A Proposal to link Disaster Risk Reduction to Sustainable Development

DR^2AD Model VERSION 1.0

Disaster Risk Reduction investments Accounts for Development

Japan International Cooperation Agency

Contents

1. Background *1*

2. Outline of the Model *2*

2.1 Assumption 3

2.2 Model structure 3

2.3 Basic features 5

2.4 Model Outputs 7

2.5 Valuables 7

3. Verification of the Model *7*

3.1 Pakistan case study 7

3.2 Conclusion 10

4. Limitation and upgrading of the Model VERSION 1.0 ..... *11*

The DR^{2}AD Team, Contributors *13*

1. Background

It has been long said that disasters and development are co-related in a sense that both mortality and economic loss risk are heavily concentrated in developing countries and within these countries disasters disproportionately affect the poor, and that it's impacts have persistent, long-term negative impacts on poverty and human development that undermine the achievement of the Millennium Development Goals (MDGs)[1]. It has also been repeated that once a disaster occurs, the achievements of long-term development efforts may disappear in an instant[2], and that preventive measures against disasters are highly cost efficient[3].

On the other hand, global framework on disasters (Hyogo Framework for Action) and on development (MDGs) both targeted at 2015, are formulated without sufficiently taking into account the co-relation of the two issues. For example, there is not one reference to disasters in the present MDGs framework. JICA considers this gap as one of the bottle necks that prevents integration of disaster risk reduction into all development policy and investments programs. As the global community gear-up consideration of the next generation of the disaster framework (HFA2) and development framework (Post-2015 Development Agenda), a compelling narrative, backed by evidence based research that demonstrates the contribution of DRR investments into sustainable development[4] to bridge this gap is strongly called on.

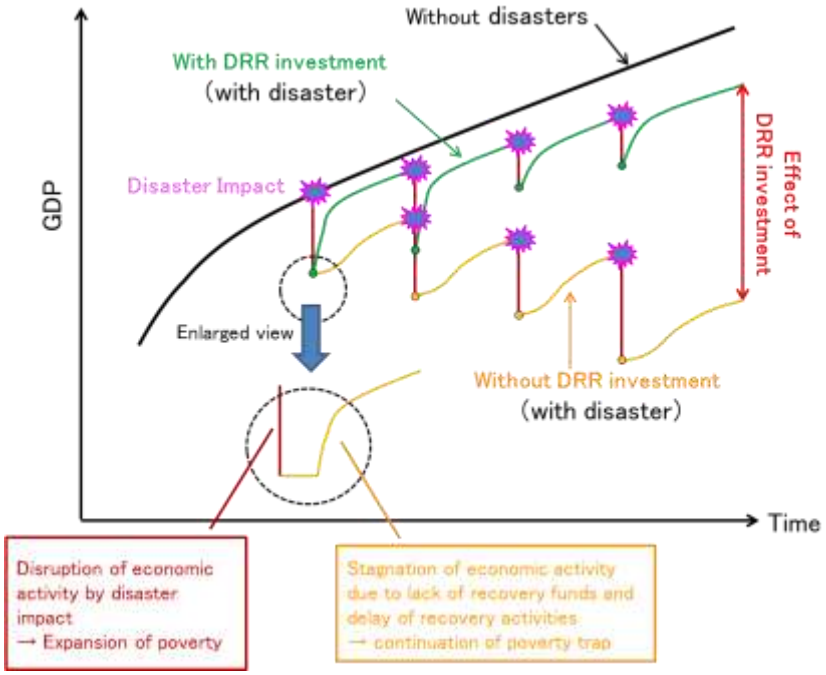


Figure 1.1 Image of verification model of DRR investment effect and its evaluation results (output A)

[1] *2009 Global Assessment Report on Disaster Risk Reduction* (GAR2009) (UNISDR, 2009)
[2] *Sendai Statement on Mainstreaming Disaster Risk Management for Sustainable Development* (Joint Statement by the Minister of Finance of Japan, Koriki Jojima and the World Bank President, Dr. Jim Yonog Kim (October 20, 2012, Sendai, Japan))
[3] *Natural Hazards, Unnatural Disasters The Economics of Effective Prevention* (The United Nations and the World Bank, 2009)
[4] *Key Conclusions: Global Thematic Consultation on Disaster Risk Reduction and the Post-2015 Development Agenda* (19-20, February, 2013, Jakarta, Indonesia)

Against this backdrop, together with a team of consultants and academia, JICA has developed a **Dynamic Stochastic General Equilibrium (DSGE) model to simulate impacts on 1) economic growth under long-term disaster risk with or without DRR investment, and on 2) the Gini coefficient in consequence of DRR investment.** The purpose of this model is to quantitatively demonstrate that DRR investment is essential to achieve sustainable development, and to make a compelling explanation that there is definite co-relation between DRR and sustainable development.

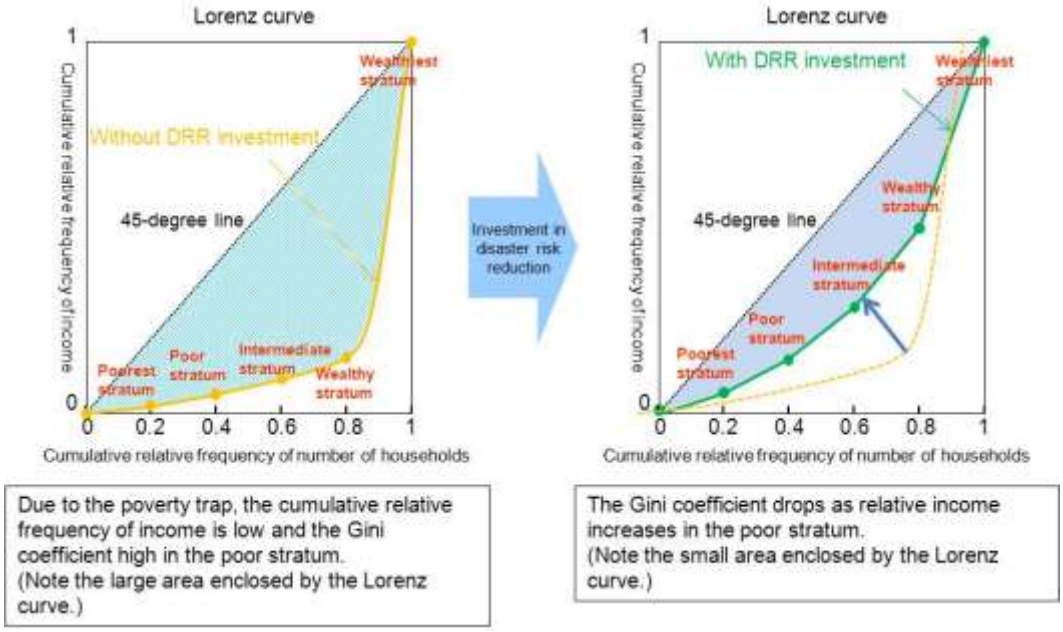


Figure 1.2 Image of verification model of DRR investment effect and its evaluation results (output B)

2. Outline of the Model

The model is named DR^{2}AD Model (hereinafter referred as DR^{2}AD: /di: **ræd/)**, which stands for "Disaster Risk Reduction investment Accounts for Development", with hope that this Model can bridge the aforementioned gap and contribute to the discussions of both the HFA2 and the Post-2015 Development Agenda.

By quantitatively evaluating the processes of economic growth with and without DRR investments, DR^{2}AD enables analysis to identify the best mix of various DRR countermeasures. The analysis will be made by describing differences in the effect of various DRR countermeasures, such as structural measures, non-structural measures, and their combination. For example, damages to properties and human lives are generally mitigated by structural measures, while non-structural measures only counts for mortality and is not to protecting properties, etc. This would enable rational consideration in making decision on DRR investments and the best mix of DRR countermeasures.

Impacts of disaster vary among income classes. DR^{2}AD describes not only the impact on macro-economic growth, but also the impact on various income groups including disaster-triggered poverty trap at household level. If disasters hit low income household and throws them into an economic level of near subsistence constraint, they cannot

choose but to decrease time of their children's schooling and have them work for a living, which will result in locking them at low level of human capital and high level of vulnerability. Disaster intrinsically brings more severe damage to lower income people, and therefore, it turns out that DRR investment is more beneficial for the poorer and more vulnerable people.

Followings are some features that outline DR^{2}AD;

2.1 Assumption

- People understand disaster risks and make rational decision on savings and human capital formation (education)
- Household is divided into five income groups, i.e. wealthiest, wealthy, middle, poor, and poorest.

2.2 Model structure

- The following 2 figures show the assumptions of DR^{2}AD on disasters' impact on economic growth.

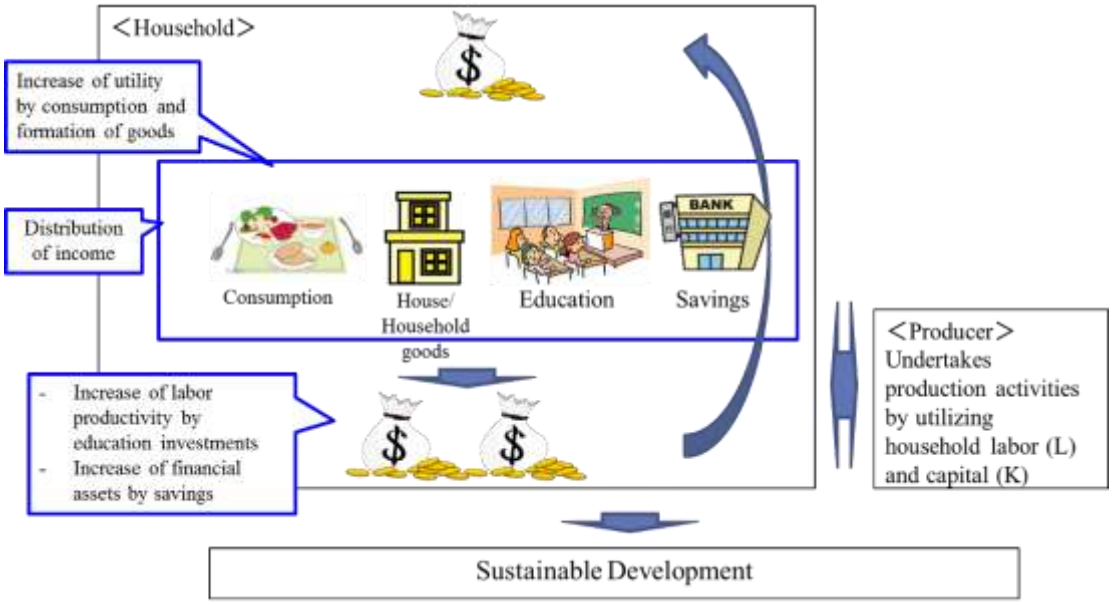


Figure2.1 Structure of DR^{2}AD without disaster (image)

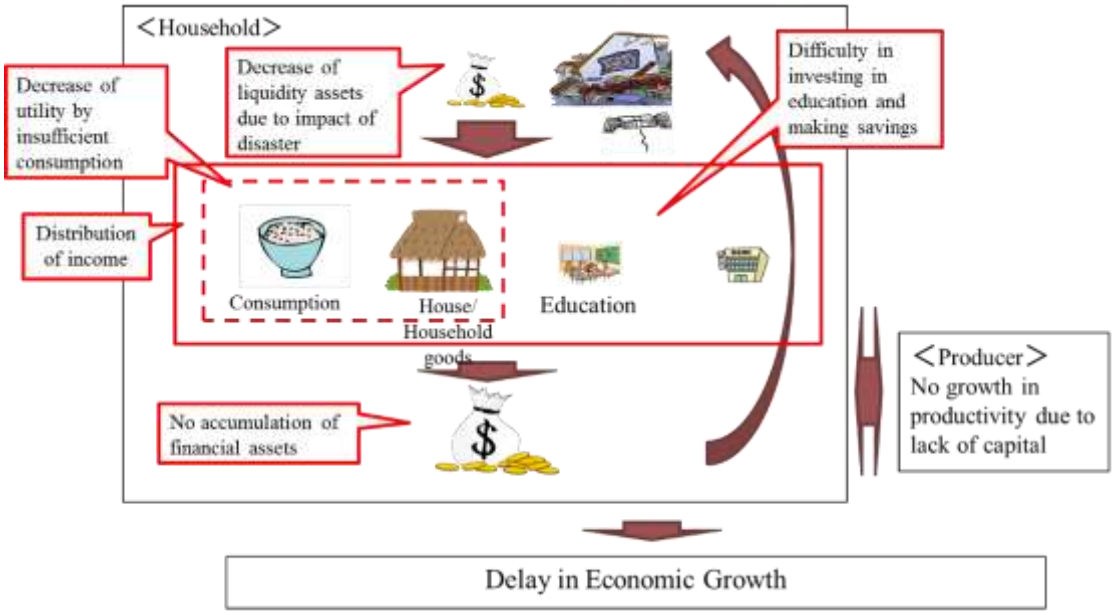


Figure 2.2 Structure of DR^{2}AD with disaster (image)

- General structure of DR^{2}AD and relation of elements is summarized as follows. The equilibrium is established between the household activity and enterprise activity, which determines household consumption and investment. Household provides labor and capital to producer's demands.

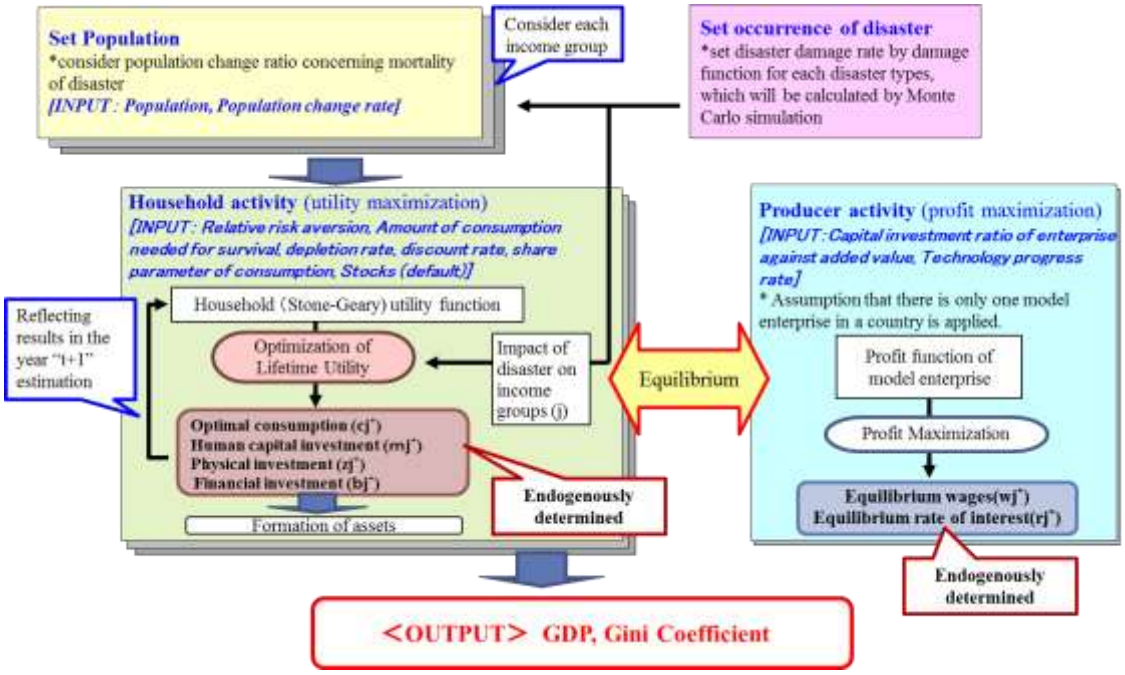


Figure 2.3 Overall DR^{2}AD Structure

2.3 Basic features

- Disaster impacts Labor (L) and Capital (K) respectively, thus it is possible to express economic growth incorporating the impact of disasters.

<Production Function>

$$Y(t) = B(t) \cdot H(t)^{\alpha} \cdot K(t)^{1-\alpha}$$

- Affected population rate
- Mortality rate
- Property loss rate
- Financial loss rate

H(t) : Human Capital Stock
K(t) : Financial Capital Stock
B(t) : Exogenous Technology Progress

- DR^{2}AD sets utility function for each income class, considering the minimum consumption amount needed for survival. By introducing this Stone-Geary Utility Function into Ramsey Economic Growth Model, demonstrating a way to escape from the so called "poverty trap" is possible.

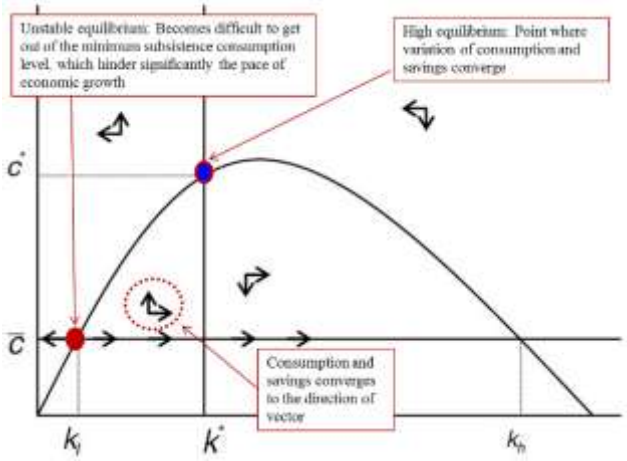


Figure2.4 General conceptual phase diagram expressing the relation between consumption and investment considering the minimum subsistence consumption level $\bar{c}$ [5]

Introduced "amount of consumption needed for survival" to express escape from poverty trap.

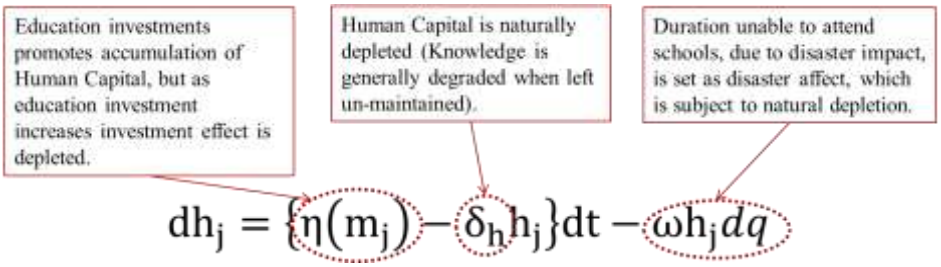
Included house/household goods (z_j) which might be affected by disasters

$$u(c_j, z_j) = \frac{\left\{(c_j - \bar{c})^{\gamma} z_j^{1-\gamma}\right\}^{1-\theta} - 1}{1-\theta}$$

[5] Kraay, Aart and Claudio Raddatz (2007) "*Poverty traps, aid, and Growth"* Journal of Development Economics 82 (2), 315-347.

c_j: consumer goods (nondurable)
z_j: house/household goods (physical assets)
θ: relative risk aversion
$\bar{c}$: minimum subsistence consumption amount (minimum consumption level)
γ : share parameter for consumption

- DR^{2}AD expresses the case that human capital investment negatively affected by disaster, will have long term effect on economic growth and poverty reduction. Human capital formation is assumed as follows:
  a) Investment in education → b) Improved school enrollment rate →
  c) Improved labor productivity → d) Improved income



δ_h : depletion rate (δ: delta), $\eta'(m_j)>0$, $\eta''(m_j)\leq 0$
ω_j : disaster affected population rate
h_j : human capital
m_j : human capital investment (education, etc.)

- DR^{2}AD considers liquidity restriction, which reflects that the poor income group will be restricted access to recovery loan (liquidity) after being impacted by disaster. By considering liquidity restriction, disaster impact will cause reducing or cutting human capital investment. This will push the poor group into a more difficult situation of escaping the poverty trap, forcing them to limit their investment.

$$(0 \leq)\ z_j + c_j + m_j \leq rb_j + wh_j$$

(physical capital investment + consumption + human capital investment) ≦(income of the period)

- In order to incorporate characteristics of disaster and its impact to each income class, human capital, property, and financial damage, and well as death rate by income class can be the input data. DR^{2}AD sets damage function based on the presence/absence of disaster risk reduction measures from the record of disasters by utilizing the international disaster database, EM-DAT of the Centre for Research on the Epidemiology of Disasters (CRED).

Financial loss rate (ψ) = Amount of damage / National savings
*Due to lack of data, Property loss rate (φ) is set as the same ratio as (ψ).
Affected population rate (ω) = Affected population / Total population
Mortality rate (ζ) = Mortality / Total population

2.4 Model Outputs

- Macro-economic growth (GDP) with and without DRR investment.
- Impact of disasters on various income groups and the shadow effect of DRR investment over income groups (Gini coefficient) at the micro-level.

2.5 Valuables

Variables		Input Data	Output Data
Household data			
c_j	Consumer goods (nondurable)		○
z_j	House / household goods (physical assets)	○	○
θ	Relative risk aversion	○	
$\bar{c}$	Minimum subsistence consumption amount (minimum consumption level)	○	
b_j	Financial savings (financial investment)	○	○
ξ_j	Investment for house / household goods		○
h_j	Human capital	○	○
m_j	Human capital investment		○
δ_h	Depletion rate of human capital	○	
w	Wage rate (per human capital)		○
η_j	Human capital formation		○
γ	Share parameter of consumption	○	
Disaster data			
q	Total of disaster	○	
ς_j	Mortality rate		○
ω_j	Disaster affected population rate		○
ϕ_j	Property loss rate		○
ψ_j	Financial loss rate		○
Macro-economic data			
n_j	Population (household)	○	○
σ	Population change rate	○	
ρ	Discount rate	○	
δ_k	Depreciation rate of financial capital stock	○	
r	Rental rate		○
B	Growth rate of exogenous technological change	○	
α	Labor relative share	○	
Real GDP			○
Gini Coefficient			○
Benefit			○

3. Verification of the Model

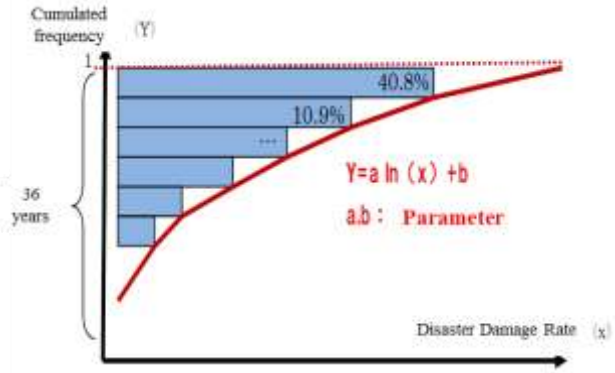
3.1 Pakistan case study

JICA have applied the case of Pakistan to verify DR^{2}AD. The reason that Pakistan case was applied is as follows:

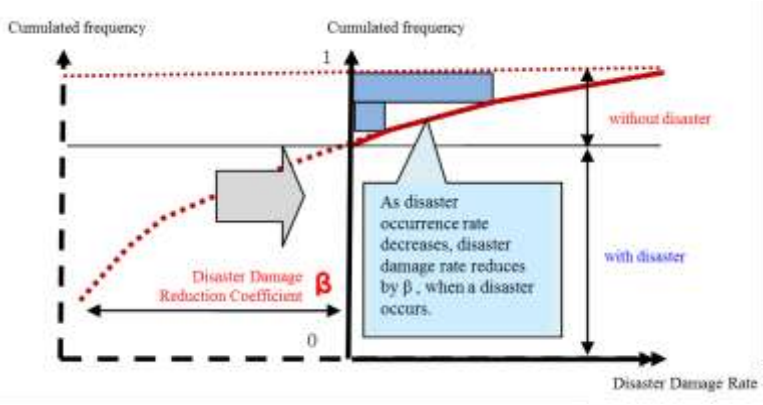
- Pakistan is vulnerable to natural disasters and has experienced major earthquakes and flood impact in the recent years.

- Statistical data, including those according to income class is well existing[6].
- UNISDR and UNESCAP have presented variations of Pakistan's actual observed GDP and projected GDP without disaster for the period 2004-2011[7], thus comparative verification was possible.

Disaster damage rate was set taking the data of 1976-2011 (36 years) from EM-DAT for earthquake, flood, and storm.



Since there was data limitation on the cost-benefits of DRR investments, "disaster damage reduction coefficient (β)" was applied to estimate the benefits of DRR investment reducing by half the largest disaster damage rate in the past 36 years.



Monte Carlo simulation was used to estimate future disasters and to analyze changes in economic growth (GDP) and social gap (Gini coefficient) with and without DRR investment for the period from 2005 to 2042 (38 years). The outputs are as follows:

[6] *World Databank* (World Bank)
Household Integrated Economic Survey (Federal Bureau of Statistics, Government of Pakistan, Islamabad)
Pakistan Economic Survey (Finance Division, Government of Pakistan)
Pakistan Millennium Development Goals Report (Government of Pakistan, 2010)
Poverty Profile Islamic Republic of Pakistan (Japan Bank for International Cooperation, 2007)

[7] *Reducing Vulnerability and Exposure to Disasters* (UNESCAP and UNISDR, 2012)

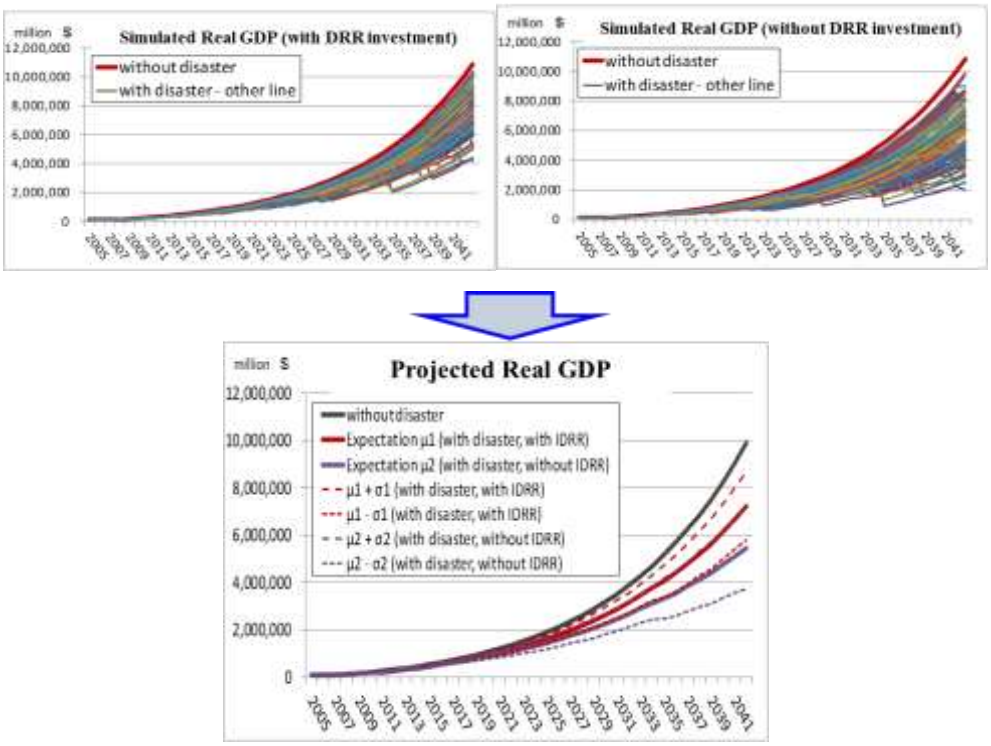


Figure 3.1 [OUTPUT 1] Expected GDP when DRR investment is made is about 25% higher in 2042 than that without investment in disaster risk reduction.

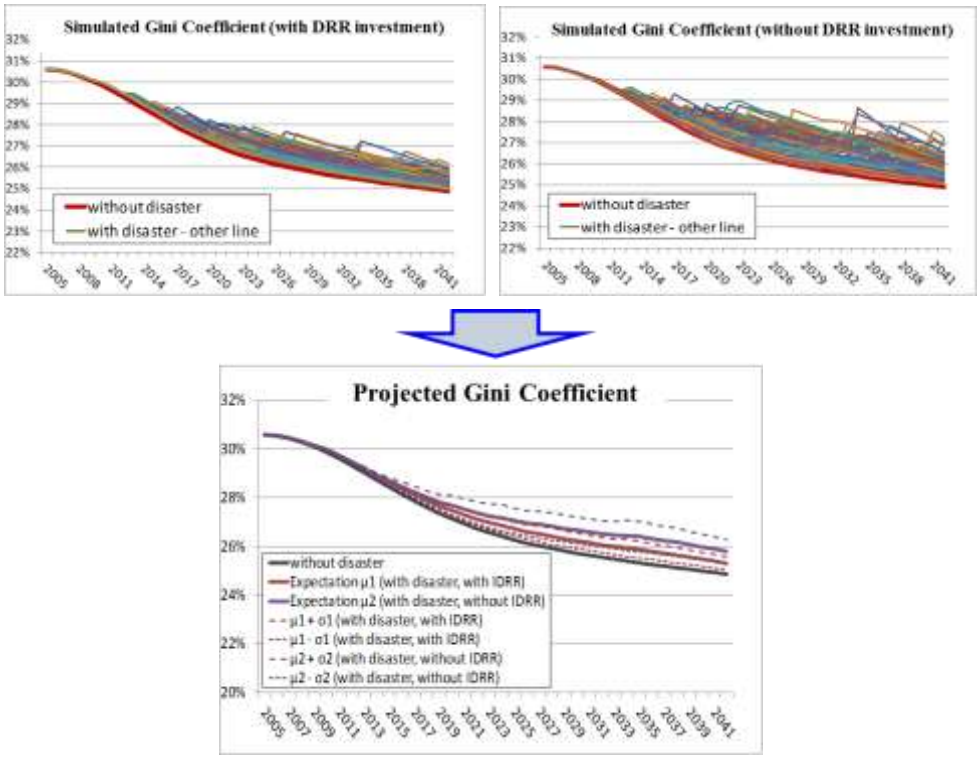


Figure 3.2 [OUTPUT 2] In case DRR investment is made, the Gini coefficient for 30 years starting from 2012 tends to improve relative to cases without DRR investment. Calculation shows about 0.5% improvement in the year 2042, thereby confirming that investment can reduce social disparities and have a positive effect on reducing poverty.

3.2 Conclusion

From these two outputs, it has been confirmed that DR^{2}AD is applicable to the case of Pakistan. Through this exercise, following conclusions have been drawn out:

- **In case DRR investment is ensured, approximately 25% more economic growth (real GDP) is projected at the year 2042 compared to the case without DRR investment.** This result suggests objectively with tangible theoretical backbone that making DRR investments to reduce the impact of disaster definitely contributes and ensures sustainable development. Additionally, it was observed from the result of Monte Carlo simulation, that without DRR investment, variability increased for the future projection of GDP.

- **As for the Gini coefficient, a measure of statistical dispersion which measures social inequality, in case DRR investment is ensured, approximately 0.5% lower figure is observed at the year 2042 compared to the case without DRR investment.** It can be said that disaster impact intensifies social disparity; however, with DRR investment before such impact, disaster damage rate can be reduced, and social disparity held down, which leads to social stability. At the micro level, this suggests that DRR investment can contribute to the escape from the "poverty trap". Additionally, it was observed from the result of Monte Carlo simulation, that without DRR investment, variability increased for the future projection of Gini Coefficient.

It has been long said that disasters and development are co-related; however, convincing evidence to support this co-relation has not been offered, which is one of the bottle-necks that prevents integration of DRR consideration into all development policy and investment. Against this situation, **DR^{2}AD is expected to be a solution that provides a compelling narrative and objective evidence that demonstrates the co-relation between disaster and development, more specifically, that DRR investment contributes to sustainable development**.

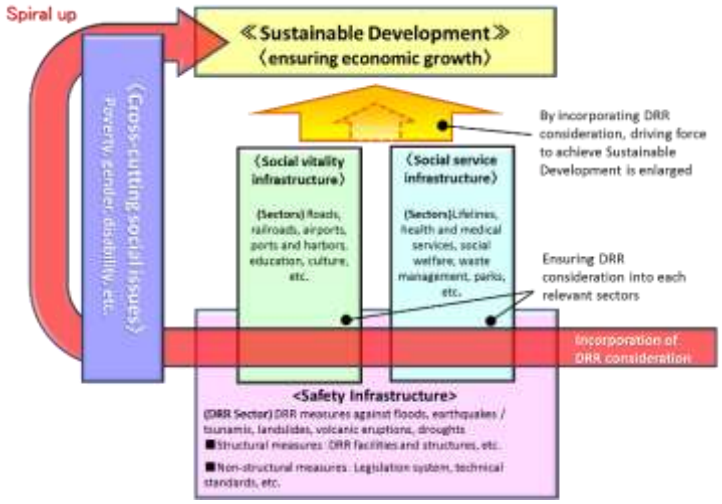


Figure 3.3 Image of co-relation between DRR and sustainable development

4. Limitation and upgrading of the Model VERSION 1.0

DR^{2}AD is an economic model framework that expresses the co-relation between DRR investment and economic growth (sustainable development) not only at the macro-economic level, but also by each income groups and interaction between households and enterprises; however, it should be noted that this framework is developed as VERSION 1.0, and is subjected to improvements and detailed configurations with incorporated expandability of the model. JICA will continue to upgrade the DR^{2}AD VERSION 1.0 to fill-in the limitation that it faces, and at the same time, intends to release and make it an open source, so that everyone who finds this framework useful, can contibute to improving and upgrading the model according to their interests. JICA is preparing to upload DR^{2}AD VERSION 1.0 application to an open website by the end of this year to be utilized by all those interested.

Figure 4.1 Image of DR^{2}AD application to be uploaded in website.

One of the critical limitations that DR^{2}AD VERSION 1.0 inherits is the lack of disaster-related data that exists to fully run the model. Even in the case of Pakistan where statistical data was well in place, there were a number of simplification and presumption made to complete verification. There needs to be further enhancement of data acquisition efforts to track impacts of disasters, especially the data at the micro level.

Another limitation that DR^{2}AD VERSION 1.0 that encounter is the fact that due to time constraints, verification was undertaken using just the case of Pakistan. There needs to be more country cases to be calibrated with this DR^{2}AD VERSION 1.0 to further review its sensitivity as well as to improve and expand applicability.

There are a number of points already listed to be improved from the upgraded version of DR^{2}AD VERSION 1.0.

- Since disaster damage rate impacts the fluctuation of GDP, there needs to be further refinement of the disaster damage rate. A way forward is to set disaster damage rate according to the characteristic and type of disaster. This requires accumulating data on frequency and magnitude of disasters by types, such as damage amount by industrial sectors (primary, secondary, and tertiary) and on household assets.

Difference of recovery period according to types of disasters also needs to be incorporated.

- DR^{2}AD VERSION 1.0 does not provide answer to the question on the amount of DRR investment and its co-relation with the extent such investment reduces disaster damage rate. Rather, DR^{2}AD VERSION 1.0 suggests that DRR investment (with the assumption that DRR investment brings in certain reduction on disaster damage rate) does actually contribute to sustainable development. In order for the DR^{2}AD to serve further as convincing and usable tool for policy makers in actually making decision on how much DRR investment to make, there needs to be further refinement of disaster damage rate with DRR investment compared to without DRR investment.
- In case of DR^{2}AD VERSION 1.0, data on the disaster damage rate by each income group was not available so it was set as to impact all income groups at the same magnitude. Actual disasters impact more the poorer and vulnerable income groups, thus there needs to be varying disaster damage rate set by each income groups to reflect this reality.
- Disaster impact varies not only on income groups within countries, but also between countries and regions according to its characteristics, which is represented by industrial structure of countries and regions, and thus, it is important to reflect the economic activity and the impact of disasters on such activity appropriately. DR^{2}AD VERSION 1.0 featured the household factor to express economic growth, and the enterprise factor was simplified into a one-country-one-enterprise model. Subdividing the industrial sector into primary industry, secondary industry, and tertiary industry to reflect the structural characteristics should be considered in upgrading DR^{2}AD.

The DR^{2}AD Team:

Assoc. Prof. Muneta Yokomatsu, Kyoto University
Dr. Katsumi Wakigawa, Japan Institute of Country-ology and Engineering
Tetsuya Okayasu, Japan Institute of Country-ology and Engineering
Toshihiro Sonoda, Japan Institute of Country-ology and Engineering
Masato Okabe, Japan Institute of Country-ology and Engineering
Hiroyuki Wada, Pacific Consultants Co., Ltd.
Hiroyuki Takamatsu, Pacific Consultants, Co., Ltd.
Hiroaki Ishiwata, Pacific Consultants, Co., Ltd.
Kimio Takeya, Japan International Cooperation Agency
Yusuke Amano, Japan International Cooperation Agency
Noriaki Nagatomo, Japan International Cooperation Agency
Junko Mimaki, Japan International Cooperation Agency

Contributors

Dr. Satoru Nishikawa, Japan Water Agency
Prof. Yasuyuki Sawada, University of Tokyo
Prof. Fumihiko Imamura, Tohoku University
Prof. Rajib Shaw, Kyoto University
Katsuhito Miyake, GFDRR, The World Bank
Tomoo Inoue, Ministry of Land, Infrastructure, Transport and Tourism
Yuki Matsuoka, UNISDR
Kiyoshi Natori, Asian Disaster Reduction Center

Japan International Cooperation Agency

Global Environment Department

Nibancho Center Building

5-25, Niban-cho, Chiyoda-ku, Tokyo 102-8012, JAPAN

TEL: +81-3-5226-6658

FAX: +81-3-5226-6343

www.jica.go.jp/english/index.htnl

Email: jicage-drr@jica.go.jp