment is, the larger the DRR effect becomes.	

Table 5-5 Example Output of GDP by Scenario (real numbers) (CSV file)

<File>	GDP_Scenario.csv			<Date>	2015/7/14		<Country>	Pakistan		<Disaster	Type>	Flood+Earthquake		<MonteCar	lo(times)>	100						
[From	above]	Period (year)		Without		Soft		Hard1		Hard2		ScenarioA		ScenarioB		*GDP (average)						
−2	−1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
9.92E+10	1.06E+11	1.14E+11	1.22E+11	1.31E+11	1.40E+11	1.51E+11	1.62E+11	1.75E+11	1.88E+11	2.04E+11	2.20E+11	2.38E+11	2.58E+11	2.80E+11	3.04E+11	3.31E+11	3.60E+11	3.91E+11	4.26E+11	4.65E+11	5.06E+11	5.53E+11
9.93E+10	1.07E+11	1.14E+11	1.22E+11	1.31E+11	1.40E+11	1.51E+11	1.62E+11	1.75E+11	1.89E+11	2.04E+11	2.20E+11	2.38E+11	2.58E+11	2.81E+11	3.05E+11	3.31E+11	3.61E+11	3.92E+11	4.27E+11	4.65E+11	5.07E+11	5.54E+11
1.00E+11	1.08E+11	1.17E+11	1.25E+11	1.35E+11	1.46E+11	1.58E+11	1.70E+11	1.84E+11	1.99E+11	2.16E+11	2.34E+11	2.55E+11	2.77E+11	3.01E+11	3.28E+11	3.57E+11	3.89E+11	4.24E+11	4.62E+11	5.04E+11	5.51E+11	6.02E+11
1.00E+11	1.08E+11	1.17E+11	1.26E+11	1.35E+11	1.46E+11	1.58E+11	1.70E+11	1.85E+11	2.00E+11	2.17E+11	2.35E+11	2.56E+11	2.78E+11	3.03E+11	3.29E+11	3.58E+11	3.90E+11	4.25E+11	4.64E+11	5.07E+11	5.53E+11	6.04E+11
9.92E+10	1.06E+11	1.14E+11	1.22E+11	1.31E+11	1.40E+11	1.51E+11	1.62E+11	1.76E+11	1.91E+11	2.08E+11	2.26E+11	2.46E+11	2.68E+11	2.92E+11	3.19E+11	3.47E+11	3.79E+11	4.13E+11	4.52E+11	4.93E+11	5.39E+11	5.90E+11
9.92E+10	1.06E+11	1.14E+11	1.22E+11	1.31E+11	1.40E+11	1.51E+11	1.62E+11	1.76E+11	1.91E+11	2.08E+11	2.26E+11	2.46E+11	2.68E+11	2.92E+11	3.19E+11	3.48E+11	3.80E+11	4.14E+11	4.53E+11	4.94E+11	5.41E+11	5.92E+11

*The periods -2 through 0 in the CSV file represent the modeling setup period (3 years).

5.1.3 Scale and Frequency of Disasters

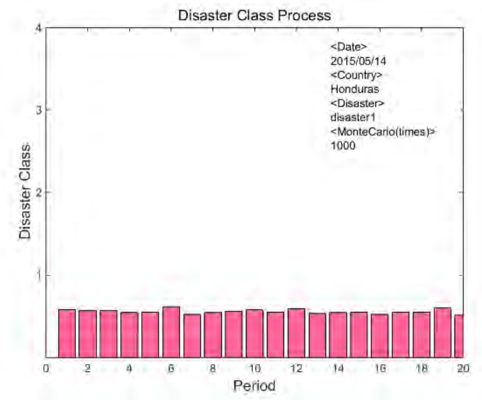
You can use average values of disaster scale and Monte Carlo simulations to analyze the frequency of disasters. This analysis assumes the following three types of disaster scale and frequency.

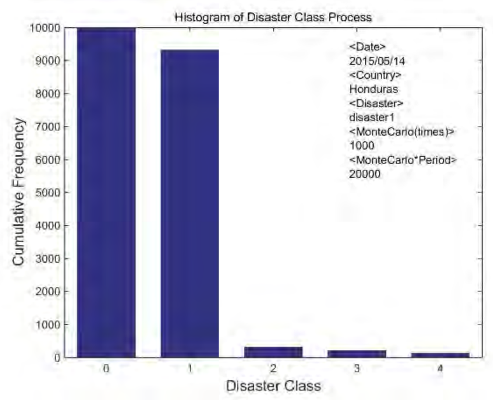
① Scale and frequency for disaster 1
② Scale and frequency for disaster 2
③ Combination disaster scale and frequency (disaster 1 + disaster 2)

This analysis can help determine the proper scale of DRR investment by analyzing the scale and frequency of disasters.

Table 5-6 Example Output of Scale and Frequency of Disasters (Graph)

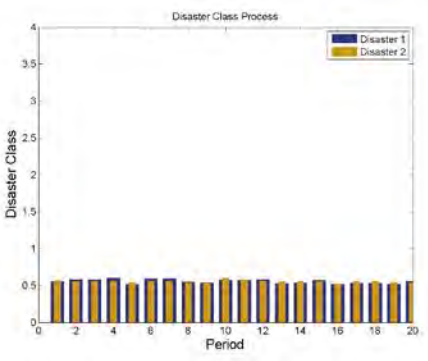
Scale of disaster	Frequency of disaster





The frequency of disasters with a scale of 0 or 1 is high. This means that significant disaster damage can be prevented even with small-scale DRR investment applicable only to the prevention of disaster with a scale of 1.

Example for the case of compound Disaster (Disaster1 and Disaster2)



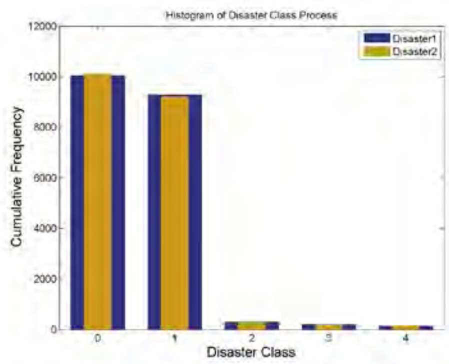


Table 5-7 Example Output of Scale and Frequency of Disasters (CSV file)

<File>	DisasterClass_Average.csv			<Date>	2015/7/14		<Country>	Pakistan		<Disaster	Type>	Flood+Earthquake		<MonteCar	lo(times)>	100						
[From	above]	Period (year)		Flood		Earthquake		*average class														
−2	−1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0.5	0.49	0.44	0.65	0.6	0.57	0.63	0.56	0.56	0.57	0.46	0.63	0.6	0.54	0.59	0.61	0.63	0.49	0.47	0.52	0.52	0.62	0.55
0.59	0.53	0.57	0.67	0.55	0.48	0.54	0.61	0.53	0.61	0.61	0.54	0.62	0.61	0.5	0.52	0.57	0.47	0.57	0.47	0.49	0.54	0.47

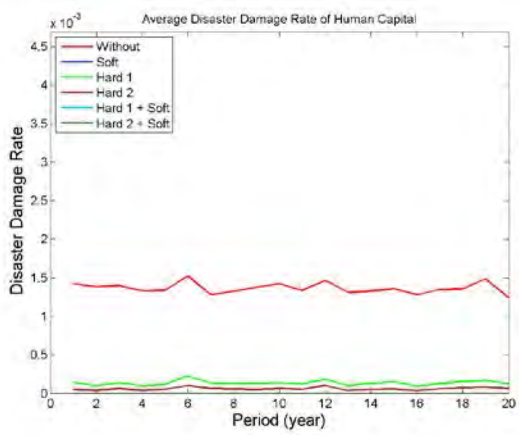
*The periods -2 through 0 in the CSV file represent the modeling setup period (3 years).

5.1.4 Disaster Damage Rate

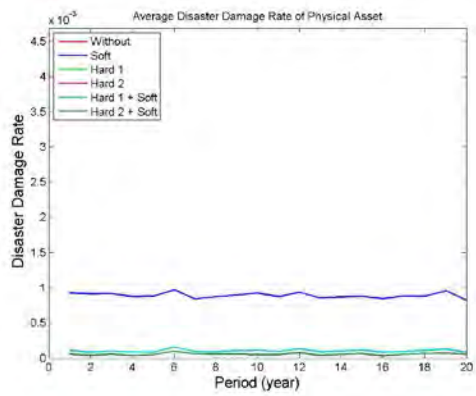
You can analyze average values of disaster damage rate by DRR measure annually. You can visually analyze the impact of each DRR measure on the annual disaster damage rate by creating a graph of the disaster damage rate by DRR measure.

Table 5-8 Example Output of Disaster Damage Rate (Graph)

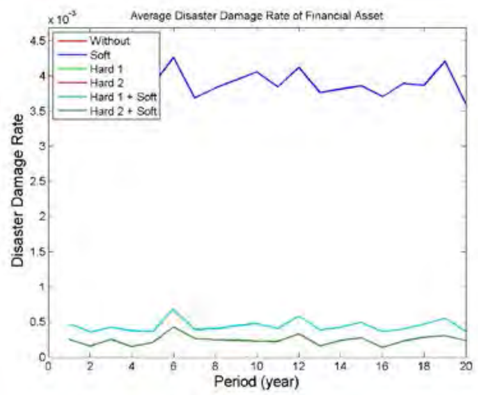
Damage rate for human capital



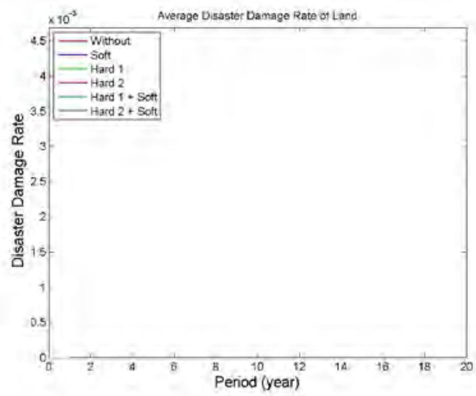
Damage rate for physical assets



Damage rate for financial assets



Damage rate for land



As you can see, hard measures are particularly effective and significantly reduce average damage rate. (*The effect of soft measures is minimal and therefore sometimes overlaps with the no measures graph.)

Table 5-9 Example Output of Disaster Damage Ratios (CSV file)

<File>	DisasterRate_Human.csv			<Date>	2015/7/14		<Country>	Pakistan		<Disaster	Type>	Flood+Earthquake		<MonteCar	lo(times)>	100						
[From	above]	Period (year)		Without		Soft		Hard1		Hard2		Hard1+Soft		Hard2+Soft		*disaster damage rate						
-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0.0014387	0.0013497	0.0012879	0.0018436	0.0016048	0.0015301	0.001663	0.0016231	0.0015476	0.0016378	0.0013679	0.001762	0.0016548	0.0015733	0.0016	0.0016357	0.0017038	0.0013191	0.0013022	0.0013893	0.0014601	0.0017386	0.0014546
0.000203	0.000159	0.00018	0.000213	0.000178	0.000152	0.000166	0.000208	0.000171	0.000199	0.000204	0.000183	0.000211	0.000205	0.000158	0.000164	0.000185	0.00015	0.00018	0.00015	0.00016	0.000183	0.000145
6.34E-05	2.60E-05	0.0002135	0.0002262	6.94E-05	7.40E-05	5.91E-05	0.0002482	0.0001774	0.0003036	0.0001793	0.0002122	0.0001421	0.0002188	0.0001183	2.97E-05	0.0001447	2.33E-05	3.47E-05	2.33E-05	0.0002726	0.0002122	1.49E-05
4.57E-06	0	0.0001327	6.88E-05	1.88E-05	1.65E-05	1.65E-05	0.0001225	4.96E-05	0.000134	5.46E-05	9.36E-05	8.67E-05	9.59E-05	6.52E-05	0	4.73E-05	2.28E-06	1.19E-05	2.28E-06	0.0001171	9.36E-05	0
2.43E-05	0	1.03E-05	2.84E-05	1.22E-05	3.70E-06	1.85E-06	6.33E-05	5.55E-06	3.02E-05	3.87E-05	2.73E-05	4.05E-05	3.39E-05	3.70E-06	3.70E-06	3.02E-05	1.03E-05	2.17E-05	1.03E-05	1.22E-05	2.73E-05	1.85E-06
4.57E-06	0	2.28E-06	1.93E-05	2.28E-06	0	0	4.08E-05	0	1.93E-05	2.15E-05	1.19E-05	2.15E-05	1.42E-05	0	0	1.42E-05	2.28E-06	1.19E-05	2.28E-06	2.28E-06	1.19E-05	0

*The periods -2 through 0 in the CSV file represent the modeling setup period (3 years).

5.2 Details of Output for Analysis / Practical Decision-making

This software exports CSV files that include the following data parameters used for quantitative analysis and practical decision-making.

① GDP per capita income class
② Consumption by income class
③ Physical asset by income class and financial asset by income class
④ Human capital by income class
⑤ Education investment time by income class
⑥ Human investment costs by income class

You can use this data to produce the following graphs and you can analyze.

Table 5-10　Example Output of Consumption by Income Class (CSV file)

<File>	Consumption_c_Without.csv			<Date>	2015/7/14		<Country>	Pakistan		<Disaster	Type>	Flood+Earthquake		<MonteCar	lo(times)>	100						
[From	above]	Period (year)		1st(poorest)		2nd(poor)		3rd(middle)		4th(rich)		5th(richest)										
−2	−1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
210.08	230.96	253.96	278.59	304.05	332.67	364.54	398.65	435.44	476.77	521.34	570.85	625.77	685.5	752.36	828.54	912.43	1004.5	1110.7	1226.3	1357.8	1503.5	1660.3
290.96	313.99	339.91	368	397.19	430.49	467.94	508.19	551.75	600.91	653.99	713.03	778.58	849.79	929.51	1020.3	1120.2	1229.6	1354.4	1488.5	1639.5	1805.4	1984.8
371.19	392.26	417.22	445.05	474.41	508.85	548.3	591.09	637.77	690.93	748.55	812.92	884.6	962.55	1050	1149.2	1257.2	1374.4	1508.4	1652.8	1815.9	1995.3	2189.4
480.13	498.5	522.33	550.14	580.16	616.64	659.35	706.18	757.72	816.98	881.49	953.87	1033.9	1120.3	1216.5	1325.9	1445.4	1575.4	1724.8	1885.9	2068.3	2268.9	2486
917.32	906.78	912.15	928.23	949.71	982.87	1026.6	1077	1134.5	1203.5	1279.7	1366.7	1464.9	1572.3	1693.5	1832.7	1985.4	2152.2	2340.7	2539.5	2760.6	2999.6	3253.3

*The periods -2 through 0 in the CSV file represent the modeling setup period (3 years).

Table 5-11　Example Output of Data by Income Class (Graph) (1/2)

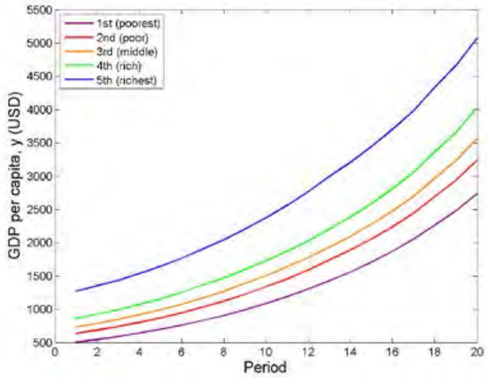
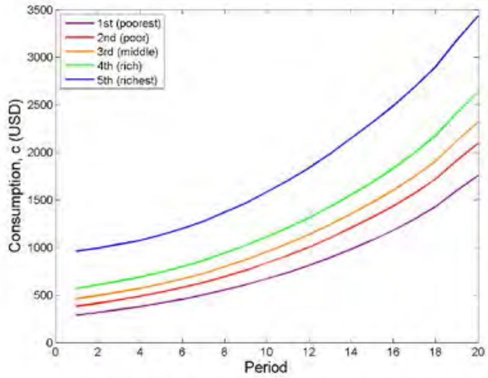
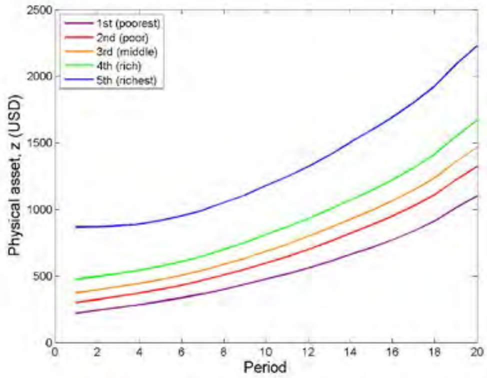
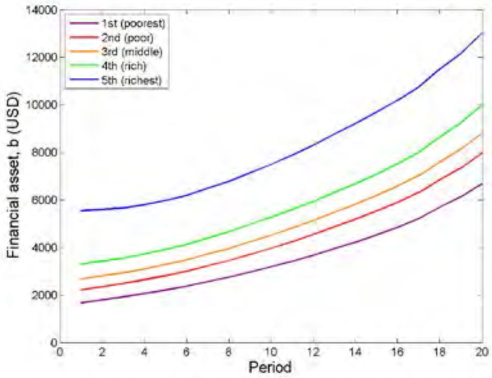
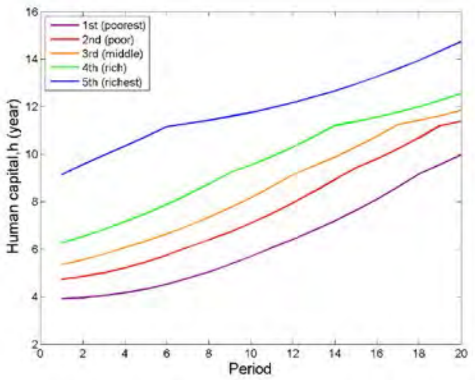
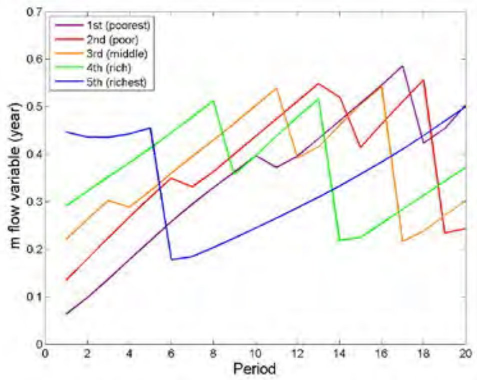
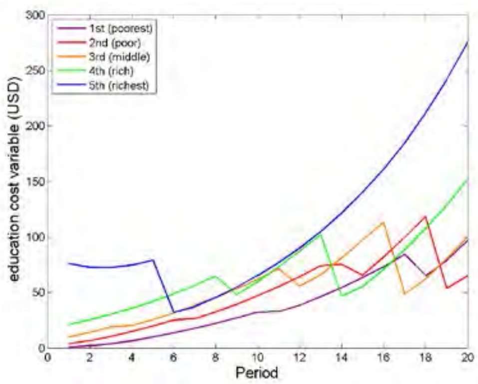
<table>
<tr><th>GDP per capita by income class</th><th>Consumption by income class</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Physical asset by income class</th><th>Financial asset by income class</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">These graphs represent the expected growth of household by income class during periods of no DRR measures. There are no reversals of classes.</td></tr>
</table>

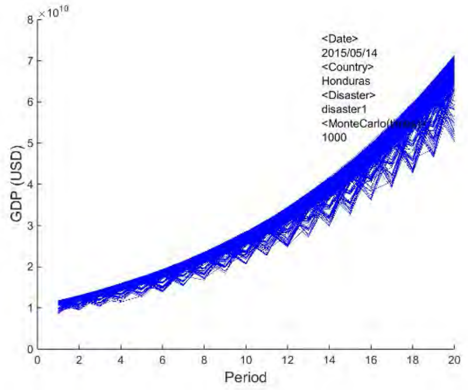
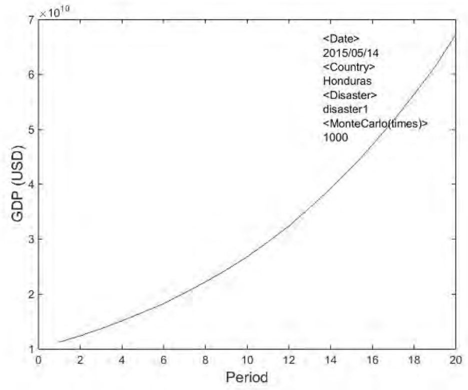
Table 5-12　Example Output of Data by Income Class (Graph) 2/2

<table>
<tr><th>Human capital by income class</th><th>Education investment time by income class</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">Human investment costs by income class</th></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">There are sudden changes in education investment time and human investment cost at education standard transitions as the human investment costs functions are configured as step functions of different education standards (primary, secondary, tertiary, etc.). The human investment costs for raising the human capital increases in direct proportion to increases in education standards. For this reason, human capital growth rates diminish along with human capital growth.</td></tr>
</table>

5.3 Details of Other Types of Output

You can also output results of Monte Carlo simulations for other purposes.

Table 5-13 GDP Output Examples (Monte Carlo simulations and expected growth)

<table>
<tr><th>GDP (Monte Carlo simulation)</th><th>GDP (expected growth)</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">These examples are calculations of expected GDP growth based on 1,000 iterations of Monte Carlo simulations.</td></tr>
</table>

Chapter 3 Building Data Sets in DR^{2}AD model (Ver. 1.4)

6 Building data sets

This chapter describes the details on the necessary data sets used to test the DR^{2}AD model (Ver. 1.4) as well as explain the basic configuration procedure using actual data. Use the following procedure to build data when you want to evaluate DRR investment benefits using data sets of your country for default values instead of the sample Excel data supplied with the application.

*Operation of the application is not guaranteed except for the five countries included with the supplied sample Excel data.

6.1 Advance preparation

6.1.1 Necessary data

The following table summarizes the data used in the model and their primary sources. Note that most of this data can be generated by combining multiple data sets. Refer to the section on creating individual data sets described later for more information.

Data source	Creatable data
The World Development Indicator	Population, GDP, etc.,
Input Output table / Social Account matrix	α_1, α_2, α_3
Household Survey	c, b, z, etc.,
Mean years of schooling (UNDP)	h, m_0
Institute for Statistic (UNESCO)	η

6.1.2 Setting the base year

Specify the base year for the model calculation period.

Typically, it is preferable to avoid setting a model base year that would significantly affect the model behavior, such as a year in which a catastrophic disaster occurs.

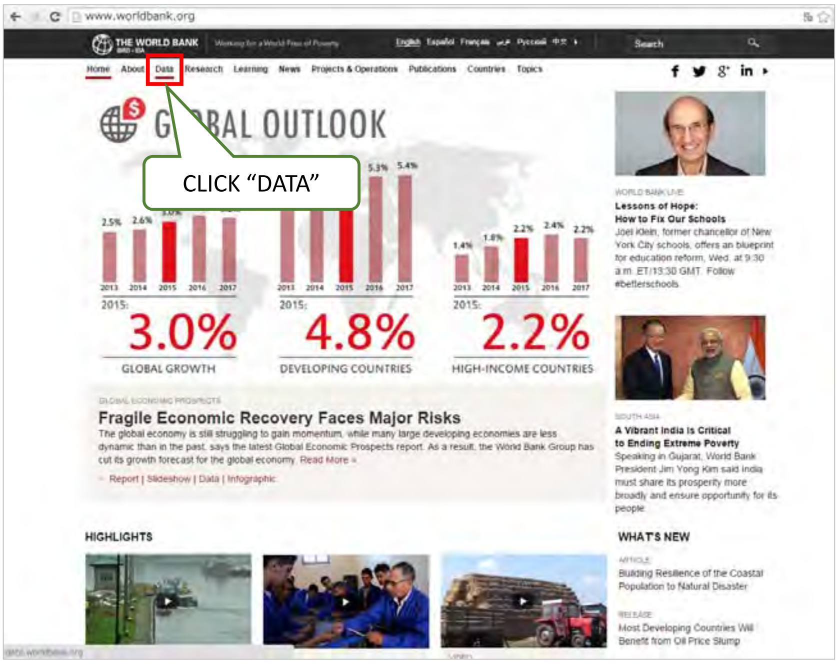
*The base year set for the sample program is 2004, as this is the year in which data was retrieved.

6.1.3 Collecting data

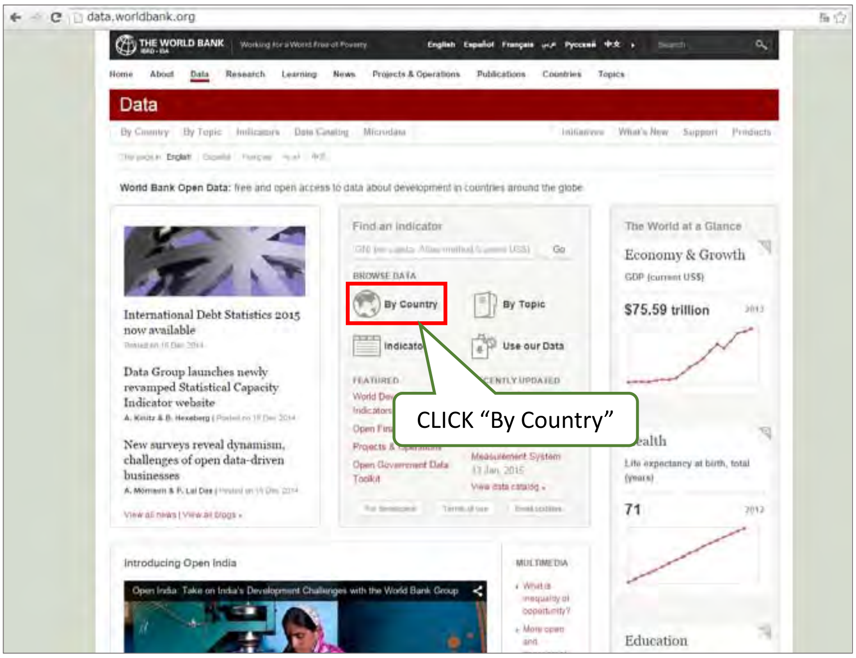
This section describes how to collect data from the international organizations which are the main sources of data (World Bank, UNDP, and UNESCE).

(1) The World Development Indicator (World Bank)

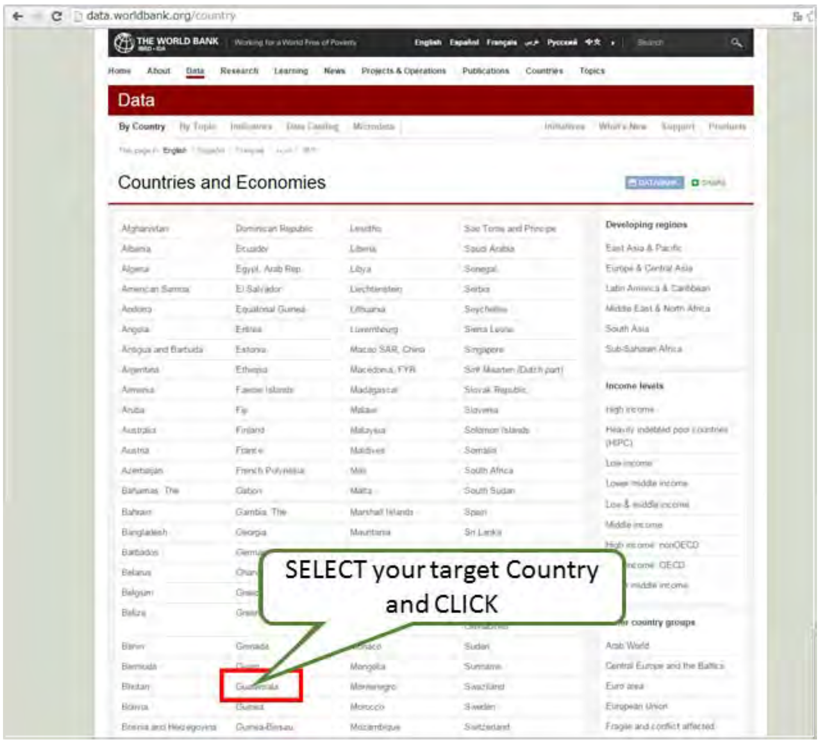
① Access worldbank.org and click “Data”



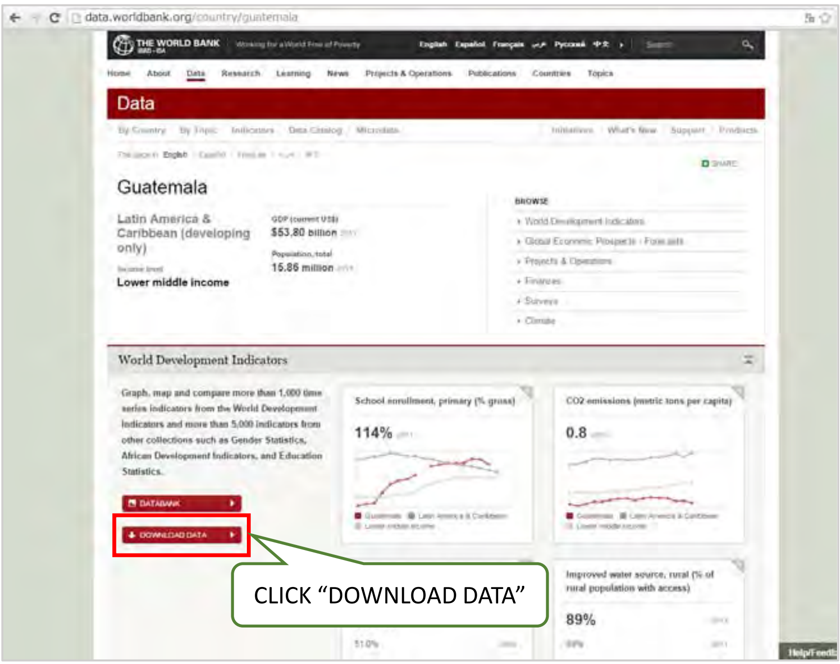
② Click “By Country”



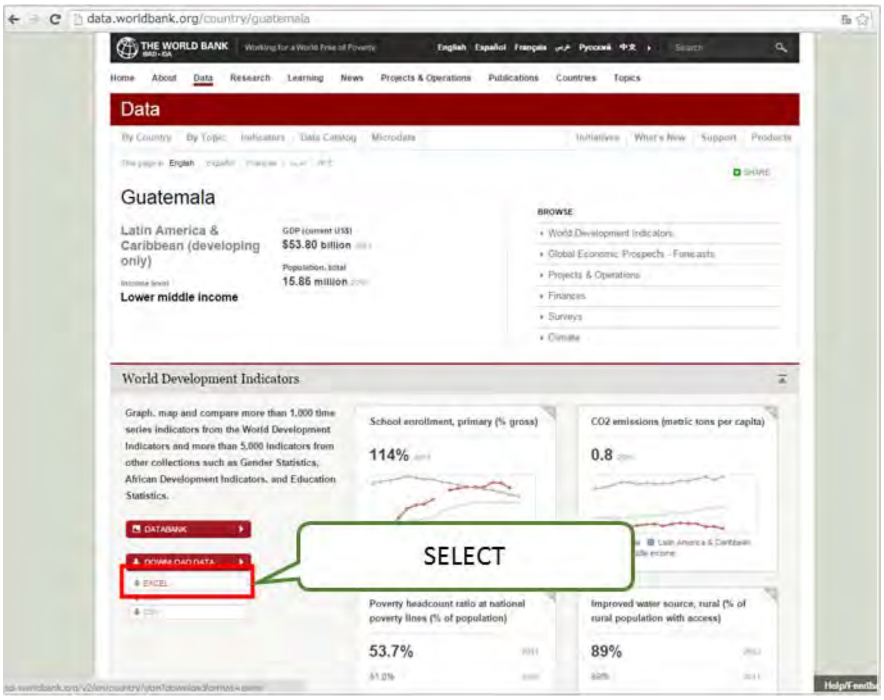
③ Choose a target country



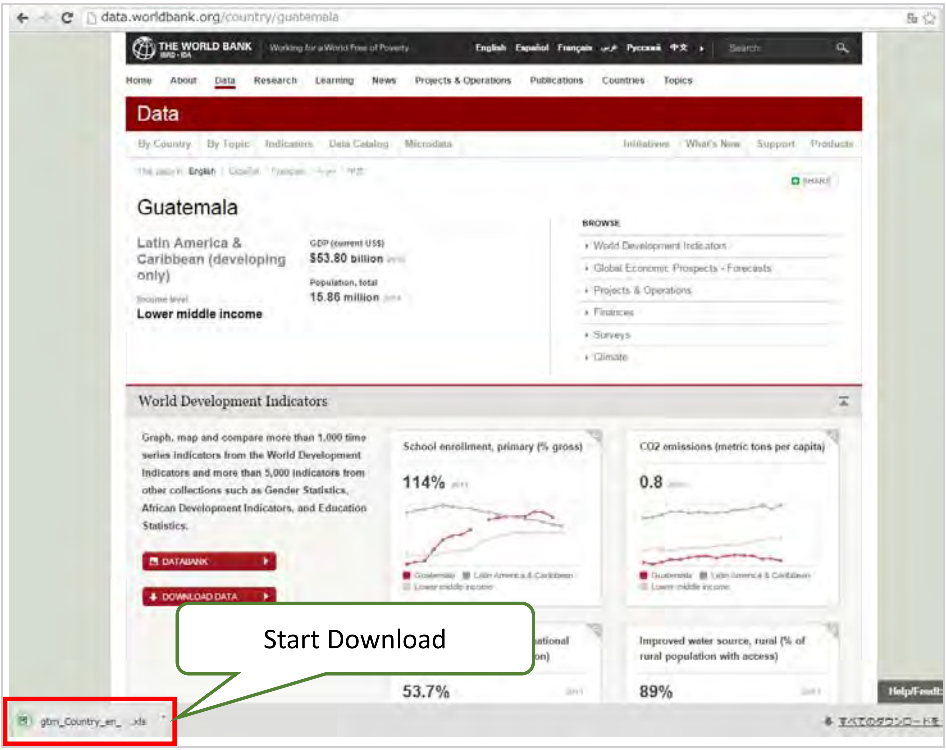
④ Click "DOWNLOAD DATA"



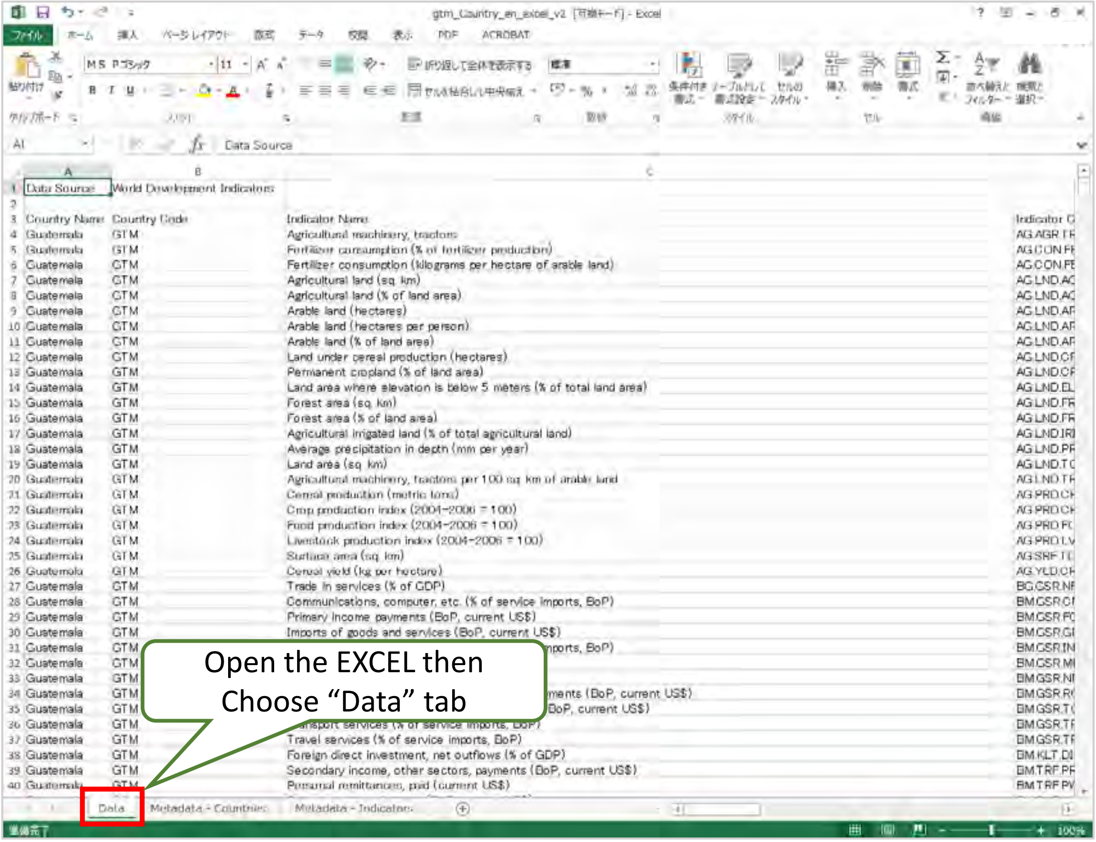
⑤ Select “EXCEL”



⑥ Download will start quickly

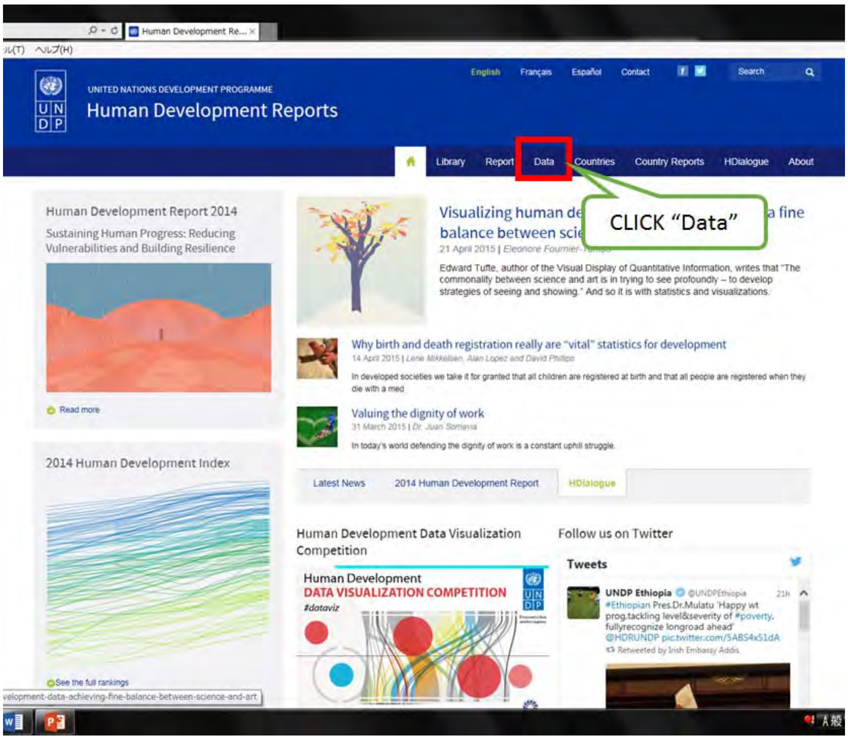


⑦ Select Data tab and you can collect all required data

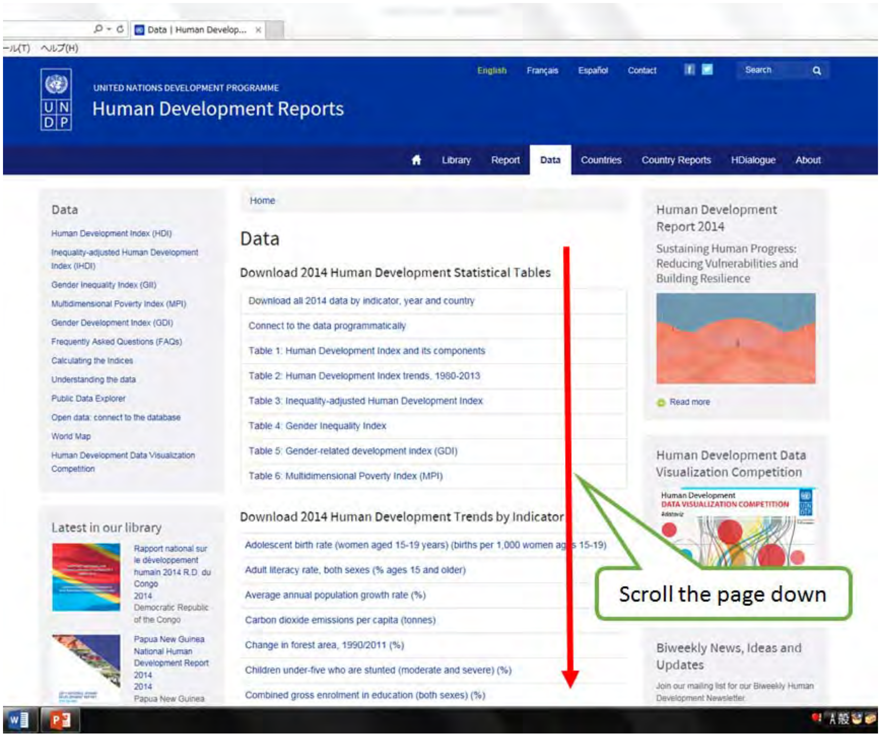


(2) Human Development Reports (UNDP)

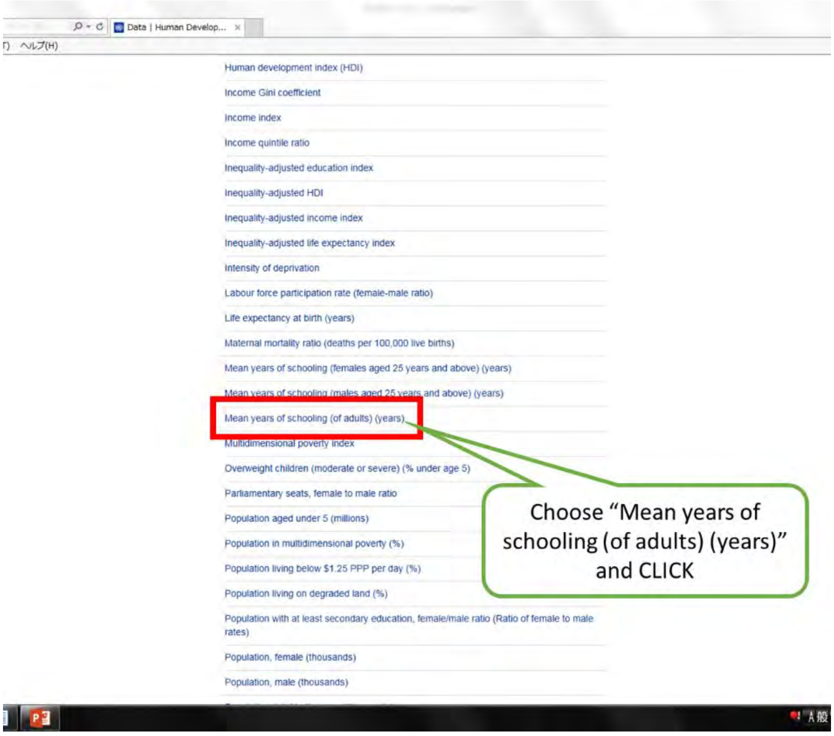
① Access undp.org and click “Data”



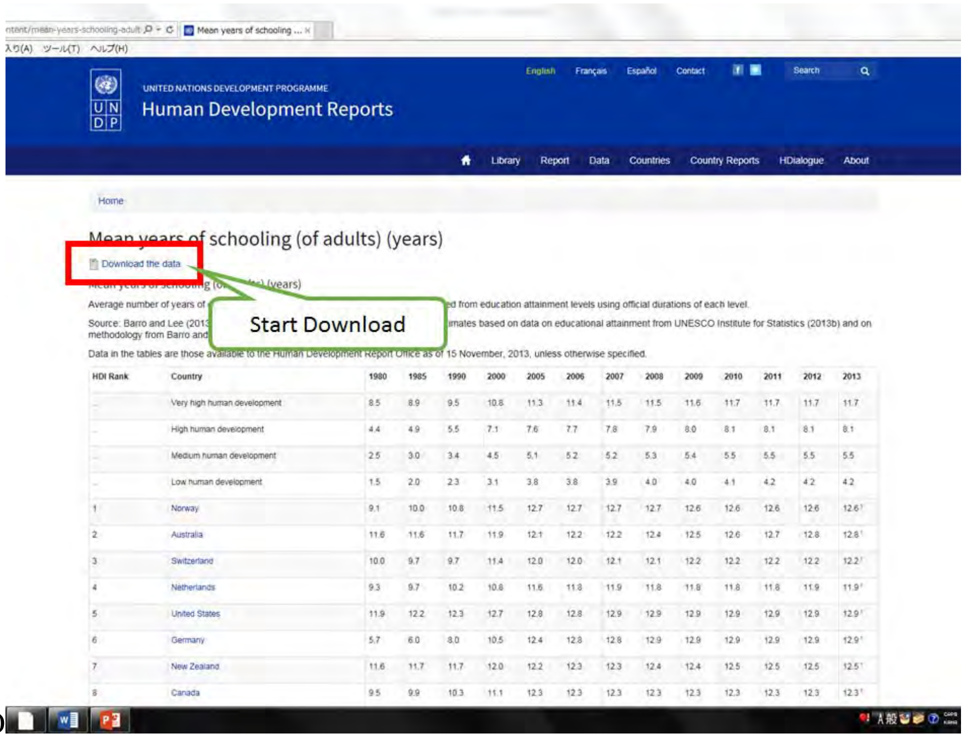
② Scroll the page down



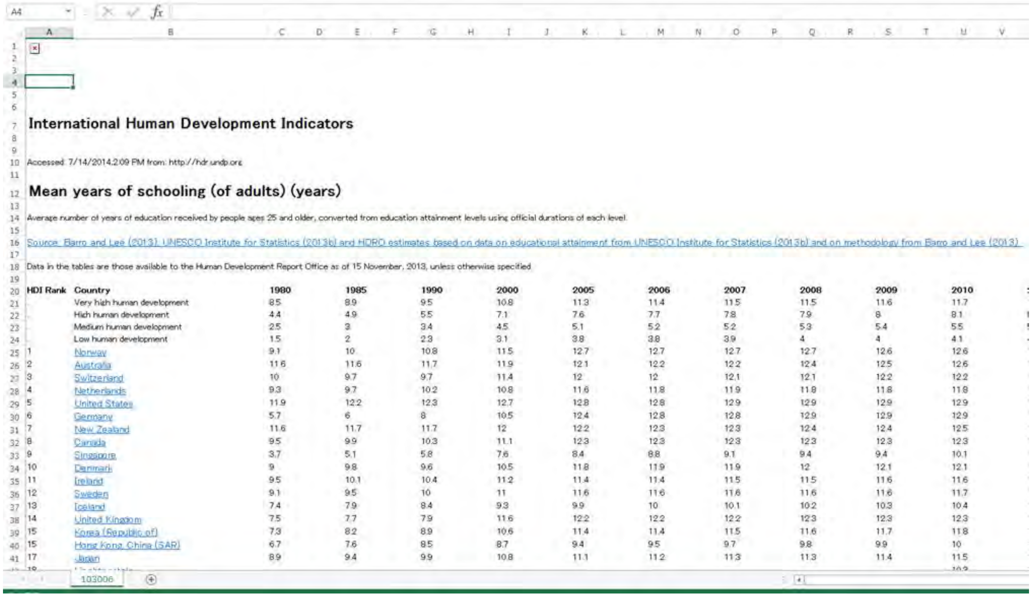
③ Choose a “Mean years of schooling (of adults) (years)” and Click



④ Click “Download the data” to start your download



⑤ You can find the data sorted by country



International Human Development Indicators

Accessed: 7/14/2014 2:09 PM from: http://hdr.undp.org

Mean years of schooling (of adults) (years)

Average number of years of education received by people ages 25 and older, converted from education attainment levels using official durations of each level

Source: Barro and Lee (2013), UNESCO Institute for Statistics (2013b) and HDRO estimates based on data on educational attainment from UNESCO Institute for Statistics (2013b) and on methodology from Barro and Lee (2013)

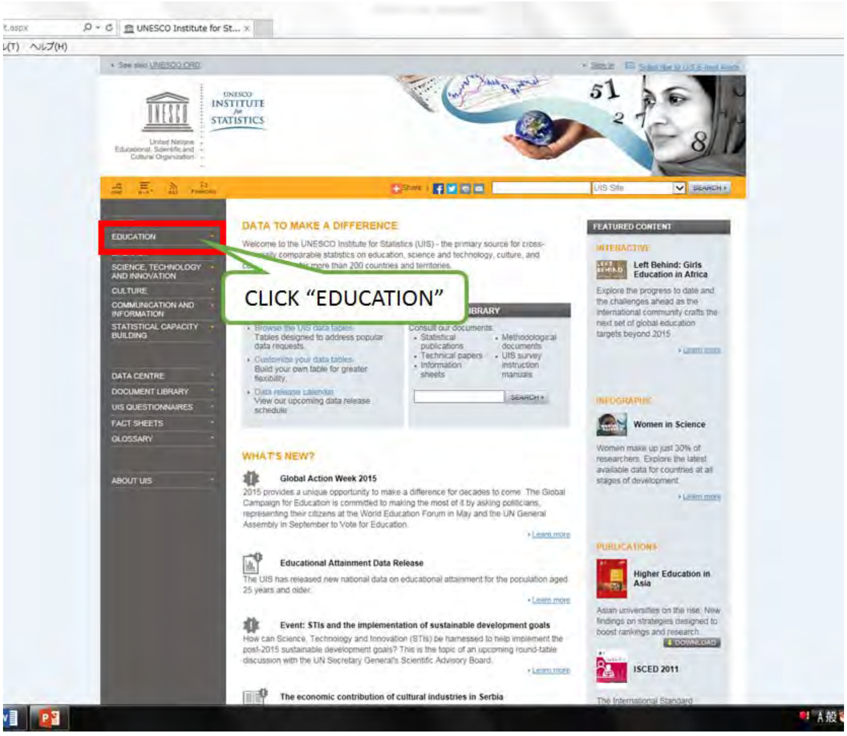
Data in the tables are those available to the Human Development Report Office as of 15 November, 2013, unless otherwise specified

HDI Rank	Country	1980	1985	1990	2000	2005	2006	2007	2008	2009	2010
	Very high human development	8.5	8.9	9.5	10.8	11.3	11.4	11.5	11.5	11.6	11.7
	High human development	4.4	4.9	5.5	7.1	7.6	7.7	7.8	7.9	8	8.1
	Medium human development	2.5	3	3.4	4.5	5.1	5.2	5.2	5.3	5.4	5.5
	Low human development	1.5	2	2.3	3.1	3.8	3.8	3.9	4	4	4.1
1	Norway	9.1	10	10.8	11.5	12.7	12.7	12.7	12.7	12.6	12.6
2	Australia	11.6	11.6	11.7	11.9	12.1	12.2	12.2	12.4	12.5	12.6
3	Switzerland	10	9.7	9.7	11.4	12	12	12.1	12.1	12.2	12.2
4	Netherlands	9.3	9.7	10.2	10.8	11.6	11.8	11.9	11.8	11.8	11.8
5	United States	11.9	12.2	12.3	12.7	12.8	12.8	12.9	12.9	12.9	12.9
6	Germany	5.7	6	8	10.5	12.4	12.8	12.8	12.9	12.9	12.9
7	New Zealand	11.6	11.7	11.7	12	12.2	12.3	12.3	12.4	12.4	12.5
8	Canada	9.5	9.9	10.3	11.1	12.3	12.3	12.3	12.3	12.3	12.3
9	Singapore	3.7	5.1	5.8	7.6	8.4	8.8	9.1	9.4	9.4	10.1
10	Denmark	9	9.8	9.6	10.5	11.8	11.9	11.9	12	12.1	12.1
11	Ireland	9.5	10.1	10.4	11.2	11.4	11.4	11.5	11.5	11.6	11.6
12	Sweden	9.1	9.5	10	11	11.6	11.6	11.6	11.6	11.6	11.7
13	Iceland	7.4	7.9	8.4	9.3	9.9	10	10.1	10.2	10.3	10.4
14	United Kingdom	7.5	7.7	7.9	11.6	12.2	12.2	12.2	12.3	12.3	12.3
15	Korea (Republic of)	7.3	8.2	8.9	10.6	11.4	11.4	11.5	11.6	11.7	11.8
15	Hong Kong, China (SAR)	6.7	7.6	8.5	8.7	9.4	9.5	9.7	9.8	9.9	10
17	Japan	8.9	9.4	9.9	10.8	11.1	11.2	11.3	11.3	11.4	11.5

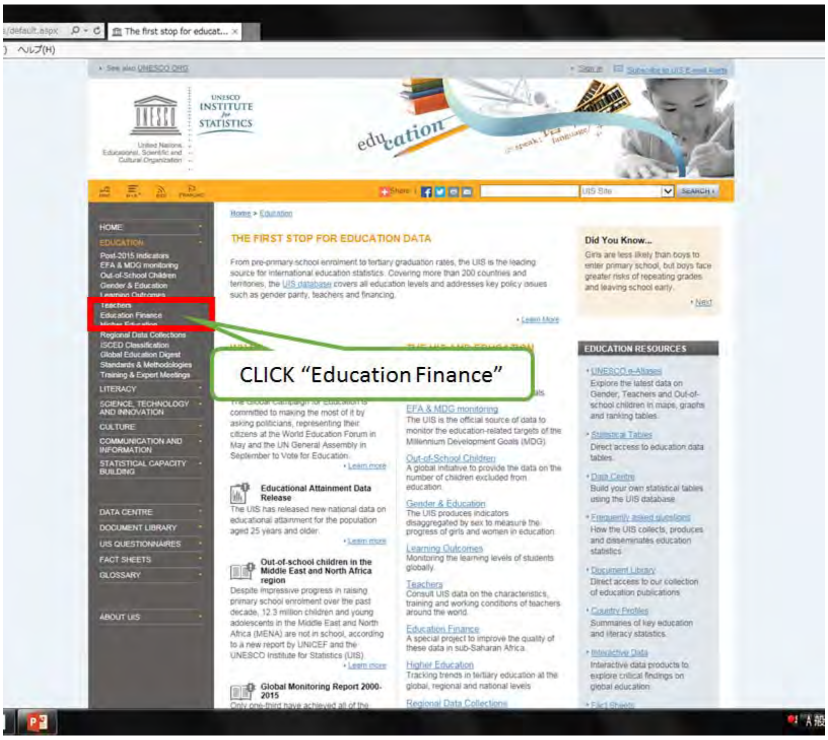
103006

(3) Institute for Statics (UNESCO)

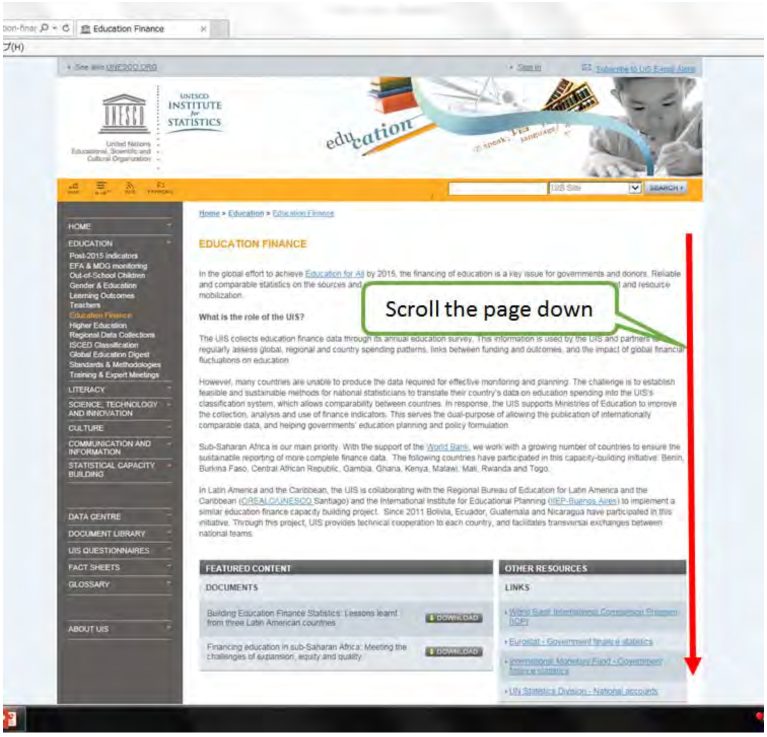
① Access uis.unesco.org and click “EDUCATION”



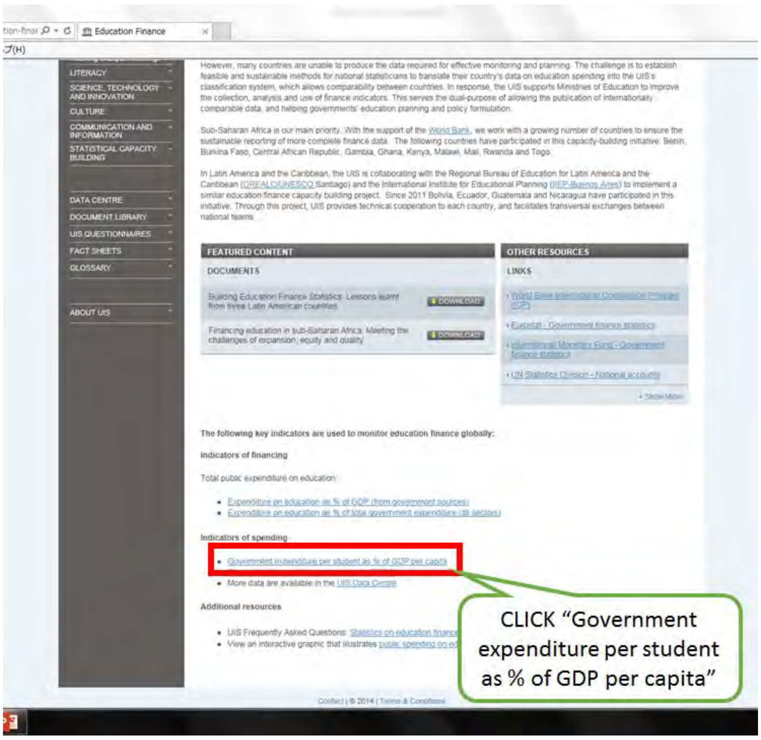
② Click “Education Finance”



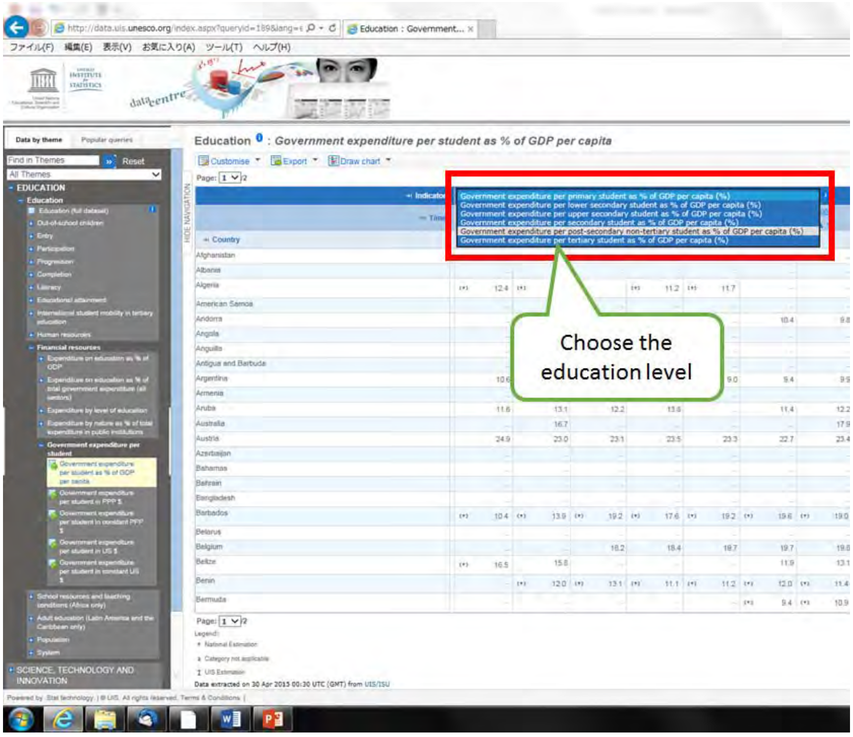
③ Scroll the page down



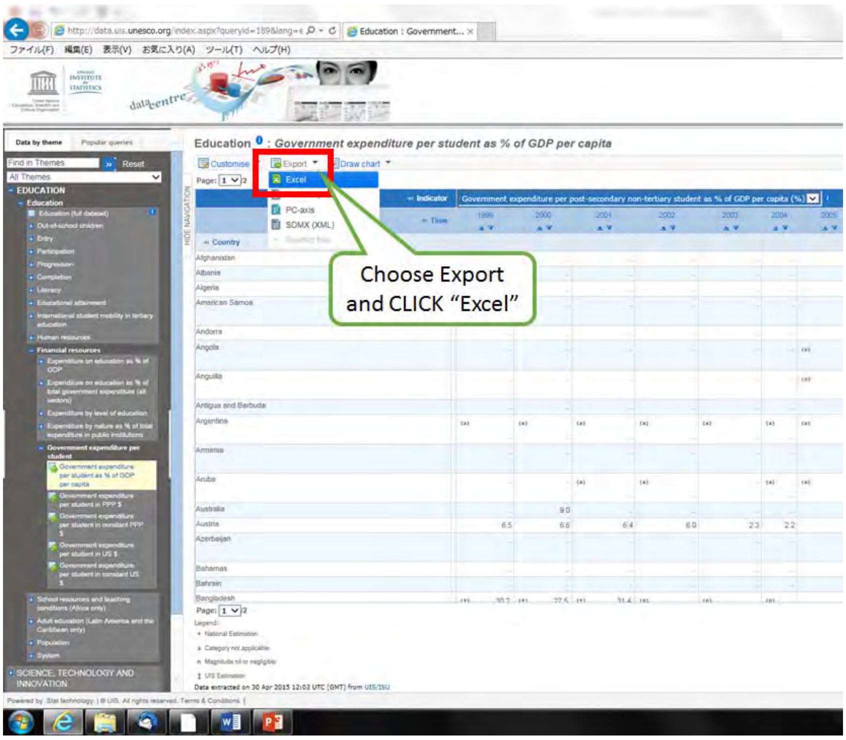
④ Click “Government expenditure per student as % GDP per capita”



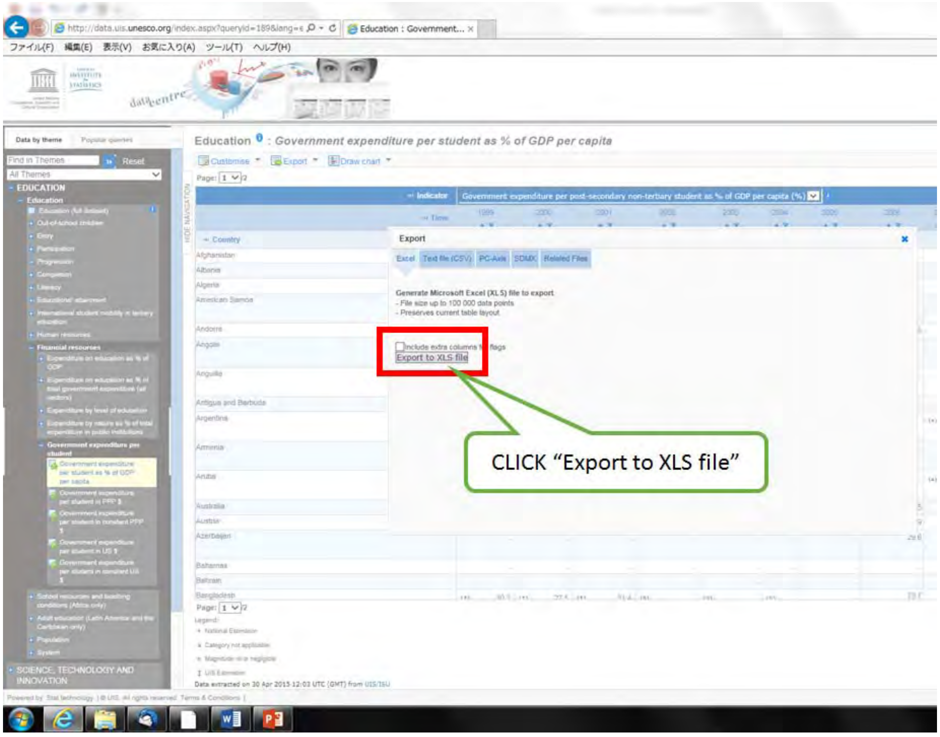
⑤ Choose the education level such as primary, secondary, etc.



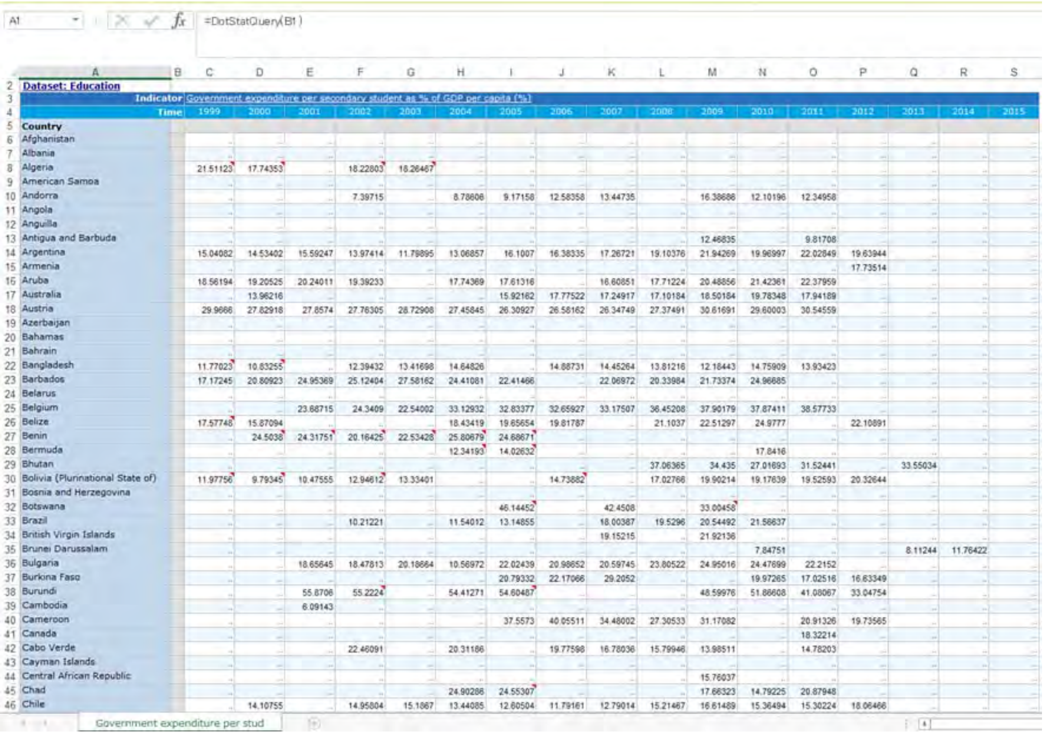
⑥ Choose Export and click “Excel”



⑦ Click “Export to XLS file”



⑧ You can collect data sorted by country



=DotStatQuery(B1)

Dataset: Education

Indicator: Government expenditure per secondary student as % of GDP per capita (%)

Time / Country	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Afghanistan																	
Albania																	
Algeria	21.51123	17.74353		18.22803	18.26467												
American Samoa																	
Andorra				7.39715		8.78606	9.17158	12.58358	13.44735		16.38686	12.10196	12.34958				
Angola																	
Anguilla																	
Antigua and Barbuda											12.46835		9.81708				
Argentina	15.04082	14.53402	15.59247	13.97414	11.79895	13.06857	16.1007	16.38335	17.26721	19.10376	21.94269	19.96997	22.02849	19.63944			
Armenia														17.73514			
Aruba	18.56194	19.20525	20.24011	19.39233		17.74369	17.61316		16.60851	17.71224	20.48856	21.42361	22.37959				
Australia		13.96216					15.92162	17.77522	17.24917	17.10184	18.50184	19.78348	17.94189				
Austria	29.9666	27.82918	27.8574	27.76305	28.72908	27.45845	26.30927	26.58162	26.34749	27.37491	30.61691	29.60003	30.54559				
Azerbaijan																	
Bahamas																	
Bahrain																	
Bangladesh	11.77023	10.83255		12.39432	13.41698	14.64826		14.88731	14.45264	13.81216	12.18443	14.75909	13.93423				
Barbados	17.17245	20.80923	24.95369	25.12404	27.58162	24.41081	22.41466		22.06972	20.33984	21.73374	24.96685					
Belarus																	
Belgium			23.68715	24.3409	22.54002	33.12932	32.83377	32.65927	33.17507	36.45208	37.90179	37.87411	38.57733				
Belize	17.57748	15.87094				18.43419	19.65654	19.81787		21.1037	22.51297	24.9777		22.10891			
Benin		24.5038	24.31751	20.16425	22.53428	25.80679	24.68671										
Bermuda						12.34193	14.02632					17.8416					
Bhutan										37.06365	34.435	27.01693	31.52441		33.55034		
Bolivia (Plurinational State of)	11.97756	9.79345	10.47555	12.94612	13.33401			14.73882		17.02766	19.90214	19.17639	19.52593	20.32644			
Bosnia and Herzegovina																	
Botswana							46.14452		42.4508		33.00458						
Brazil				10.21221		11.54012	13.14855		18.00387	19.5296	20.54492	21.58637					
British Virgin Islands									19.15215		21.92136						
Brunei Darussalam												7.84751			8.11244	11.76422	
Bulgaria			18.65645	18.47813	20.18664	10.56972	22.02439	20.98652	20.59745	23.80522	24.95016	24.47699	22.2152				
Burkina Faso							20.79332	22.17066	29.2052			19.97265	17.02516	16.63349			
Burundi			55.8706	55.2224		54.41271	54.60487				48.59976	51.86608	41.08067	33.04754			
Cambodia			6.09143														
Cameroon							37.5573	40.05511	34.48002	27.30533	31.17082		20.91326	19.73565			
Canada													18.32214				
Cabo Verde				22.46091		20.31186		19.77598	16.78036	15.79946	13.98511		14.78203				
Cayman Islands																	
Central African Republic											15.76037						
Chad						24.90286	24.55307				17.66323	14.79225	20.87948				
Chile		14.10755		14.95804	15.1867	13.44085	12.60504	11.79161	12.79014	15.21467	16.61489	15.36494	15.30224	18.06466			

Government expenditure per stud

6.2 Configuration example of input data

The following table illustrates variables used in the program, configuration methods, and the setting values for a Honduras case study as an example. The next section contains supplemental explanation of data that requires estimation or processing.

Table 6-1 Configuring variables and example case study configuration

Parameter name	Default value	Description	Data source
J	5	The number of income class	<fixed data>
L	4	The number of disaster classes (not including the no-disaster state)	<fixed data>
rho	0.12	Time preference rate	Recommended value
theta	2	Degree of relative risk aversion	Recommended value
cbar	0	The subsistence level of consumption	Recommended value
deltaz	0.1	Depreciation rate of physical asset	<fixed data>
deltak	0.02	Depreciation rate of production capital	<fixed data>
gb	0.042	Exogenous technological growth rate	Recommended value
iota	1	Compensation coefficient between the human capital investment and the years of education.	Those parameters are defined by the assumption. There will be no effect to the model when you use 1.
Pop0	6762426	Initial population	World Bank data (by Country)
GDP0	9120240790	Initial GDP US$ (2004, from World bank HP, 2005US$)	World Bank data (by Country)
alpha1	0.45	Share parameter for human capital	Social Account Matrix/Input Output Table
alpha2	0.47	Share parameter for physical capital	Social Account Matrix/Input Output Table
alpha3	0.08	Share parameter for land	Social Account Matrix/Input Output Table
c0	93 243 448 787 2564	Initial consumption per capita: Data of Households' survey 2004	Household Survey /JICA Poverty Profile
h0	3.3 4.2 5.0 6.0 6.9	Initial human capital per capita (using mean years of schooling as a proxy variable)	UNDP data (Mean years of schooling)/Household Survey /JICA Poverty Profile
z0	112 293 540 949 3091	Initial physical asset investment per capita as flow variable	Household Survey /JICA Poverty Profile
b0	321 842 1554 2732 8899	Initial financial assets per capita	World Bank data (by Country)
T0	0.02 0.05 0.08 0.15 0.48	Initial land per capita	World Bank data (by Country)
m0	0.33	Initial education time per capita	Household Survey /JICA Poverty Profile
deltah	0.004	Depreciation rate of human capital	World Bank data (by Country)
eta0	0	Coefficient of human investment cost function	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank
eta1	0	Coefficient of human investment cost function	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank

eta2M	205.8	Coefficient of human investment cost function	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank
eta2Mvector	205.8 245.3 381.3 1092.6 1504.3 1918.7 5347.2 20000	0<h<=6 6<h<=9 9<h<=11 11<h<=15 15<h<=17 17<h<=20 20<h<=60	INSTITUTE for STATISTICS, UNESCO/World Development Indicator, World Bank

Table 6-2 Reference of Input Data of Disaster Parameters

	Description	Data source
omegaV_DISASTER (1 or 2)	Human capital damage rate due to disaster by rank	Human capital damage: Desinventar / UNISDR population：World Bank data (by Country)
phiV_DISASTER (1 or 2)	Physical assets damage rate due to disaster by rank	Physical assets damage：Desinventar / UNISDR Household: Household Survey /JICA Poverty Profile
psiV_DISASTER (1 or 2)	Production capital damage rate due to disaster by rank	Set following the relationship between Capital damage rate and Physical assets damage rate
tauV_DISASTER (1 or 2)	Damage rate of land due to disaster by rank	There are no disaster in this study
mu	Probability of disaster occurrence by rank	UNISDR database Desinventar

Table 6-3 Input Data List of disaster 1 on Disaster Parameters (Disaster1 =FLOOD)

Parameter name	Sample value				
Disaster Rank	Rank 0	Rank 1	Rank 2	Rank 3	Rank 4
mu	0.500	0.464	0.019	0.011	0.007
DRR	Without				
omegaV_DISASTER1	0	0.110046	0.298150	0.400638	0.475017
phiV_DISASTER1	0	0.000191	0.000488	0.000634	0.000749
psiV_DISASTER1	0	0.000840	0.002149	0.002789	0.003294
tauV_DISASTER1	0	0	0	0	0
DRR	Soft				
omegaV_DISASTER1	0	0	0	0	0
phiV_DISASTER1	0	0.000191	0.000488	0.000634	0.000749
psiV_DISASTER1	0	0.000840	0.002149	0.002789	0.003294
tauV_DISASTER1	0	0	0	0	0
DRR	Hard1				
omegaV_DISASTER1	0	0	0.078125	0.273375	0.402195
phiV_DISASTER1	0	0	0.000153	0.000474	0.000656
psiV_DISASTER1	0	0	0.000671	0.002084	0.002886
tauV_DISASTER1	0	0	0	0	0
DRR	Hard2				
omegaV_DISASTER1	0	0	0	0.099688	0.313246
phiV_DISASTER1	0	0	0	0.000200	0.000541
psiV_DISASTER1	0	0	0	0.000881	0.002380
tauV_DISASTER1	0	0	0	0	0
DRR	Hard1+soft				
omegaV_DISASTER1	0	0	0	0	0
phiV_DISASTER1	0	0	0.000153	0.000474	0.000656
psiV_DISASTER1	0	0	0.000671	0.002084	0.002886
tauV_DISASTER1	0	0	0	0	0
DRR	Hard2+soft				
omegaV_DISASTER1	0	0	0	0	0
phiV_DISASTER1	0	0	0	0.000200	0.000541
psiV_DISASTER1	0	0	0	0.000881	0.002380
tauV_DISASTER1	0	0	0	0	0

Table 6-4 Input Data List of disaster 2 on Disaster Parameters (Disaster2 =EARTHQUAKE)

Parameter name	Sample value				
Disaster Rank	Rank 0	Rank 1	Rank 2	Rank 3	Rank 4
mu	0.5	0.468048	0.015625	0.009615	0.006711
DRR	Without				
omegaV_DISASTER2	0	0.000300	0.000928	0.001243	0.001485
phiV_DISASTER2	0	0.001339	0.003731	0.005008	0.005959
psiV_DISASTER2	0	0.005893	0.016416	0.022035	0.026222
tauV_DISASTER2	0	0	0	0	0
DRR	Soft				
omegaV_DISASTER2	0	0.000300	0.000928	0.001243	0.001485
phiV_DISASTER2	0	0.001339	0.003731	0.005008	0.005959
psiV_DISASTER2	0	0.005893	0.016416	0.022035	0.026222
tauV_DISASTER2	0	0	0	0	0
DRR	Hard1				
omegaV_DISASTER2	0	0	0.000139	0.000719	0.00116
phiV_DISASTER2	0	0	0.000914	0.003369	0.004995
psiV_DISASTER2	0	0	0.004019	0.014823	0.021976
tauV_DISASTER2	0	0	0	0	0
DRR	Hard2				
omegaV_DISASTER2	0	0	0	0.000175	0.000813
phiV_DISASTER2	0	0	0	0.001179	0.003873
psiV_DISASTER2	0	0	0	0.005188	0.017041
tauV_DISASTER2	0	0	0	0	0
DRR	Hard1+soft				
omegaV_DISASTER2	0	0	0.000139	0.000719	0.00116
phiV_DISASTER2	0	0	0.000914	0.003369	0.004995
psiV_DISASTER2	0	0	0.004019	0.014823	0.021976
tauV_DISASTER2	0	0	0	0	0
DRR	Hard2+soft				
omegaV_DISASTER2	0	0	0	0.000175	0.000813
phiV_DISASTER2	0	0	0	0.001179	0.003873
psiV_DISASTER2	0	0	0	0.005188	0.017041
tauV_DISASTER2	0	0	0	0	0

6.3 Configuring input data

Input data is organized into four types of data: deep parameters, macroeconomic data, household data, and disaster data.

Table 6-5 Types of input data

Data Type		Example of Data	Details of Data
Socio Economic Parameters	Deep Parameters	Relative risk aversion level, rate of decrease, etc.	Fixed value
	Macroeconomic data	Total population, GDP, etc.	Configuration method described later in this chapter.
	Household data	Consumption, savings, human investment, physical investment, etc.	
Disaster Parameters	Disaster data	Human casualties, material damage, etc.	Configuration method described later in this chapter.

6.3.1 Deep Parameter

In this application, the parameter of fixed value is called Deep Parameter.

(1) Income group number J

The income group level number used in this model can accommodate up to five income groups, which was determined for consistency with usable data such as income group share data from the World Bank.

Income group number	J = 5

(2) Disaster rank number L

There are a total of five disaster ranks available from 0-4. (Refer to Appendix D for specific information on configuring the disaster rank and other disaster damage ratios.)

Disaster rank number	L = 4

(3) Time preference rate ρ

The time preference rate is an interest rate level designed to reduces current consumption and encourage saving money for the future. That is to say, it correlates current consumption with future consumption (savings). A larger time preference rate represents a more significant trend toward a preference for current consumption. The default value is 0.12.

Time preference rate	$\rho = 0.12$

(4) Relative risk aversion level θ

This parameter represents the level of risk acceptability for households. A larger value represents a more significant trend towards risk avoidance. This is set to a value of "2" in reference to Kraay and Raddatz (2007).

Relative risk aversion level	$\theta = 2$

(5) Subsistence level of consumption cbar

This parameter represents the minimum level of required consumption for survival, which can be used for consideration of poverty traps. This is set to a value of "0" for simplicity.

Subsistence level of consumption	cbar = 0

(6) Physical asset depreciation rate δz

This is the ratio of depreciation that physical assets experience each term. The amortization period for physical assets is set to 10 years, and so this value is set to "0.1".

Physical asset depreciation rate	$\delta_z = 0.1$

(7) Production capital depreciation rate δ_k

This is the ratio of depreciation that production capital experience each term. The amortization period for production capital is set to 50 years, and so this value is set to "0.02".

Production capital depreciation rate	$\delta_k = 0.02$

(8) Exogenous rate of technological progress gb

This parameter represents the progress rate of total-factor productivity. This is set to "0.042" due to the relationship between the GDP per capita and the GDP growth rate. (Refer to Appendix B for specific information on configuring this parameter.)

Exogenous rate of technological progress	gb = 0.042

(9) Correction coefficient for human capital formation ι

This coefficient is used to correct the relationship between personal investment and the mean years of schooling. This is fundamentally set to a value of "1" as this parameter was incorporated to adjust parameter particulars (calibration). (No effect on the model when set to "1".)

Correction coefficient for human capital formation	ι = 1

6.3.2 Organizing and configuring socio-economic data

You can collect and organize data regarding population and GDP. Set distribution ratios such as capital input and others as well as the labor input based on input-output tables and SAM for share parameters of production functions.

(1) Population per group n

The population per income group is set to average out each group for the purpose of consistency with usable data such as income group share data from the World Bank.

1) Required data

- Use the World Bank data (by country)
- Used parameter is "population, total"

2) Configuring settings

The total population is derived by dividing by the number of income groups.

$$n = \frac{\mathrm{POT}}{\mathrm{ICG}}$$

n: Population per income groups

POT : Total population

ICG : Income group number

3) Configuration example

The following table summarizes the results of calculating stratified populations using the previously described expression.

Table 6-6 Stratified populations (2004 values)

Country	Honduras	Pakistan	Guatemala	Peru	Costa Rica
Total population (people)	6,762,426	155,151,394	12,367,800	27,403,845	4,246,336
Income group number	5	5	5	5	5
Population per group n (people)	1,352,485	31,030,279	2,473,560	5,480,769	849,267

(2) GDP

The initial GDP value is used to calibrate the exogenous rate of technological progress coefficient B_0. The program has been created to automatically calculate the exogenous rate of technological progress coefficient B_0 by inputting the initial GDP value.

1) Required data

- Use the World Bank data (by country)
- Used parameter is "GDP (constant 2005 US$)"

2) Configuring settings

Use the raw data obtained from the World Bank database without any modification.

3) Configuration example

The following reference table lists the GDP for various countries.

Table 6-7 GDP (2004 values)

Group	Lower-middle-income economies			Upper-middle-income economies	
Country	Honduras	Pakistan	Guatemala	Peru	Costa Rica
GDP (constant 2005 US$)	9,120,240,790	101,704,136,879	26,352,121,441	70,530,831,291	18,855,016,400

*Groups are classified by the standards used by the World Bank. The "Lower-middle-income economies" classification represents average income levels from $1,046 to $4,125. The "Upper-middle-income economies" classification represents average income levels from $4,126 to $12,745.

(3) Share parameter α for production functions

1) Required data

- Social account matrix or input-output table

2) Configuring settings

The input ratio for production factors is calculated from "Wage" and "Capital" from the Social Account Matrix (SAM) or the "Wage" and "Non-wage Income" from the input-output table. This ratio is used as the share parameter for production functions.

$$\alpha_1 = \frac{\mathrm{WIN}}{(\mathrm{WIN} + \mathrm{CIN} + \mathrm{RIN})}$$

$$\alpha_2 = \frac{\mathrm{CIN}}{(\mathrm{WIN} + \mathrm{CIN} + \mathrm{RIN})}$$

$$\alpha_3 = \frac{\mathrm{RIN}}{(\mathrm{WIN} + \mathrm{CIN} + \mathrm{RIN}))}$$

α_1 : *Share parameter for wage*

α_2: *Share parameter for capital*

α_3: *Share parameter for Land*

WIN: *Labor income*

CIN: *Capital income*

RIN: *Land income*

3) Configuration example

The following table illustrates an example share parameter configuration for production functions in the case of Honduras. The Honduras SAM data was organized by Lizardo et al. (1999).

Table 6-8 Share parameters for production functions (Honduras, 1991 values)

Production functions	Input value	Subtotal	Total	Ratio
Urban Wage Earner	α_1	5606.70	6917.80	0.45
Rural Wage Earner		1311.10		
Capital	α_2	7084.50	7084.50	0.47
Land	α_3	Unknown	Unknown	0.08※

Table 6-9 Share parameter for production functions

Production functions	Honduras	Pakistan	Guatemala	Peru	Costa Rica	Input value
Urban Wage Earner	0.45	0.52	0.38	0.38	0.45	α_1
Rural Wage Earner						
Capital	0.47	0.40	0.54	0.54	0.47	α_2
Land	0.08	0.08	0.08	0.08	0.08	α_3

*As there is insufficient land data, the land ratio α3 for each country was set to the same ratio as that for Pakistan (0.08 in principle).

*Assumed values were used for Guatemala and Costa Rica as no data for these countries has been obtained.

Social Accounting Matrix of Honduras, 1991 *(continued)*
Millions of current Lempiras

	FACTORS			HOUSEHOLDS AND OTHER INSTITUTIONS					
	Urblab	Rulab	Capital	hhalto	hhmedio	hhlowurb	hhlowrur	Empres	Gov
BIEN COMPUESTO*									
Agricultural exports (AgrExp)				27.60	27.20	27.20	20.80	0.00	
Agricultural grains (Grains)				36.00	46.80	44.10	53.90	0.00	
Livestock (Livestock)				80.70	67.70	34.80	18.40	0.00	
Other agricultural (OtherAgr)				136.60	191.90	187.20	194.40	0.00	
Agroindustry (IndAgr)				333.50	746.60	872.70	1028.50	0.00	
Other industry (OtherInd)				481.30	795.40	736.00	733.00	0.00	
Construction (Constr)				0.00	0.00	0.00	0.00	0.00	
Trade (Trade)				314.20	441.40	430.60	447.10	0.00	
Mercantile services (MerSer)				596.50	838.00	817.40	848.80	0.00	
Public administration (PubAdmin)				0.00	0.00	0.00	0.00		1769.00
HOUSEHOLDS, ETC.									
High income (hhalto)	1513.80	354.00						1549.60	
Medium income (hhmedio)	2192.20	512.60						2244.10	
Urban wage Earner (hhlowurb)	1900.70	0.00						1384.70	
Rural wage Earner (hhlowrur)	0.00	444.50						560.90	
Enterprises (Empres)			7084.50						
Direct tax (Dirtax)				119.70	173.40	0.00	0.00		
SAVINGS/ INVESTMENT (CAPACC)				1291.20	1620.50	270.80	0.00	1345.10	−1018.10
TOTAL	5606.70	1311.10	7084.50	3417.40	4948.90	3420.70	3345.00	7084.50	750.90

(continued on next page)

Reference: Lizardo et al. (1999)

6.3.3 Organizing and configuring household data

Next, we will discuss collecting and organizing initial household data such as consumption amounts, physical assets, financial assets, and human capital. Data will be obtained per income group if possible.

Initial data for consumption share data is set by calculating a distribution ratio for consumption and physical assets using household survey data.

(1) Income distribution

Obtain income distribution amounts per group. This data is used to configure financial assets and other parameters described later.

1) Required data

- Use the World Bank data (by country)
- Used parameters are ”GDP (constant 2005 US$)”, “Income share held by lowest 20%”、”Income share held by second 20%", ”Income share held by third 20%”, ”Income share held by fourth 20%”, and ”Income share held by highest 20%”

Table 6-10 World Bank Data required to configure income distributions

Name of Data
GDP (constant 2005 US$)
Income share held by lowest 20%
Income share held by second 20%
Income share held by third 20%
Income share held by fourth 20%
Income share held by highest 20%

2) Configuring settings

First, GDP is divided by the share parameter α_i which is set by socio-economic data to obtain the labor income and capital income. Next, income share data is used to calculate data per group and distribute the labor income and capital income to each group. (Refer to "Reference: Calculation of income distribution relationships" in Appendix C for proof of concept.)

$$\beta_1 = \frac{\mathrm{GDP} \cdot \alpha_1 \cdot a}{n}$$

$$\beta_2 = \frac{\mathrm{GDP} \cdot \alpha_2 \cdot a}{n}$$

$$\beta_3 = \frac{\mathrm{GDP} \cdot \alpha_3 \cdot a}{n}$$

β_1 : *Labor income per person and per group*
β_2 : *Capital income per person and per group*
β_3 : *Land income per person and per group*
GDP
α_1 : *Share parameter for human capital*
α_2: *Share parameter for physical capital*
α_3: *Share parameter for land*
a : *Income share*
n : *Population per group n*

* represents the share parameter for production functions.

3) Configuration example

Income per group can be obtained as illustrated below using Honduras as an example.

Table 6-11 Income distribution (Honduras, 1994 values)

Income classification	GDP (billion $)	Value	GDP (billion $)×Value
Labor income	6.376	0.45	2.869
Capital income		0.47	2.997

The calculated labor and capital income is divided by income share data into five different groups. Then the labor and capital income per capita is calculated by dividing the sorted data by the population in each group.

Table 6-12 Stratified labor income per capita (Honduras, 1994 values)

Income group	Labor income (total) (billion $)	Income share	Labor income (stratified) (billion $)	Labor income (per capita) ($)
1st (poorest)	2.869	0.032	0.092	84.4
2nd (poor)		0.069	0.200	182.9
3rd (middle)		0.115	0.334	305.6
4th (rich)		0.192	0.556	509.0
5th (richest)		0.593	1.717	1573.3

Table 6-13 Stratified capital income per capita (Honduras, 1994 values)

Income group	Capital income (total) (billion $)	Income share	Capital income (stratified) (billion $)	Capital income (per capita) ($)
1st (poorest)	2.997	0.032	0.094	86.5
2nd (poor)		0.069	0.204	187.4
3rd (middle)		0.115	0.342	313.0
4th (rich)		0.192	0.569	521.3
5th (richest)		0.593	1.758	1611.2

(2) Household expenditure share

1) Required data

- Household surveys, JICA poverty profile, or similar

2) Configuring settings

Reference household survey data form each country, poverty profiles, and similar data and then classify this data into non-durable goods expenditures (food, health, and others), durable goods expenditures (rent, housing, and durables), and education investment to obtain each share.

$$H_1 = \frac{h_1}{h}$$

$$H_2 = \frac{h_2}{h}$$

H_1 : Share of non − durable goods expenditure
H_2 : Share of durable goods expenditure
h_1 : Non − durable goods expenditure
h_2 : Durable goods expenditure
h : Total expenditure amount

3) Configuration example

Using Honduras as an example, the breakdown of household expenditures is published by the Honduras Poverty Assessment, Document of the World Bank (2006), and so this data was used to configure the household expenditure share.

Table 6-14 Breakdown of expenditures per month (Honduras, 2004 values)

Expenditure type	Expenditure breakdown	Subtotal (Lempira)	Total (Lempira)	Expenditure ratio
Non-durable goods (consumption)	Food	600	980	0.69
	Health	139		
	Others	241		
Durable goods (physical)	Rent	177	353	0.25
	Housing	116		
	Durables	60		
Education investment	Education	89	89	0.06

Table A 2 – B.4 Honduras 2004 - Monthly Average Per Capita values of Consumption Aggregate

		Montly PC consumption	Food	Rent	Housing	Health	Education	Durables	Others
Area	Urban	2,005	765	278	171	196	145	97	353
	Rural	881	446	84	65	87	38	26	137
Group Total		1,424	600	177	116	139	89	60	241
Regions	Tegucigalpa	2,507	846	387	207	249	207	123	489
	San Pedro Sula	2,488	867	355	254	236	197	113	467
	Central Urban	2,034	826	247	168	216	138	101	337
	Central Rural	1,072	530	100	78	104	47	34	179
	Occident Urban	1,400	614	193	110	104	71	76	232
	Occident Rural	609	324	64	46	53	25	12	85
	Orient Urban	1,450	642	178	114	150	92	66	208
	Orient Rural	830	424	75	61	94	34	26	115
Group Total		1,424	600	177	116	139	89	60	241
Extreme Poor		358	209	44	35	18	13	3	35
Non-Extreme Poor		735	415	81	57	49	29	12	92
Non Poor		2,314	889	294	187	247	159	114	422
Group Total		1,424	600	177	116	139	89	60	241
All Poor		558	319	63	47	35	22	8	65
Non Poor		2,314	889	294	187	247	159	114	422
Group Total		1,424	600	177	116	139	89	60	241

The values in the table are the National averages Housing includes utilities and other services, others includes transportation, transfers and personal expenditures

Reference: Honduras Poverty Assessment, Document of the World Bank (2006)

(3) Consumption c

1) Required data

- Household Survey or Poverty Profile of JICA etc.
- Household expenditure share（calculated in the formal part）

2) Configuring settings

Reference household survey data form each country, poverty profiles, and similar data and then classify this data into non-durable goods expenditures (food, health, and others), durable goods expenditures (rent, housing, and durables), and education investment to obtain each share. Data on household survey results per group is used instead of income share data when available.

Consumption c is calculated by multiplying each expenditure share as calculated in step 2 with the total expenditure amount.

$$h = \text{GDP} - \text{Gross Domestic Saving}$$

$$c = \frac{h \cdot H_1 \cdot a}{n}$$

h : *Total expenditure amount*
GDP
Gross Domestic Saving
c : *Consumption per person and per income group*
H_1 : *Share of non − durable goods expenditure*
a : *Income share*
n : *Population per income group n*

3) Configuration example

The following table illustrates the calculation results of using the previously described expression.

Table 6-15 Consumption per capita c (2004 values)

Consumption c	Honduras	Pakistan	Guatemala	Peru	Costa Rica
1st (poorest)	93	208	241	295	462
2nd (poor)	243	289	545	583	1,032
3rd (middle)	448	369	889	926	1,613
4th (rich)	787	480	1,427	1,457	2,575
5th (richest)	2,564	924	3,820	3,777	6,574

(4) Human capital h

1) Required data

- UNDP data (Mean years of schooling)
- Household surveys, JICA poverty profile, or similar

2) Configuring settings

The mean years of schooling per income group is used as the proxy variable for human capital.

3) Configuration result

The following table illustrates the result of configuring the proxy variable for human capital by using the mean years of schooling.

Table 6-16 Human capital (mean years of schooling) configuration values (2004 values)

Personal investment h	Honduras	Pakistan	Guatemala	Peru	Costa Rica
1st (poorest)	3.3	3.2	3.5	8.4	7.9
2nd (poor)	4.2	3.9	3.5	8.4	7.9
3rd (middle)	5.0	4.2	3.5	8.4	7.9
4th (rich)	6.0	4.4	3.5	8.4	7.9
5th (richest)	6.9	5.6	3.5	8.4	7.9

*Initial values for Guatemala, Peru, and Costa Rica are all the same as there is no data on the mean years of schooling per group for these countries.

(5) Physical asset z

1) Required data

- Household surveys, JICA poverty profile, or similar
- Household expenditure share (calculated as described previously)

2) Configuring settings

Reference household survey data form each country, poverty profiles, and similar data and then classify this data into non-durable goods expenditures (food, health, and others), durable goods expenditures (rent, housing, and durables), and education investment to obtain each share. Data on household survey results per group is used instead of income share data when available.

Physical asset z is calculated by multiplying each expenditure share as calculated in step 2 with the total expenditure amount. Physical asset is obtained by dividing the durable goods expenditure amount with the interest rate and converting from flow values to stock values.

$$h = \text{GDP} - \text{Gross Domestic Saving}$$

$$z = \frac{h \cdot H_2 \cdot a}{(I + \text{DEP} + \text{HDR} - \text{CDR}) \cdot n}$$

h : *Total expenditure amount*
GDP
Gross Domestic Saving
z : *Physical asset per person*
H_2 : *Share of durable goods expenditure*
a : *Income share*
I : *Interest rate*
DEP : *Depreciation rate of human capital*
HDR : *Depreciation rate of household assets*
CDR : *Depreciation rate capital*
n : *Population per income group*

3) Configuration example

The following table illustrates the calculation results of using the previously described expression.

Table 6-17 Physical asset z per capita (2004 values)

Physical asset z	Honduras	Pakistan	Guatemala	Peru	Costa Rica
1st (poorest)	112	186	364	306	498
2nd (poor)	293	259	825	605	1,112
3rd (middle)	540	331	1,345	962	1,738
4th (rich)	949	429	2,158	1,513	2,775
5th (richest)	3,091	827	5,779	3,923	7,084

(6) Financial asset b

1) Required data

- Use the World Bank data (by country)
- Used parameters are ”GDP (constant 2005 US$)”, “Income share held by lowest 20%”、”Income share held by second 20%", ”Income share held by third 20%”, ”Income share held by fourth 20%”, and ”Income share held by highest 20%”

Table 6-18 World Bank data required to configure financial assets

Name of Data
GDP (constant 2005 US$)
Rental rate (lending rate)
Income share held by lowest 20%
Income share held by second 20%
Income share held by third 20%
Income share held by fourth 20%
Income share held by highest 20%

2) Configuring settings

This parameter is expressed as follows incorporating the relationship of the income distribution calculated in step 1.

$$CI = \mathrm{GDP} \times \alpha_2 = (I + \mathrm{PCD}) \cdot \mathrm{FA}$$

CI : *Capital income*
GDP
α_2 : *Share parameter for physical capital*
I : *Interest rate*
PCD : *Depreciation rate of production capital*
FA : *Financial assets*

Thus, the financial assets parameter is obtained by dividing the capital income by the sum of the interest rate and the production capital depreciation ratio.

$$\mathrm{SFA} = \frac{CI \cdot a}{(I + \mathrm{PCD})n}$$

SFA : *Financial assets parameter per person*
CI : *Capital Income*
I : *Interest rate*
PCD : *Depreciation rate of production capital*
a : *Income share*
n : *Population per income group n*

3) Configuration example

The financial assets per capita is calculated by dividing the sum of the interest rate and depreciation ratio from the capital income per capita as calculated in step 2.

Table 6-19 Financial assets per capita (Honduras, 2004 values)

Income group	Capital income (per capita) ($)	Interest rate	Depreciation ratio	Financial assets (per capita) ($)
1st (poorest)	70	0.199	0.02	321
2nd (poor)	184			842
3rd (middle)	340			1,554
4th (rich)	598			2,732
5th (richest)	1,947			8,899

Table 6-20 Financial assets per capita (2004 values)

Financial assets b	Honduras	Pakistan	Guatemala	Peru	Costa Rica
1st (poorest)	321	1297	1277	1101	1793
2nd (poor)	842	1801	2892	2176	4005
3rd (middle)	1554	2306	4713	3458	6259
4th (rich)	2732	2992	7564	5440	9993
5th (richest)	8899	5765	20256	14104	25513

(7) Land area T

1) Required data

- Use the World Bank data (by country)

Table 6-21 World Bank data required to configure land area

Name of Data
GDP (constant 2005 US$)
Arable Land
Income share held by lowest 20%
Income share held by second 20%
Income share held by third 20%
Income share held by fourth 20%
Income share held by highest 20%

2) Configuring settings

The land area T is configured as a stratified value by using the income share data and assuming that the area is for cultivated land. Then the stratified land area per capita is calculated.

$$T = \frac{CA \cdot a}{\mathrm{SPO}}$$

T : *Land area per person*
CA : Cultivated land area
a : *Income share*
SPO : *Population per income group*

3) Configuration example

The following table illustrates the results of calculating this parameter using data for Honduras with the previously described expression.

Table 6-22 Stratified land area per capita (Honduras, 1994 values)

Income group	Land area (total) (ha)	Income share	Land area (Stratified) (ha)	Land area (per capita) (ha)
1st (poorest)	1,650,000	0.032	52,470	0.05
2nd (poor)		0.069	113,685	0.10
3rd (middle)		0.115	189,915	0.17
4th (rich)		0.192	316,305	0.29
5th (richest)		0.593	977,625	0.90

(8) Education time m

1) Required data

- Household surveys, JICA poverty profile, or similar

2) Configuring settings

The human capital investment parameter uses education time data. Note that statistics data is likely not available for developing countries.

In such cases, use the following method to configure the mean years of schooling of the representative household.

◇Assumptions

- Students attend school throughout the year. (x time × y days)
- Workers work throughout the year. (x time × y days)

The mean years of schooling per capita can be expresses as following with assumptions that students attend school throughout the year and workers work throughout the year.

$$m_0 \fallingdotseq \frac{\mathrm{SPO}}{(\mathrm{SPO}+\mathrm{EPO})} = \frac{\mathrm{TET}}{(\mathrm{TET}+\mathrm{TWT})}$$

m_0 : *Initial value of mean years of schooling*
SPO : Student population
EPO : *Worker population*
TET : *Total education time*
TWT : Total working time

*Student population: Total number of students in primary and secondary schools as published by the World Bank database.

*Worker population: Total population of those of first-year primary school age (around 5) to the retirement age (65 years) minus the student population.

3) Configuration example

The following table illustrates the calculated results for several countries using population data.

Table 6-23 *Initial value of mean years of schooling* m_0

Country	Honduras	Pakistan	Guatemala	Peru	Costa Rica
Initial value of mean years of schooling m_0	0.33	0.18	0.31	0.31	0.26

(9) Human capital depreciation ratio δh

1) Required data

- Use the World Bank data (by country)

Table 6-24 World Bank data required to configure the human capital depreciation ratio

Name of Data
Death rate, crude (per 1,000 people)
Mortality rate, infant (per 1,000 live births)
Number of infant deaths
Population, total

2) Configuring settings

The human capital depreciation ratio δ_h is obtained by dividing the number of deaths of those with human capital by the total population. The DR^2AD model incorporates the obsolescence of knowledge and labor-generation turnover into the human capital depreciation ratio δ_h.

$$\delta_h \ (\equiv \mathrm{CFR}) = \frac{\mathrm{DT} - \mathrm{IDT}}{\mathrm{TPO}}$$

δ_h : *Human capital depreciation ratio*
CFR : *Death rate*
DT : Total *number of deaths*
IDT : *Nunber of infantile death*
TPO : *Total population*

3) Configuration example

The following table illustrates the calculation results using 2004 values for case study countries. The human capital depreciation ratio δ_h for all countries is within 0.4 to 0.5%.

Table 6-25 Human capital depreciation ratio δ

	Honduras	Pakistan	Guatemala	Peru	Costa Rica
Death rate, crude (per 1,000 people)	5.21	7.45	5.92	5.49	4.02
Mortality rate, infant (per 1,000 live births)	26.50	81.60	34.60	23.00	9.20
Number of deaths	35,239	1,155,412	73,168	150,420	17,049
Number of infant deaths	5,160	329,382	14,941	14,105	720
Population, total	6,762,426	155,151,394	12,367,800	27,403,845	4,246,336
Depletion rate δ_k	0.004	0.005	0.005	0.005	0.004

*Data sourced from "The World Development Indicator, World Bank"

(10) Human investment cost function η

The human investment cost functions are configured per education level group (primary, secondary, tertiary, etc.) to incorporate human investment costs in accordance with representative human capital (mean years of education) levels.

1) Required data

■INSTITUTE for STATISTICS, UNESCO

- Duration by level of education
- Government expenditure per student as % of GDP per capita

■World Development Indicator, World Bank

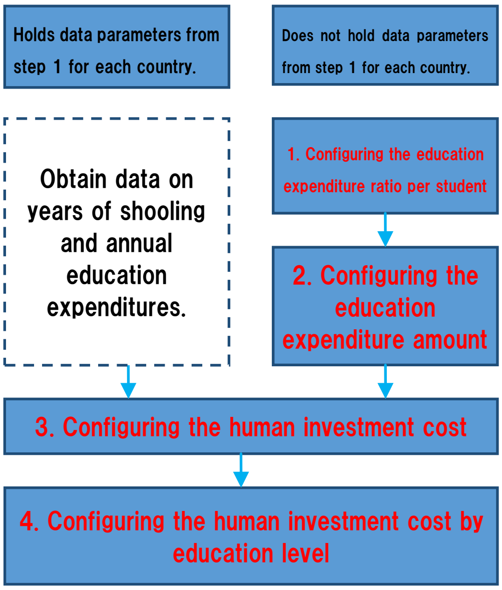
- Country and Lending Groups
- GDP per capita (constant 2005 US$)

2) Configuring settings

If data on the relationship between the cost and education time spent by household annually per education level is available, then this relationship is used to estimate the human investment cost function.

If this data is not available, a simple human investment cost function is estimated using the education expenditure ratio for each income group.

The following section describes the configuration procedure.



1. Configuring the education expenditure ratio per student

(Required data)

- Country and Lending Groups
- Government expenditure per student as % of GDP per capita

The education expenditure ratio per student (% GDP per capita) is calculated for each income group and country as published in the World Bank "Country and Lending Groups." The calculated values are used as universal values.

Table 6-26 Education expenditure ratio per student (% GDP per capita, average values from 2004-2012) (Unit of measure: %)

Education Level \ Income class	Low income (GNI per capita of $1,045 or less)	Lower middle income (GNI per capita of $1,046 to $4,125)	upper middle income (GNI per capita of $4,126 to $12,745)	High income: non OECD (GNI per capita of $12,746 or more)	High income: OECD (GNI per capita of $12,746 or more)
Primary	12.5	13.8	17.0	15.5	20.8
Lower secondary	17.9	16.4	19.4	18.9	24.2
Upper secondary	62.7	25.7	20.5	21.2	26.7
Tertiary	215.1	74.3	36.3	28.9	29.4

2. Configuring the education expenditure amount per student (country-specific values)

(Required data)

- GDP per capita (constant 2005 US$)

The country-specific education expenditure per student ($) is calculated by multiplying the education expenditure ratio per student (% GDP per capita) calculated in step 1 with the country-specific GDP per capita.

$$\mathrm{USD} = \mathrm{EOR} \cdot \mathrm{GDP}\ \mathit{per\ capita}(\mathrm{USD})$$

USD : $Education\ expenditure\ per\ student$
EOR : $Education\ expenditure\ ratio\ per\ student$ （$\%GDP\ per\ capita$）

Table 6-27　GDP per capita (average values from 2004-2012) (Unit of measure: USD)

Country	Honduras	Pakistan	Guatemala	Peru	Costa Rica
GDP per capita (constant 2005 US$)	1,490	731	2,248	3,242	5,150
Income class	Lower-middle-income	Lower-middle-income	Lower-middle-income	Upper-middle-income	Upper-middle-income

Table 6-28　Education expenditure amount per student (Unit of measure: USD)

Country	Honduras	Pakistan	Guatemala	Peru	Costa Rica
Primary	205.8	100.9	310.0	555.4	880.3
Lower secondary	245.3	120.3	369.8	632.0	1001.9
Upper secondary	381.3	187.3	575.6	665.4	1056.8
Tertiary	1092.6	536.4	1653.3	1154.8	1858.0

3. Configuring the human investment cost function

The human investment cost function is configured using the education expenditure amount per student calculated in step 2. The human investment cost function is the line m for vertical axis of education expenditure amount η and horizontal axis of education time.

The "m" in line m for education time equals "1" when school is attended throughout the year and equals "0" when school is not attended at all.

The human investment cost function assumes that the education expenditure amount η multiplicatively increases as line m for education time increases. This relationship is expressed as a quadratic function. The human investment cost function could also be expressed as an exponential or logistic function, but a quadratic function improves model stability and ease of use by analytically resolving the stepped nature of line m for education time.

The following table illustrates an example human investment cost function configuration using data for Pakistan.

Table 6-29 Human investment cost function configuration values (Honduras example)

Pakistan	Education expenditure amount η ($) (average values from 2004-2012)	Education time line m (years)	Human investment cost function η (m) ($)
Primary	205.8	1	$\eta(m)=205.8\ m^2$
Lower secondary	245.3	1	$\eta(m)=245.3\ m^2$
Upper secondary	381.3	1	$\eta(m)=381.3\ m^2$
Tertiary	1092.6	1	$\eta(m)=1092.6\ m^2$

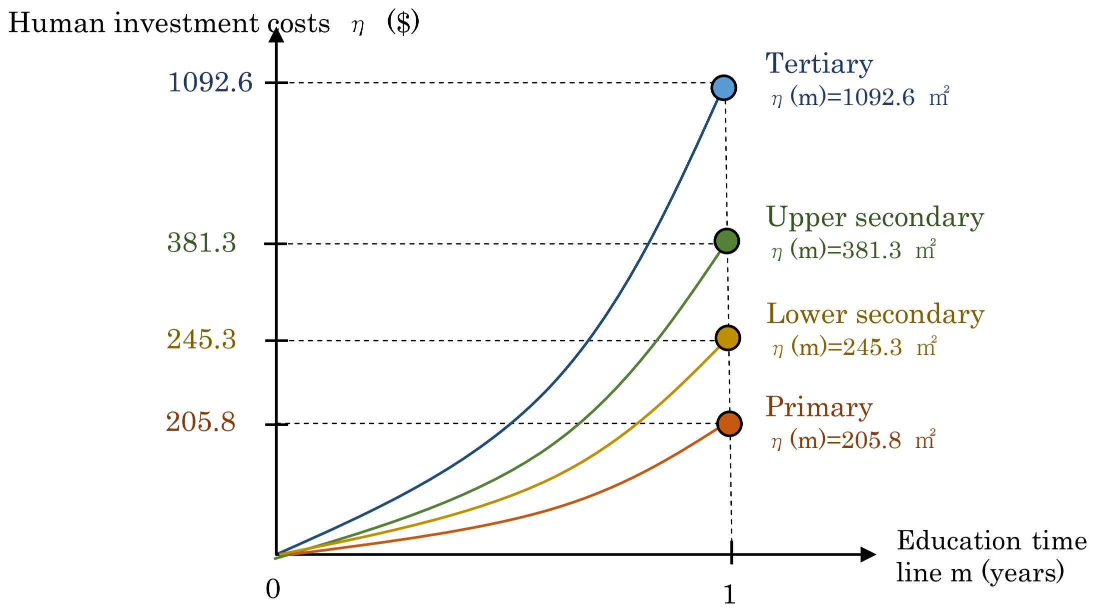


Fig. 6-1 Human investment cost function configuration (Honduras example)

4. Configuring the human investment cost function per education level

(Required data)

- Duration by level of education

The usable range of the human investment cost function per education level is established with reference to the country-specific duration by level of education.

3) Configuration example

The following table summarizes the human investment cost function after incorporating the human investment level. The range of human capital in the table is configured on the basis of the duration by education level.

Table 6-30 Human investment cost function (stepped function)

Education Level	Country					Duration
	Honduras	Pakistan	Guatemala	Peru	Costa Rica	
Primary	y = 205.8 ㎡	y = 100.9 ㎡	y = 310.0 ㎡	y = 555.4 ㎡	y = 880.3 ㎡	$0 \leqq h \leqq 6$
Lower secondary	y = 245.3 ㎡	y = 120.3 ㎡	y = 369.8 ㎡	y = 632.0 ㎡	y = 1001.9 ㎡	$6 < h \leqq 9$
Upper secondary	y = 381.3 ㎡	y = 187.3 ㎡	y = 575.6 ㎡	y = 665.4 ㎡	y = 1056.8 ㎡	$9 < h \leqq 11$
Tertiary (Bachelor)	y = 1092.6 ㎡	y = 536.4 ㎡	y = 1653.3 ㎡	y = 1164.8 ㎡	y = 1858.0 ㎡	$11 < h \leqq 15$
Tertiary (Master)	y = 1504.3 ㎡	y = 651.4 ㎡	y = 2275.5 ㎡	y = 1412.9 ㎡	y = 2256.9 ㎡	$15 < h \leqq 17$
Tertiary (Doctor)	y = 1918.7 ㎡	y = 820.0 ㎡	y = 2904.4 ㎡	y = 1679.8 ㎡	y = 2685.6 ㎡	$17 < h \leqq 20$
Post-tertiary	y = 5347.2 ㎡	y = 2064.6 ㎡	y = 8097.9 ㎡	y = 3860.1 ㎡	y = 6188.3 ㎡	$20 < h \leqq 60$

*Tertiary (Masters), tertiary (Doctorate), and post-tertiary levels are calculated by regression analysis of data for primary through tertiary (Bachelors) levels.

6.3.4 Disaster data

(1) Configuration procedure

Use the following procedure to make configurations using disaster data.

1) Identify applicable disasters

Select a maximum of two disasters for analysis (Ex.: floods and earthquakes).

2) Type of applicable disasters

Use disaster data such as the UNISDR DesInventar for the country under analysis to configure the human damage ratio, household damage ratio, production facilities damage ratio, and the land damage ratio.

$$\mathrm{HSR} = \frac{\sum(\mathrm{DT} + \mathrm{MS} + \mathrm{IJ} + EVC + \mathrm{MO} + \mathrm{AFP})}{\mathrm{TPO}}$$

$$\mathrm{HDR} = \frac{\mathrm{CHN}}{\mathrm{THN}} \ or \ \frac{\mathrm{AHN}}{\mathrm{THN}}$$

$$\mathrm{PDR} = \frac{\mathrm{PD}}{\mathrm{PDS}}$$

$$\mathrm{LDR} = \frac{\mathrm{DFL} \cdot \mathrm{FA}}{\mathrm{FL}}$$

HSR : *Human damage ratio*
DT : *Total number of dead*
MS : Number of missing
IJ : *Number of injured*
EVC : *Number of evacuees*
MO : Number of moving people
AFP : *Number of victim*
TPO : *Total population*
HDR : *Household damage ratio*
CHN : *Collapsed household number*
AHN : *Influenced household number*
THN : *Total household number*
PDR : *Production facilities damage ratio*
PD : *Production facilities damage*
PDS : *Production facilities stock amount*
LDR : *Land damage ratio*

DFL : *Damaged farmland*

FA : *Fores area*

FL : *Farmland area*

*If data on the total number of households is not available, you can use the number of families as a replacement.

*If the production facilities stock amount cannot be determined, you can use the annual gross domestic savings published in the World Bank Indicators.

Table 6-3161 Status of damage data availability

Index of damage that should be input into model	Index of damage in databases	Data availability			
		EM=DAT	DesInventar	Netcat-SERVICE	Sigma (Swiss Re)
Human damage	Number of dead (people)	○	○	–	○
	Number of injured (people)	○	○	○	○
	Number of missing (people)	–	○	–	○
	Number of evacuees (people)	–	○	–	–
	Number of moving people (people)	–	○	–	–
	Number of victim (people)	–	○	–	–
Physical damage	Collapsed household number	–	○	–	–
	Influenced househole number	–	○	–	–
Productiuon facilities damage	Amount of damage and loss (dollar)	○	○	△	△
Land damage	Farmland and forest (ha)	–	○	–	–

○ : Available　△ : Available but limited　– : no data

3) Estimating the damage function

The damage function can be estimated using previously generated damage data when no additional investment has been made.

Up to five occurrence probability ranks and damage ratios can be configured. Rank 0 is used for cases of no disasters or very low damage caused by disasters and ranks 1-5 are used for damage-causing disasters.

Configure damage ratios per rank by incorporating occurrence ratios (refer to Appendix C).

4) Configuring damage ratios when investment is made

You can configure damage ratios per disaster rank incorporating DRR investment.

By inputting the effect of direct and soft disaster reduction measures, the benefit of each measure, the combined benefit of measures, and the benefit as a result of differences in investment timing can be measured.

This version does not include the benefit for measures against land damage ratios (cannot be input).

＜Types of measures＞

Name of measure	Benefit of measure
No policy	Configures damage ratios per probability scale.
Soft measures	Benefit of indirect measures that only reduce human damage such as measuring the reduction of damage including death and injury caused by warning systems in place when disasters occur.
Hard measures 1	Direct measures (two types can be configured) produce reductions in not only human damage, but also physical and production facilities damage due to infrastructure investment such as the establishment of dykes.
Hard measures 2	
Include hard measures 1 + soft measures	Combined benefit of previously described measures.
Include hard measures 2 + soft measures	Combined benefit of previously described measures.
Scenario A	Benefit when no investment is made to the first five years followed by direct measures 1 implemented after the fifth year.
Scenario B	Benefit when no investment is made in the first five years followed by direct measures 1 implemented after the fifth year and direct measures 2 implemented after the tenth year.

*Requires the configuration of damage ratios for overlapping portions. Refer to Appendix D - III for specific information on configuring damage ratios.

(2) Configuration example

For this case study, damage ratios were configured for floods and earthquakes as the applicable disasters.

The case study was configured so that hard measures 1 can prevent rank 1 damage and hard measures 2 can prevent rank 2 damage. Sliding the damage function in accordance with investment enables damage for ranks 2, 3, and 4 to also be reduced.

Soft measures are configured so that there is no human damage for floods but no benefit for earthquakes.

1) Floods

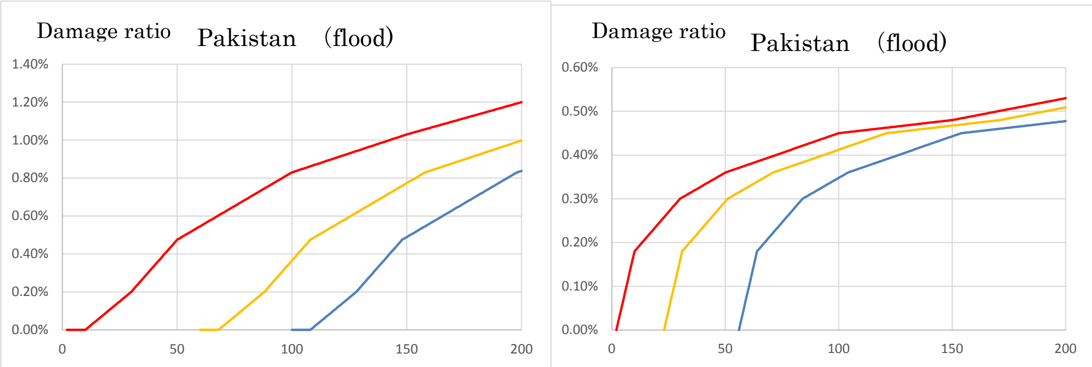


Fig. 6-2 Human damage function (left) and household damage function (right)

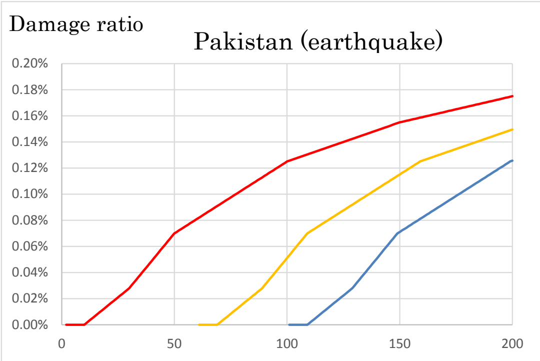
Table 6-31 Configuration results of human damage, household damage, and production facilities damage per rank (Example of floods occurring in Pakistan)

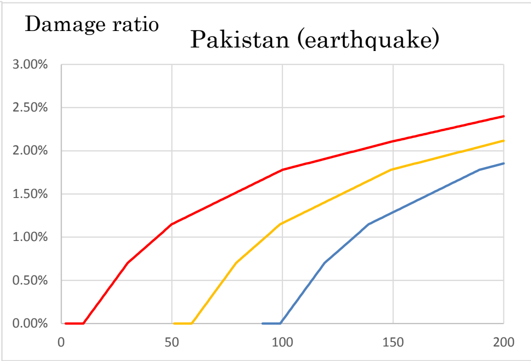
Country (disaster)	Rank	Occuring probability	Probability	Human damage			
				No measure	Soft measure	Hard measure 1	Hard measure 2
Pakistan (flood)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%
	1	46.6%	1/2～1/60	0.23%	0.00%	0.00%	0.00%
	2	1.7%	1/60～1/100	0.68%	0.00%	0.13%	0.00%
	3	1.0%	1/100～1/146	0.92%	0.00%	0.57%	0.17%
	4	0.7%	1/146～1/200	1.11%	0.00%	0.89%	0.65%

Country (disaster)	Rank	Occuring probability	Probability	Household damage			
				No measure	Soft measure	Hard measure 1	Hard measure 2
Pakistan (flood)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%
	1	46.6%	1/2～1/60	0.16%	0.16%	0.00%	0.00%
	2	1.7%	1/60～1/100	0.32%	0.32%	0.21%	0.00%
	3	1.0%	1/100～1/146	0.42%	0.42%	0.38%	0.27%
	4	0.7%	1/146～1/200	0.49%	0.49%	0.47%	0.44%

Country (disaster)	Rank	Occuring probability	Probability	Production facilities damage			
				No measure	Soft measure	Hard measure 1	Hard measure 2
Pakistan (flood)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%
	1	46.6%	1/2～1/60	0.72%	0.72%	0.00%	0.00%
	2	1.7%	1/60～1/100	1.43%	1.43%	0.92%	0.00%
	3	1.0%	1/100～1/146	1.84%	1.84%	1.67%	1.17%
	4	0.7%	1/146～1/200	2.15%	2.15%	2.08%	1.93%

2) Earthquakes





Red: No investment, Yellow: Hard measures 1, Blue: Hard measures 2

Fig. 6-3 Human damage function (left) and household damage function (right)

Table 6-32 Configuration results of human damage, household damage, and production facilities damage per rank (Example of earthquakes occurring in Pakistan)

Country (disaster)	Rank	Occuring probability	Probability	Human damage			
				No measure	Soft measure	Hard measure 1	Hard measure 2
Pakistan (earthquake)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%
	1	46.7%	1/2～1/61	0.03%	0.03%	0.00%	0.00%
	2	1.6%	1/61～1/101	0.10%	0.10%	0.02%	0.00%
	3	1.0%	1/101～1/146	0.14%	0.14%	0.08%	0.02%
	4	0.7%	1/146～1/200	0.16%	0.16%	0.13%	0.10%

Country (disaster)	Rank	Occuring probability	Probability	Household damage			
				No measure	Soft measure	Hard measure 1	Hard measure 2
Pakistan (earthquake)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%
	1	46.7%	1/2～1/61	0.53%	0.53%	0.00%	0.00%
	2	1.6%	1/61～1/101	1.41%	1.41%	0.41%	0.00%
	3	1.0%	1/101～1/146	1.87%	1.87%	1.34%	0.53%
	4	0.7%	1/146～1/200	2.23%	2.23%	1.91%	1.53%

Country (disaster)	Rank	Occuring probability	Probability	Production facilities damage			
				No measure	Soft measure	Hard measure 1	Hard measure 2
Pakistan (earthquake)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%
	1	46.7%	1/2～1/61	2.34%	2.34%	0.00%	0.00%
	2	1.6%	1/61～1/101	6.20%	6.20%	1.82%	0.00%
	3	1.0%	1/101～1/146	8.24%	8.24%	5.92%	2.34%
	4	0.7%	1/146～1/200	9.79%	9.79%	8.42%	6.75%

Appendices

APPENDIX A: RESTRICTIONS OF THIS MODEL

The DR²AD model (Ver. 1.4) has also been developed to enable stable analysis of case studies using data from various countries. The following restrictions are in place to improve stability of the DR²AD model (Ver. 1.4).

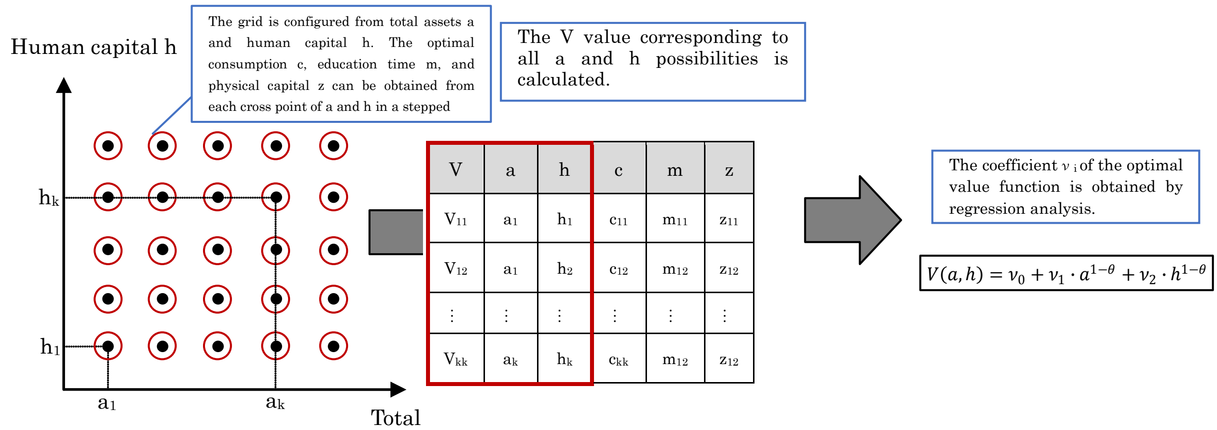
I Simplification of method to configure coefficients of optimal value functions

The following assumptions are made regarding optimal value functions in for the DR²AD model (Ver. 1.4).

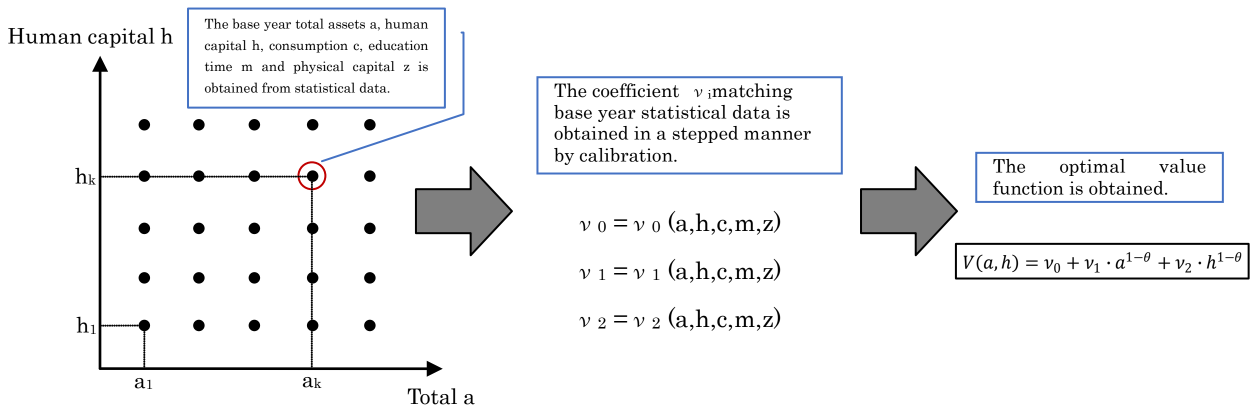
$$V(a,h) = \nu_0 + \nu_1 \cdot a^{1-\theta} + \nu_2 \cdot h^{1-\theta}$$

Note that a represents total assets, h represents human capital, and θ represents the relative risk aversion level. ν is the coefficient of the optimal value function. Originally, the coefficient of the optimal value functions is determined recursively after incorporating all combinations of variables with potential to take life. This would create a significantly complex program algorithm, and so the coefficient of the optimal value function is obtained in Ver. 1.4 by calibrating the base year data (data from specific point in time). For this reason, the program is restricted to pulling long-term economic levels into base year data.

[Original Method (The following method is the result of collocation method analysis)]



[Simplified Method (current method)]



II Incorporating approach periods into the model

The DR^{2}AD model (Ver. 1.4) is configured with an approach period of 3 years.

The DR^{2}AD model (Ver. 1.4) produces optimal asset distribution simulation results as fully reasonable behavior of representative households is assumed. On the other hand, actual statistical data contains unreasonable behavior as well, which does not represent an optimal asset distribution. For this reason, inconsistencies in asset distribution develop between initially input statistics and initial simulation results.

As a result, some cases require two to three years for initial values of unreasonable behavior to transition to reasonable behavior. Therefore, the model is configured with a 3-year approach period to eliminate these inconsistencies that occur initially (the 3-year approach period is removed from the application output graph).

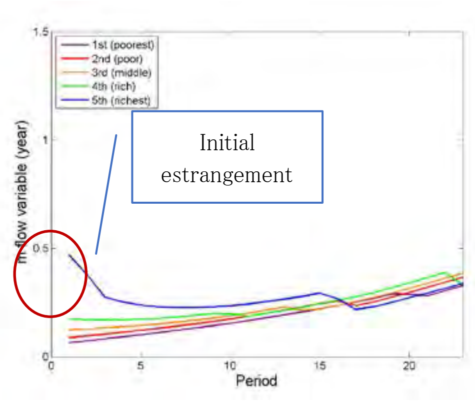


Fig. A-1 No approach period

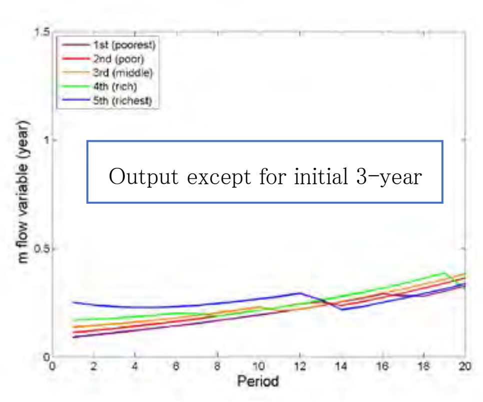


Fig. A-2 Includes approach period

In the example including the approach period as illustrated in the right figure, the total calculation period is 23 years. The graph represents the calculation results from the 4th year until the 23rd year, with the initial 3-year period removed from the output. Examples of violent behavior do not occur after the fourth year.

APPENDIX B: HOW TO SET EXOGENIOUS TECHNOLOGICAL RATE

I EXOGENIOUS TECHNOLOGICAL RATE COEFFICIENT

To better evaluate DRR investment, the technological rate coefficient B_0, which is a variable representing exogenous technological growth, is configured to match actual GDP results during years of disaster with the model GDP results.

The technological rate coefficient B_0 is configured as a correction value used to estimate GDP on the basis of the production function. This coefficient is defined as follows.

$$B_0 = \frac{\mathrm{GDP}_0}{H(0)^{\alpha_1} K(0)^{\alpha_2}\, T(0)^{\alpha_3}}$$

As a constant rate of growth that matches the rate of progress gb is assumed, the technological rate coefficient B is configured as:

$$B(t) = B_0 \cdot (1 + gb)^{t-1}$$

Ⅱ EXOGENIOUS TECHNOLOGICAL RATE

(1) How to estimate using production function residuals

TFP growth rate (hereinafter, gb) is typically estimated by using production function.

In this case study, the gb growth function was estimated using time series data for the Honduras gb. 2004 is used as the base year (the calculation period is from 2005 to 2011, which is the period usable for statistical data).

As a result, a declining gb and GDP growth trend is confirmed, and a negative regression analysis can be seen for the future.

Data	2004	2005	2006	2007	2008	2009	2010	2011
TFP rate gb								
t: Period	0	1	2	3	4	5	6	7
Y: GDP	9,120,240,790	9,672,095,584	10,307,270,097	10,945,102,350	11,408,284,210	11,130,848,997	11,546,149,370	11,989,031,445
N: Total population	6,762,426	6,898,825	7,037,428	7,178,436	7,322,368	7,469,844	7,621,204	7,776,669
H: Human stock (mean years of schooling)	33,812,130	32,424,478	33,779,654	35,174,336	37,344,077	38,843,189	41,154,502	42,771,680
K: Capital stock	19,405,645,752	21,612,568,226	24,684,226,554	27,383,427,502	26,635,781,164	24,160,164,907	25,758,669,483	27,146,308,804
T: Land stock	1,050,000	1,050,000	1,050,000	1,050,000	1,018,000	1,020,000	1,020,000	1,020,000
ω: Human damage rate	0.006	0.012	0.002	0.009	0.049	0.005	0.012	0.002
ψ: Capital damage rate	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
τ: Land damage rate	0.013	0.157	0.057	0.070	0.213	0.049	0.099	0.006
{ (1−ω) H } ^α1: Human stock share	2,636	2,579	2,640	2,681	2,703	2,809	2,875	2,939
{ (1−ψ) K } ^α2: Capital stock share	61,487	64,348	68,771	72,177	71,248	68,091	70,144	71,878
{ (1−τ) T } ^α3: Land stock share	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
B0: TFP coefficient	18.6	19.5	18.8	18.8	20.0	19.3	19.1	18.8
α1: Share parameter								
α2: Share parameter								
α3: Share parameter								
TFP rate gb		0.049	0.006	0.003	0.018	0.008	0.005	0.001

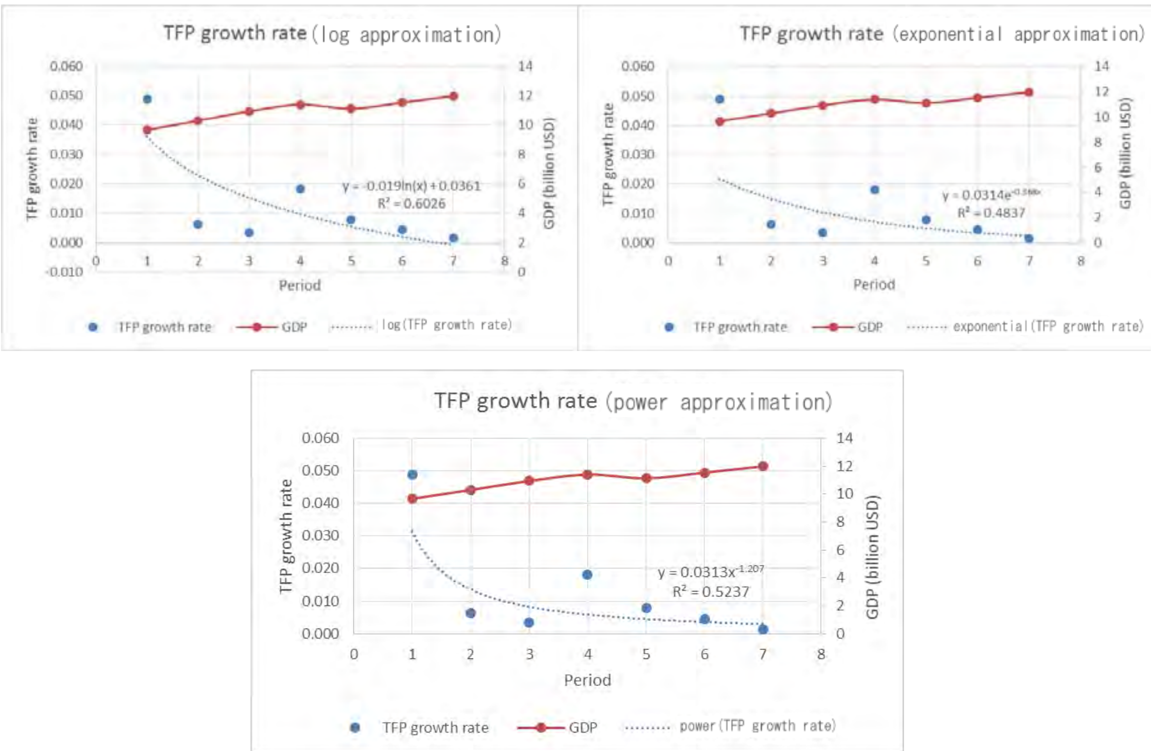


Fig. B-1 gb estimations

(2) Configuring the rate of technological progress by the GDP line

The gb can also be configured using a simplified method of aligning the GDP growth rate and the rate of technological growth to the same value.

In this case, country-specific economic disparities are affected by the size of gb, and so countries with similar economic scales can be grouped and estimated.

For this case study, five countries are grouped and configured.

As illustrated in the following figure, the average growth rate of all countries was approximately 4%, regardless of their GDP scale. All data from 1960 to 2013 for the GDP per capita and the GDP growth rate changes for the five countries under analysis are plotted on this graph. In this case study, a gb value of 4% was used.

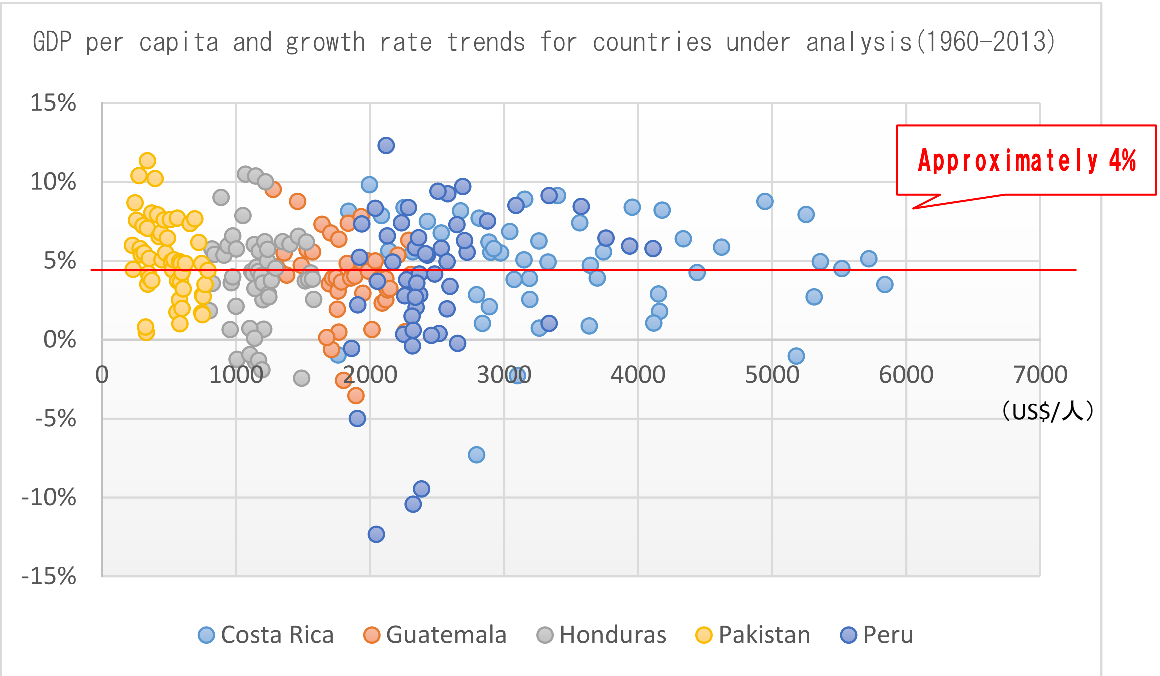
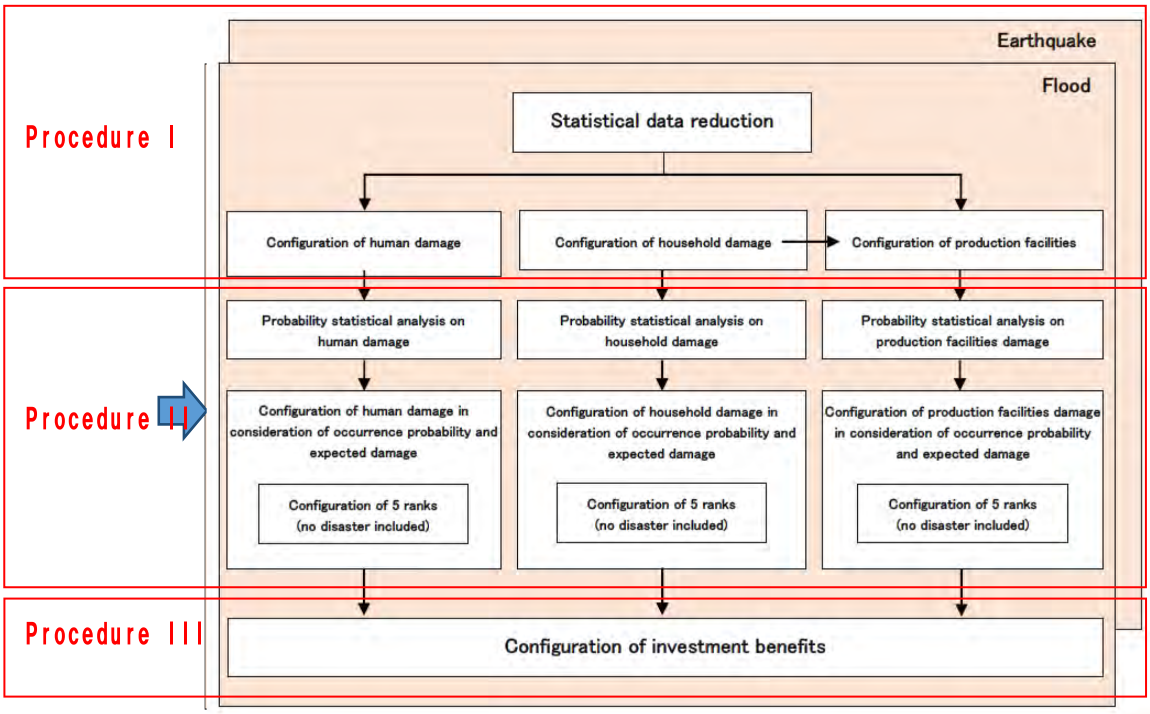


Fig. B-2 GDP per capita and growth rate trends for countries under analysis

APPENDIX C: DETERMINATION OF DISASTER PARAMETERS

This section serves as a reference for the method used to configure damage ratios for this case study. Procedures I, II, and III were conducted sequentially to configure the damage ratios per rank.

<Configuration flow>



I Configure various damage ratios

1. Earthquakes and floods were used as the disaster types.
2. The human damage ratio (1), household damage ratio (2), and production facilities damage ratio (3) were configured for each disaster type.

   *Land damage ratios are currently not supported.
3. Damage ratios per rank were configured for the following two damage ratios.

$$① \quad \mathrm{HSR} = \frac{\mathrm{HS}}{\mathrm{TPO}}$$

$$② \quad \mathrm{HDR} = \frac{DHN}{FN}$$

HSR : *Human damage ratio*
HS : *Human damage (dead, injured), etc.*
TPO : *Total population*
HDR : *Household damage ratio*
DHN : *Damaged household*
FN : *Number of households*

Required data	・Damage data：DesInventar（UNISDR） ・Population data：WDI（World Bank）etc.

3. Configure using the production facilities damage ratio and household damage ratio

3. Production facilities damage is configured as the household damage ratio times a factor of 4.4.

* A=B+C

Production facilities damage ratio = Plant damage + public facilities damage = 1+3.4+=4.4

Plant damage 1 (=1 × household damage)

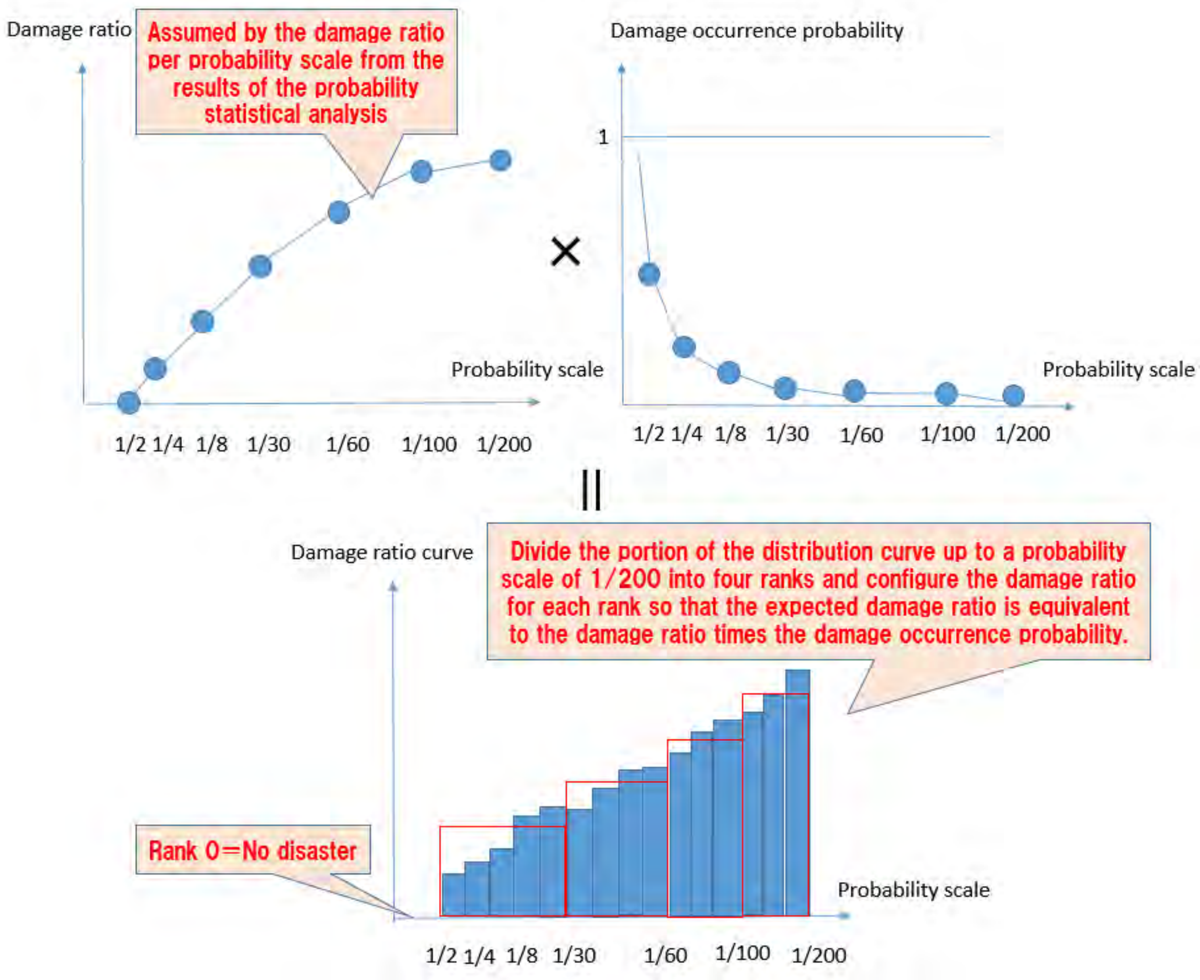
Public facilities damage 3.4 (= 1.7 × general asset damage (households+plants) = (1+1)×1.7=2×1.7

The general asset damage factor of 1.7 is taken from the calculation ratio published in the Japanese Flood Control Economy Survey Manual.

II Configuring damage ratios per rank

1. Configure the damage ratio per event on the basis of damage ratio concept A for each damage ratio per disaster type.
2. Perform probability statistical analysis on non-annual damage ratio data for each damage ratio per disaster type.
3. Graph the damage ratio distribution curve (exponential distribution) per probability scale from the results of the probability statistical analysis.
4. Divide the portion of the distribution curve up to a probability scale of 1/200 into four ranks and configure the damage ratio for each rank so that the expected damage ratio is equivalent to the damage ratio times the damage occurrence probability.

<Configuring damage ratios per rank>

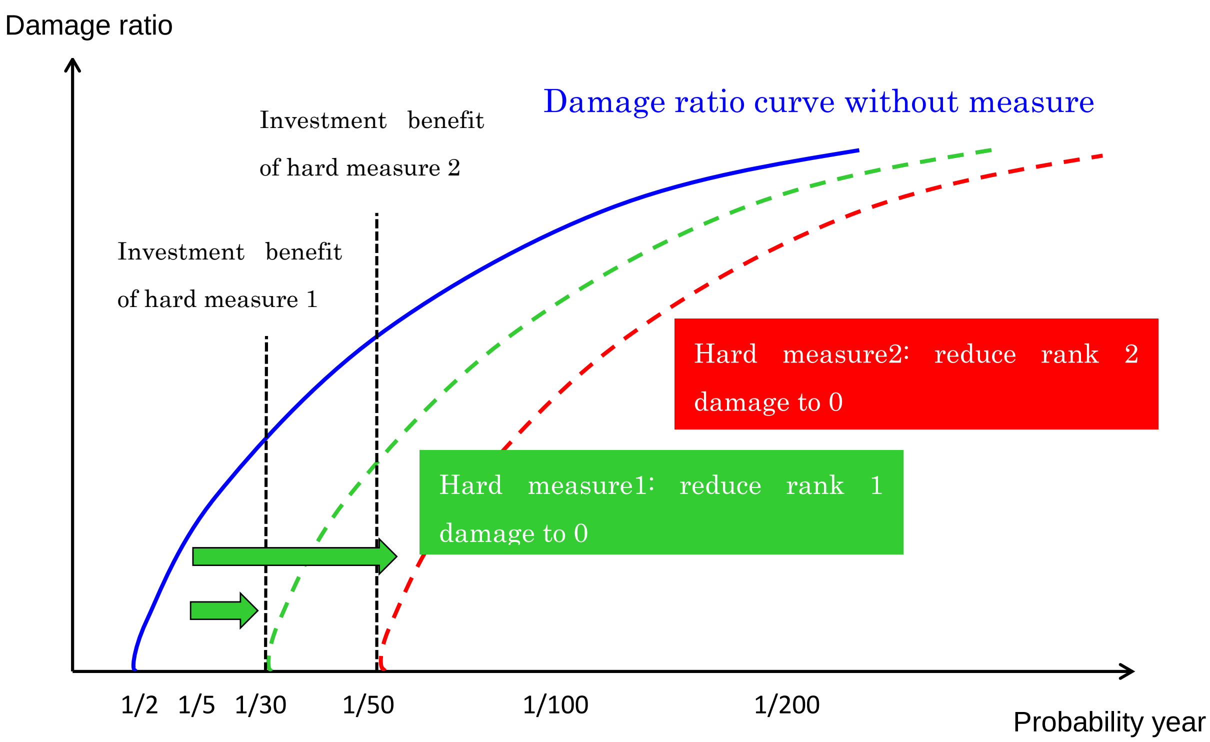


III Configuring investment benefits

Investment benefit has been configured so that soft measures prevents 100% of human damage caused by floods but has no effect on earthquakes.

The configured investment benefits of the two types of hard measures are illustrated in the following figure.

<Conceptual image of investment benefits when implementing hard measures>



<Configuring a benefit to reduce damage ratios when investment is made>

	Earthquakes		Floods	
	Soft measures	Hard measures	Soft measures	Hard measures
Human damage ratio	No benefit	Benefit of reducing rank 1 damage to "0" by sliding the damage function for no investment (Rank 2 damage is reduced to "0" by implementing hard measures 2).	100% reduction	Benefit of reducing rank 1 damage to "0" by sliding the damage function for no investment (Rank 2 damage is reduced to "0" by implementing hard measures 2).
Household damage ratio	No benefit		No benefit	
Production facilities damage ratio	No benefit		No benefit	

APPENDIX D: SAMPLE DATA SET（FIVE COUNTRIES）

The following table illustrates the sample data set (five countries) included in this build of the application.

❙ Socio-Economic Parameters

Category	Country	HONDURAS	PAKISTAN	PERU	GUATEMALA	COSTARICA
Deep Parameters	J	5	5	5	5	5
	L	4	4	4	4	4
	rho	0.12	0.12	0.12	0.12	0.12
	theta	2	2	2	2	2
	cbar	0	0	0	0	0
	deltaz	0.1	0.1	0.1	0.1	0.1
	deltak	0.02	0.02	0.02	0.02	0.02
	gb	0.042	0.042	0.042	0.042	0.042
	iota	1	1	1	1	1
Socio Economic Parameters	Pop0	6762426	155151394	27403845	12367800	4246336
	GDP0	9120240790	10170413687 9	70530831291	26352121441	18855016400
	alpha1	0.45	0.52	0.38	0.38	0.45
	alpha2	0.47	0.4	0.54	0.54	0.47
	alpha3	0.08	0.08	0.08	0.08	0.08
Household Parameters	c0	93 243 448 787 2564	208 289 369 480 924	295 583 926 1457 3777	241 545 889 1427 3820	462 1032 1613 2575 6574
	h0	3.3 4.2 5.0 6.0 6.9	3.2 3.9 4.2 4.4 5.6	8.4 8.4 8.4 8.4 8.4	3.5 3.5 3.5 3.5 3.5	7.9 7.9 7.9 7.9 7.9
	z0	112 293 540 949 3091	186 259 331 429 827	306 605 962 1513 3923	364 825 1345 2158 5779	498 1112 1738 2775 7084
	b0	321 842 1554 2732 8899	1297 1801 2306 2992 5765	1101 2176 3458 5440 14104	1277 2892 4713 7564 20256	1793 4005 6259 9993 25513
	T0	0.02 0.05 0.08 0.15 0.48	0.06 0.09 0.11 0.15 0.28	0.03 0.05 0.09 0.14 0.35	0.02 0.05 0.08 0.13 0.36	0.01 0.02 0.03 0.05 0.13
	m0	0.33	0.18	0.31	0.31	0.26
	deltah	0.004	0.005	0.005	0.005	0.005
	eta0	0	0	0	0	0
	eta1	0	0	0	0	0
	eta2M	205.8	100.9	632	310	1001.9
	eta2Mvect or	205.8 245.3 381.3 1092.6 1504.3 1918.7 5347.2 20000	100.9 120.3 187.3 536.4 651.4 820.0 2064.6 20000	555.4 632.0 665.4 1164.8 1412.9 1679.8 3860.1 20000	310.0 369.8 575.6 1653.3 2275.5 2904.4 8097.9 20000	880.3 1001.9 1056.8 1858.0 2256.9 2685.6 6183.3 20000

Ⅱ Disaster parameters

Table D-1 Input Data Sample List 1

Country(Disaster)	Rank	rate	Proba.	Damege rate of human capital				damage rate of physical asstes				Damage rate of financial assets			
				without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2
GUATE MALA (FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	43.0%	1/2～1/23	1.44%	0.00%	0.00%	0.00%	0.89%	0.89%	0.00%	0.00%	3.93%	3.93%	0.00%	0.00%
	2	4.3%	1/23～1/56	2.82%	0.00%	1.83%	0.00%	1.62%	1.62%	1.18%	0.00%	7.13%	7.13%	5.20%	0.00%
	3	1.8%	1/56～1/112	3.61%	0.00%	3.30%	2.32%	2.09%	2.09%	1.94%	1.46%	9.20%	9.20%	8.55%	6.43%
	4	0.9%	1/112～1/200	4.26%	0.00%	4.11%	3.81%	2.51%	2.51%	2.45%	2.28%	11.05%	11.05%	10.76%	10.03%
COSTA RICA (FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.5%	1/2～1/56	0.15%	0.00%	0.00%	0.00%	0.03%	0.03%	0.00%	0.00%	0.13%	0.13%	0.00%	0.00%
	2	1.8%	1/56～1/96	0.41%	0.00%	0.09%	0.00%	0.08%	0.08%	0.02%	0.00%	0.36%	0.36%	0.08%	0.00%
	3	1.0%	1/96～1/143	0.55%	0.00%	0.37%	0.12%	0.11%	0.11%	0.07%	0.02%	0.49%	0.49%	0.32%	0.11%
	4	0.7%	1/143～1/200	0.65%	0.00%	0.55%	0.42%	0.13%	0.13%	0.11%	0.08%	0.58%	0.58%	0.48%	0.37%
PAKISTAN(FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.6%	1/2～1/60	0.23%	0.00%	0.00%	0.00%	0.16%	0.16%	0.00%	0.00%	0.72%	0.72%	0.00%	0.00%
	2	1.7%	1/60～1/100	0.68%	0.00%	0.13%	0.00%	0.32%	0.32%	0.21%	0.00%	1.43%	1.43%	0.92%	0.00%
	3	1.0%	1/100～1/146	0.92%	0.00%	0.57%	0.17%	0.42%	0.42%	0.38%	0.27%	1.84%	1.84%	1.67%	1.17%
	4	0.7%	1/146～1/200	1.11%	0.00%	0.89%	0.65%	0.49%	0.49%	0.47%	0.44%	2.15%	2.15%	2.08%	1.93%
PERU(FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.0%	1/2～1/48	0.19%	0.00%	0.00%	0.00%	0.03%	0.03%	0.00%	0.00%	0.15%	0.15%	0.00%	0.00%
	2	2.1%	1/48～1/87	0.49%	0.00%	0.16%	0.00%	0.07%	0.07%	0.04%	0.00%	0.30%	0.30%	0.19%	0.00%
	3	1.1%	1/87～1/136	0.64%	0.00%	0.48%	0.21%	0.09%	0.09%	0.08%	0.05%	0.38%	0.38%	0.35%	0.24%
	4	0.7%	1/136～1/200	0.75%	0.00%	0.66%	0.55%	0.10%	0.10%	0.10%	0.09%	0.46%	0.46%	0.44%	0.40%
HONDURAS(FLOOD)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.4%	1/2～1/54	11.00%	0.00%	0.00%	0.00%	0.02%	0.02%	0.00%	0.00%	0.08%	0.08%	0.00%	0.00%
	2	1.9%	1/54～1/94	29.82%	0.00%	7.81%	0.00%	0.05%	0.05%	0.02%	0.00%	0.21%	0.21%	0.07%	0.00%
	3	1.1%	1/94～1/142	40.06%	0.00%	27.34%	9.97%	0.06%	0.06%	0.05%	0.02%	0.28%	0.28%	0.21%	0.09%
	4	0.7%	1/142～1/200	47.50%	0.00%	40.22%	31.32%	0.07%	0.07%	0.07%	0.05%	0.33%	0.33%	0.29%	0.24%

Table D-2 Input Data Sample List 2

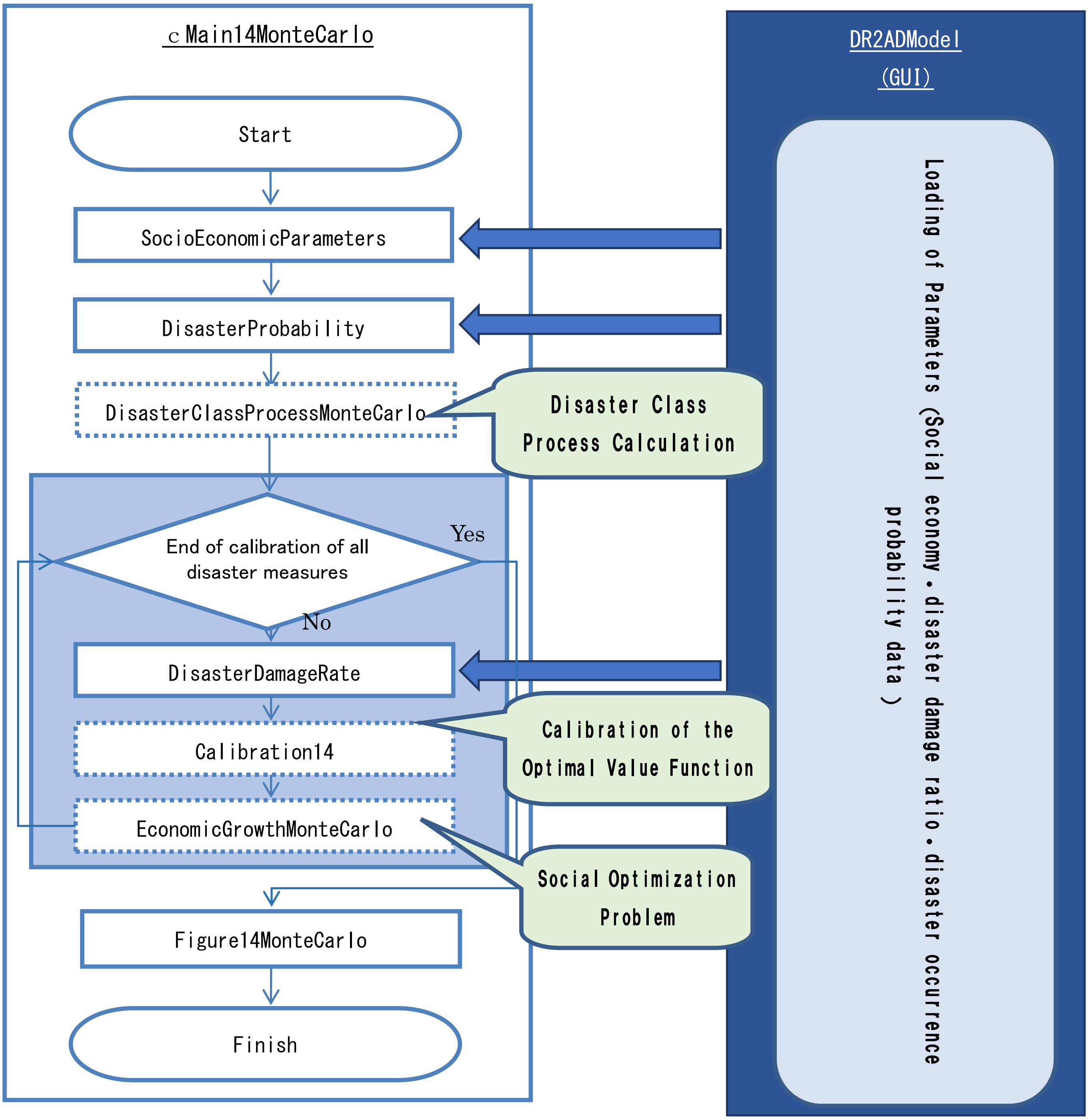
Country(Disaster)	Rank	rate	Proba.	Damege rate of human capital				damage rate of physical asstes				Damage rate of financial assets			
				without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2	without DRR	soft	hard1	hard2
GUATE MALA (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	45.7%	1/2～1/43	0.19%	0.19%	0.00%	0.00%	0.31%	0.31%	0.00%	0.00%	1.35%	1.35%	0.00%	0.00%
	2	2.3%	1/43～1/82	0.48%	0.48%	0.18%	0.00%	0.78%	0.78%	0.25%	0.00%	3.43%	3.43%	1.09%	0.00%
	3	1.2%	1/82～1/133	0.63%	0.63%	0.50%	0.24%	1.03%	1.03%	0.75%	0.32%	4.51%	4.51%	3.32%	1.41%
	4	0.8%	1/133～1/200	0.75%	0.75%	0.67%	0.57%	1.21%	1.21%	1.06%	0.87%	5.33%	5.33%	4.67%	3.82%
COSTA RICA (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.4%	1/2～1/54	0.46%	0.46%	0.00%	0.00%	0.44%	0.44%	0.00%	0.00%	1.95%	1.95%	0.00%	0.00%
	2	1.9%	1/54～1/95	1.29%	1.29%	0.33%	0.00%	1.18%	1.18%	0.34%	0.00%	5.20%	5.20%	1.51%	0.00%
	3	1.1%	1/95～1/142	1.72%	1.72%	1.18%	0.40%	1.58%	1.58%	1.13%	0.44%	6.95%	6.95%	4.96%	1.95%
	4	0.7%	1/142～1/200	2.05%	2.05%	1.72%	1.33%	1.87%	1.87%	1.61%	1.29%	8.21%	8.21%	7.10%	5.67%
PAKISTAN (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.7%	1/2～1/61	0.03%	0.03%	0.00%	0.00%	0.53%	0.53%	0.00%	0.00%	2.34%	2.34%	0.00%	0.00%
	2	1.6%	1/61～1/101	0.10%	0.10%	0.02%	0.00%	1.41%	1.41%	0.41%	0.00%	6.20%	6.20%	1.82%	0.00%
	3	1.0%	1/101～1/146	0.14%	0.14%	0.08%	0.02%	1.87%	1.87%	1.34%	0.53%	8.24%	8.24%	5.92%	2.34%
	4	0.7%	1/146～1/200	0.16%	0.16%	0.13%	0.10%	2.23%	2.23%	1.91%	1.53%	9.79%	9.79%	8.42%	6.75%
PERU (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	45.4%	1/2～1/39	0.54%	0.54%	0.00%	0.00%	0.63%	0.63%	0.00%	0.00%	2.79%	2.79%	0.00%	0.00%
	2	2.6%	1/39～1/77	1.32%	1.32%	0.55%	0.00%	1.60%	1.60%	0.51%	0.00%	7.03%	7.03%	2.22%	0.00%
	3	1.3%	1/77～1/128	1.75%	1.75%	1.40%	0.71%	2.06%	2.06%	1.56%	0.69%	9.04%	9.04%	6.87%	3.05%
	4	0.8%	1/128～1/200	1.99%	1.99%	1.86%	1.64%	2.42%	2.42%	2.14%	1.80%	10.63%	10.63%	9.40%	7.90%
HONDURAS (EARTHQUAKE)	0	50.0%	～1/2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	1	46.8%	1/2～1/64	0.03%	0.03%	0.00%	0.00%	0.13%	0.13%	0.00%	0.00%	0.59%	0.59%	0.00%	0.00%
	2	1.6%	1/64～1/104	0.09%	0.09%	0.01%	0.00%	0.37%	0.37%	0.09%	0.00%	1.64%	1.64%	0.40%	0.00%
	3	1.0%	1/104～1/149	0.12%	0.12%	0.07%	0.02%	0.50%	0.50%	0.34%	0.12%	2.20%	2.20%	1.48%	0.52%
	4	0.7%	1/149～1/200	0.15%	0.15%	0.12%	0.08%	0.60%	0.60%	0.50%	0.39%	2.62%	2.62%	2.20%	1.70%

APPENDIX E: PROGRAMING ALGORITHM FLOW

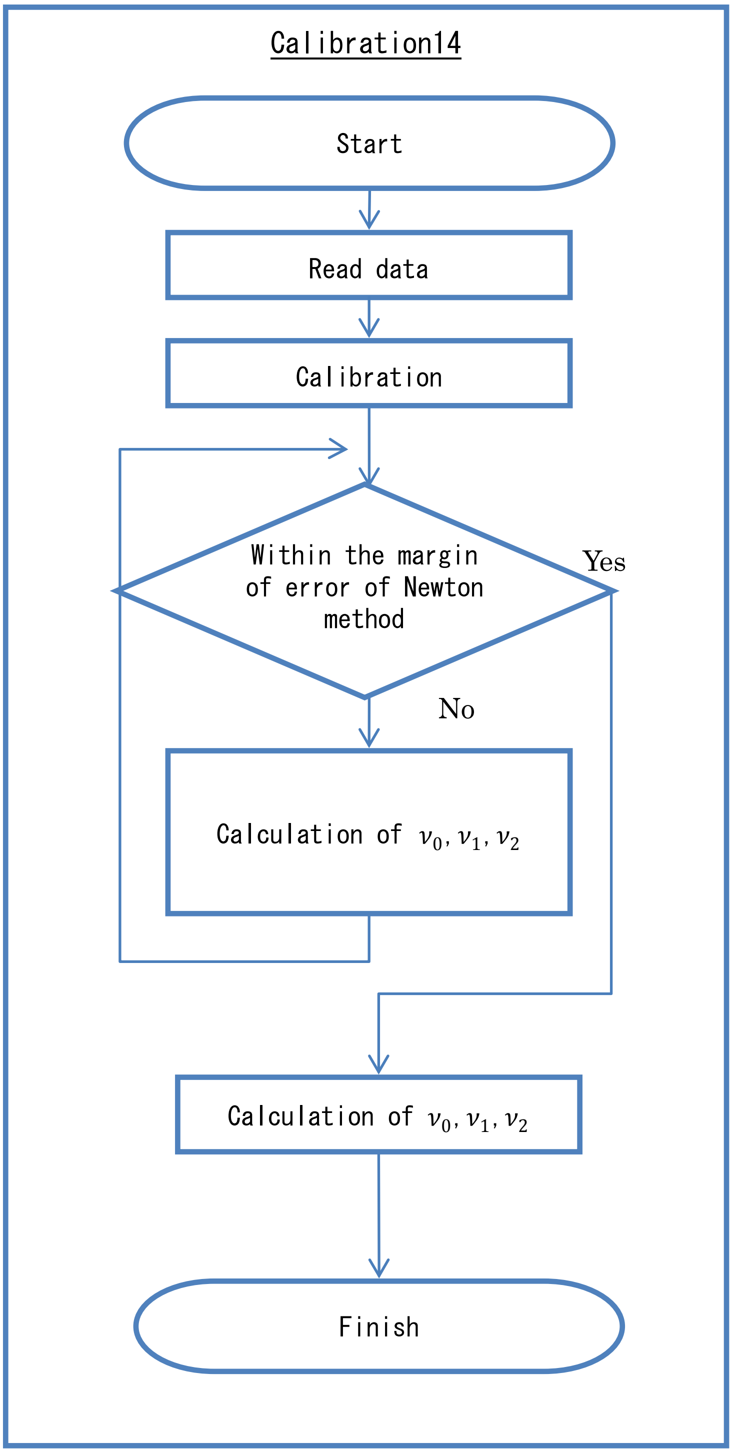
The programs constructed above were performed in accordance with the following calculation algorithms.

The program algorithms are as follows.

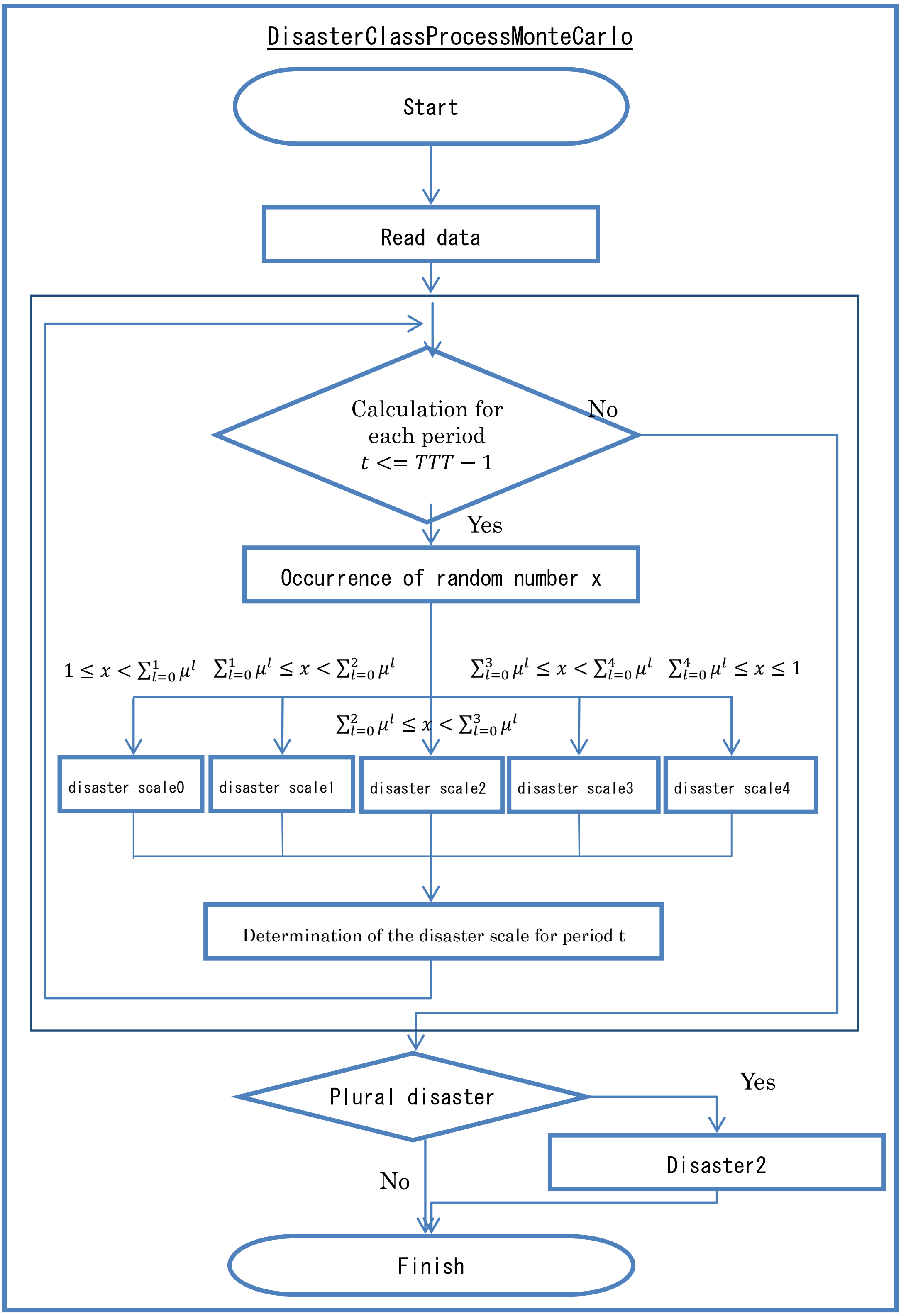
Ⅰ Overall Calculation Algorithm for the Program



II Calibration Calculation Algorithm



Ⅲ Disaster Class Process Calculation Algorithm



Ⅳ Economic Growth Calculation Algorithm