

# Measuring Economic Losses Induced by Lifeline and Transportation Disruptions



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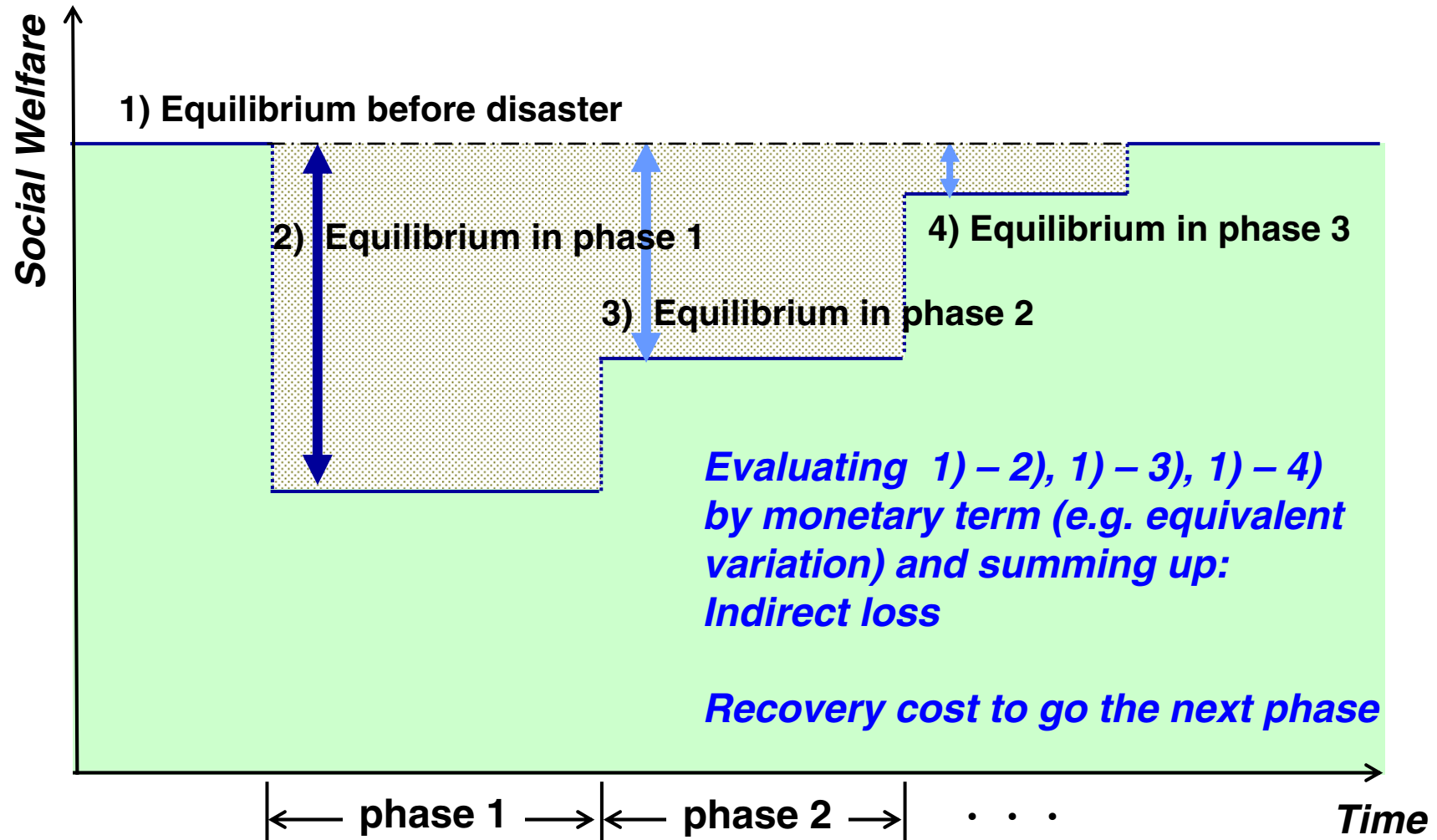
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# Loss Estimation: Theory and Methodology

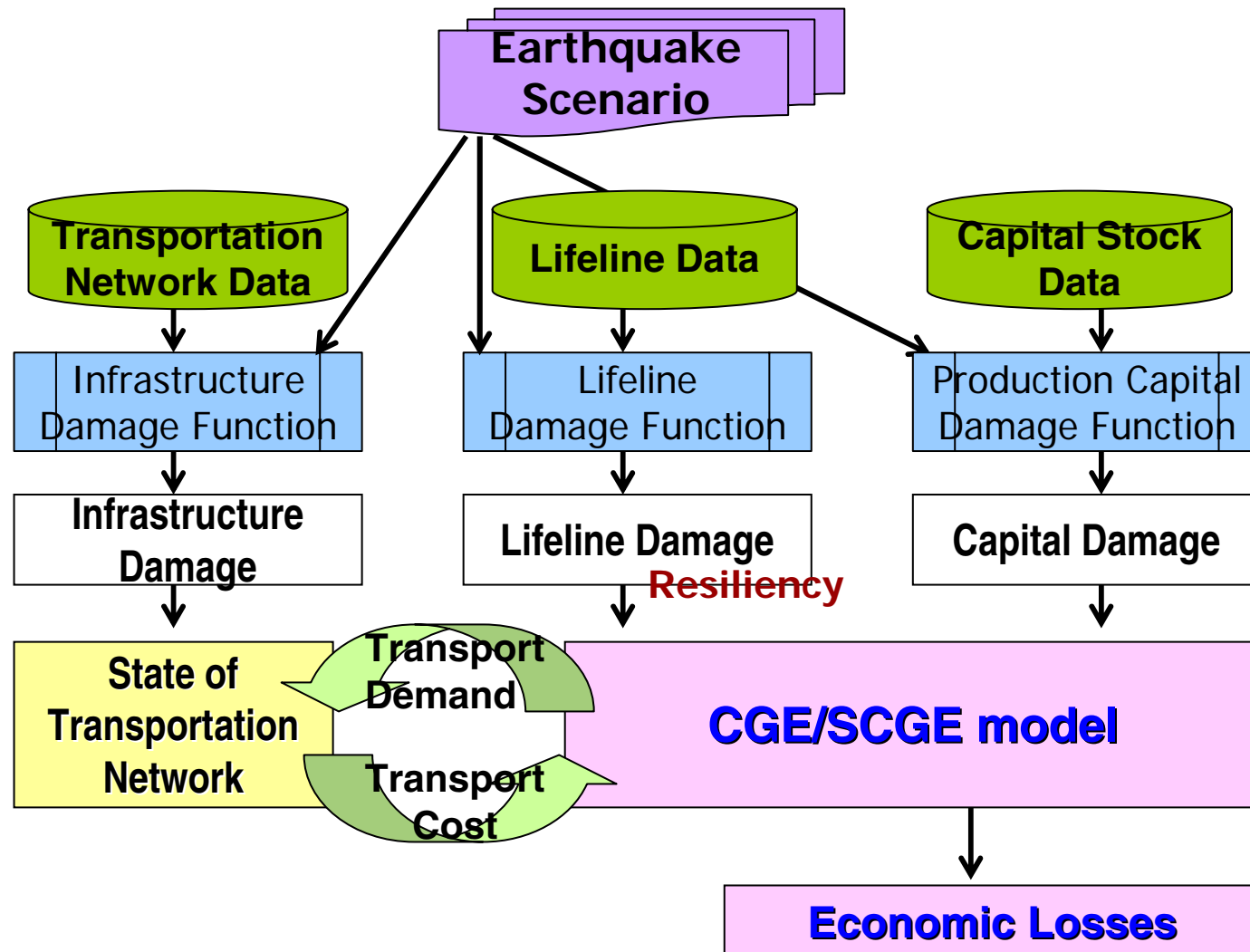
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- Significance of Loss Estimation
  - For best resource allocation to mitigation and response (integrated disaster risk management)
  - Loss estimation: consistent with theory?
  - Issues: stock vs. flow, double counting problem, etc.
    - Tatano(2006), Rose(2004)
  
- Comprehensive approach
  - Input-output analysis, Computable general equilibrium (CGE) analysis

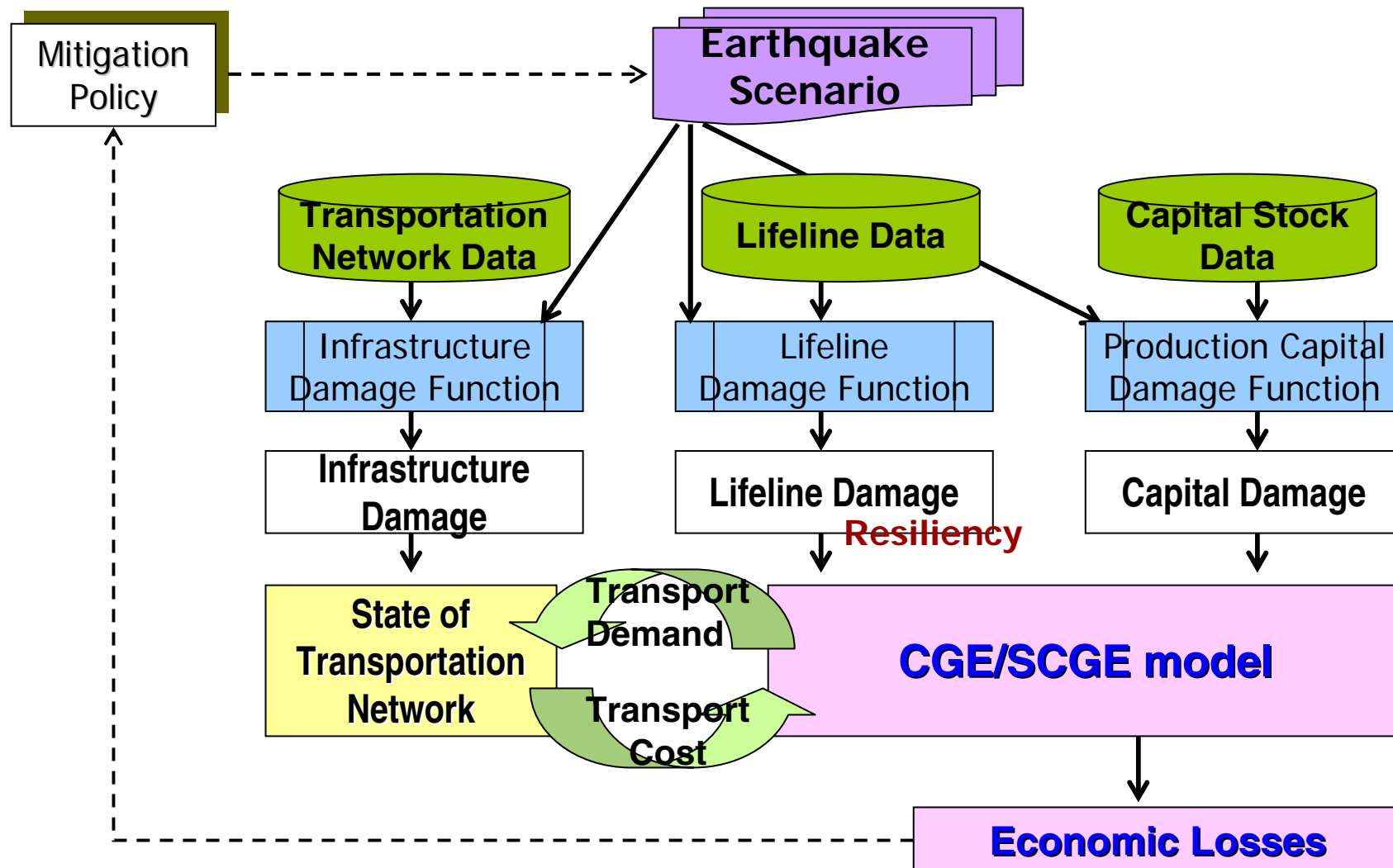
# Loss Measurement in CGE model



# Overall Framework



# Overall Framework



# Lifeline Disruption: Background

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- Lifeline Disruption by Disaster
  - Big regional economic impacts
  - **Resilience** enables firms/regions to avoid potential losses
  - Resilience/resiliency in loss evaluation
    - Without consideration → **Overestimation?**
    - Policy analysis → building resiliency and loss reduction

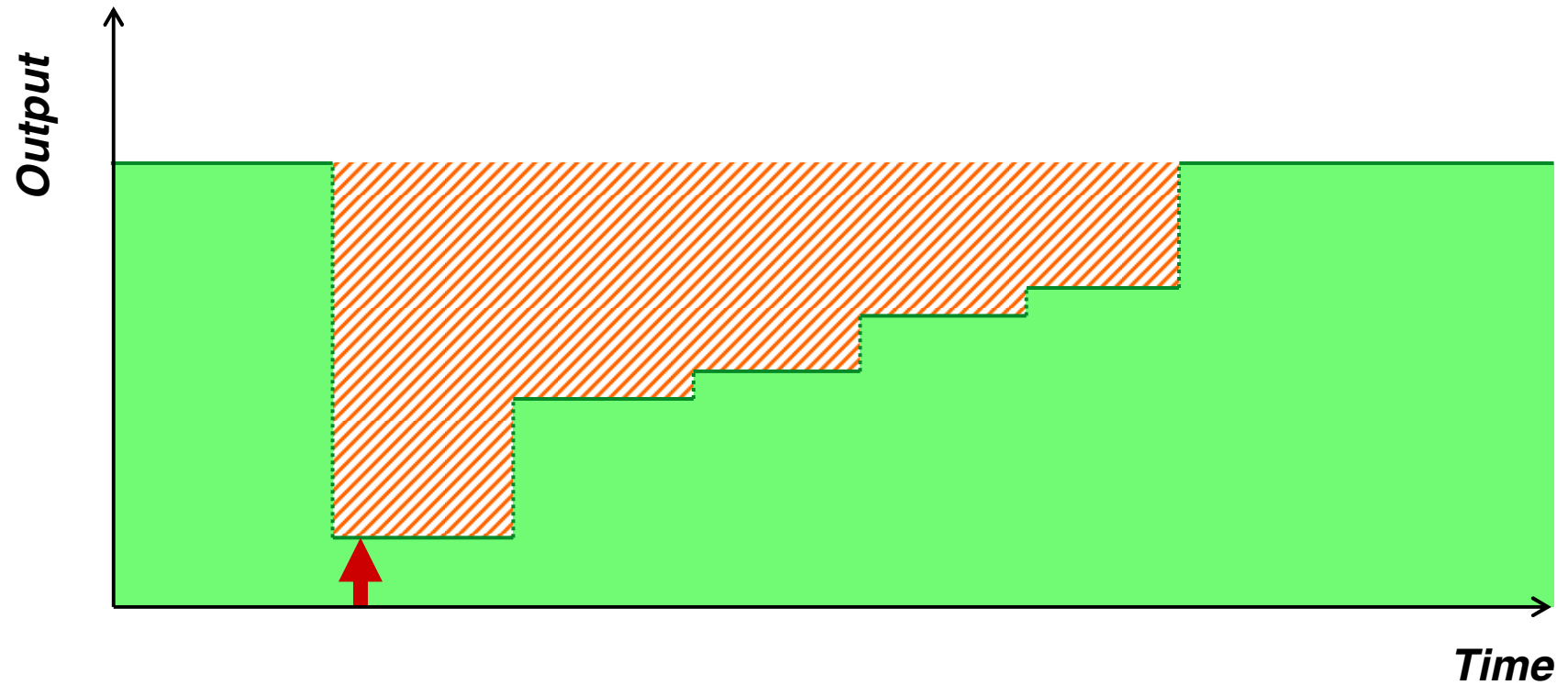
# Resiliency and Loss Estimation: Review

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- Rose and Liao (2005)
  - A [computable general equilibrium](#) analysis of water service disruptions
  - Reflecting resiliency on substitution parameters of [CES](#) production/utility functions
  
- Kajitani et al. (2006)
  - Estimating local [resiliency factors](#) (ratio of the remaining amount of production under system disruption) in Japan

# Resiliency, Resiliency Factor

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# Purpose of This Study

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- Using survey data on Niigata-Chuetsu earthquake (2004), estimate the substitution parameters of CES production functions on utility -power, water, gas- inputs.
  - Index of business resilience
  
- Building a CGE model for loss estimation caused by lifeline disruption in which the estimated substitution parameters are put.
  - Link resiliency factor and CGE model

# The Model and Parameters



## CGE Model -1

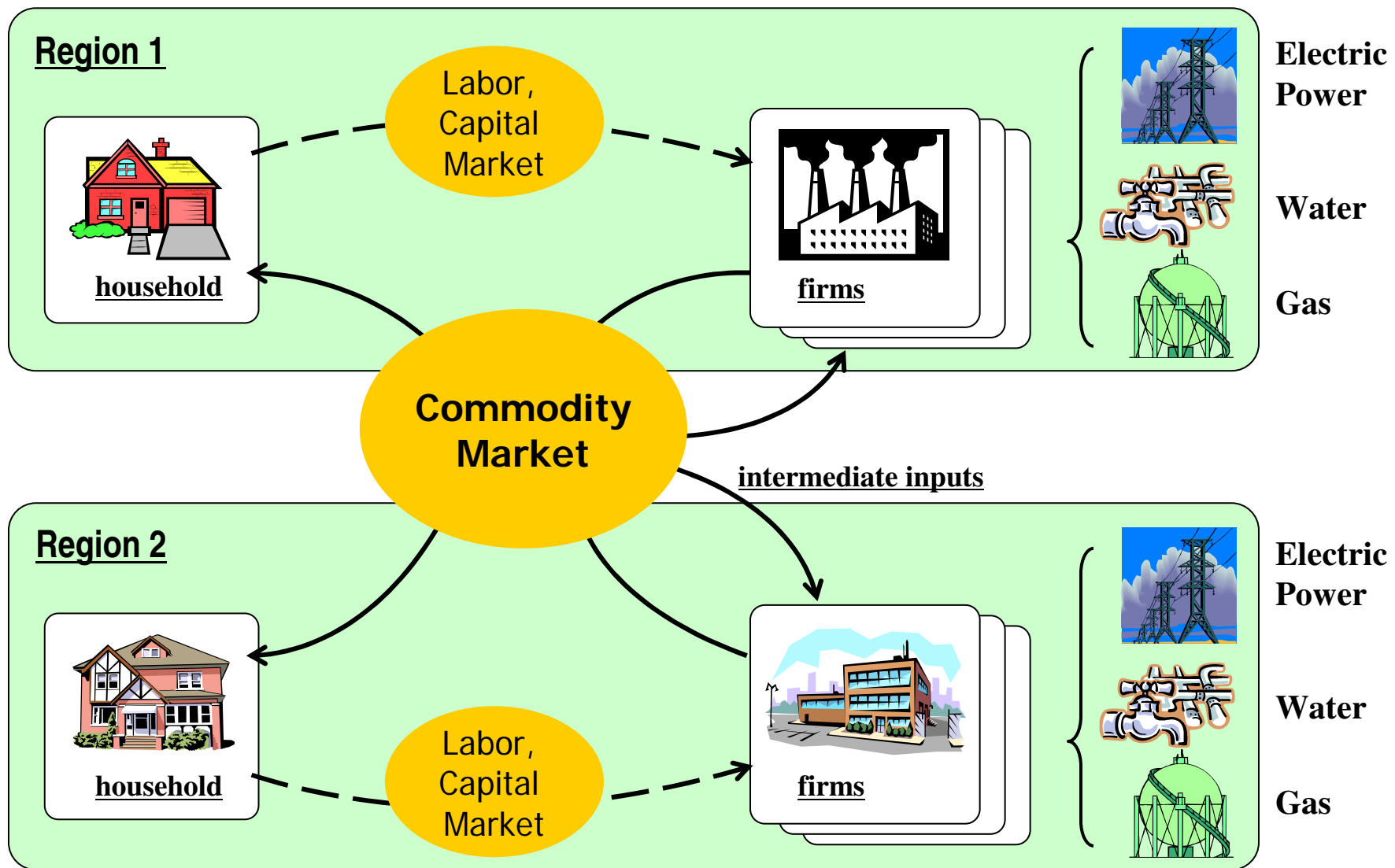
# Major Modeling Assumptions

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- ❑ Bi-region model: Niigata pref.- the rest of Japan (no interaction with overseas)
- ❑ Industry side: maximizing profit with nested CES production function (coming soon)
- ❑ Household: maximizing CES utility function with given parameter of substitution
- ❑ Short-run equilibrium: labor and capital adjustments are restricted in equilibrium under lifeline disruption
- ❑ Losses to industrial sectors
- ❑ Armington Assumption
- ❑ For loss estimation, only lifeline disruption is considered as inputs (as damage scenarios).

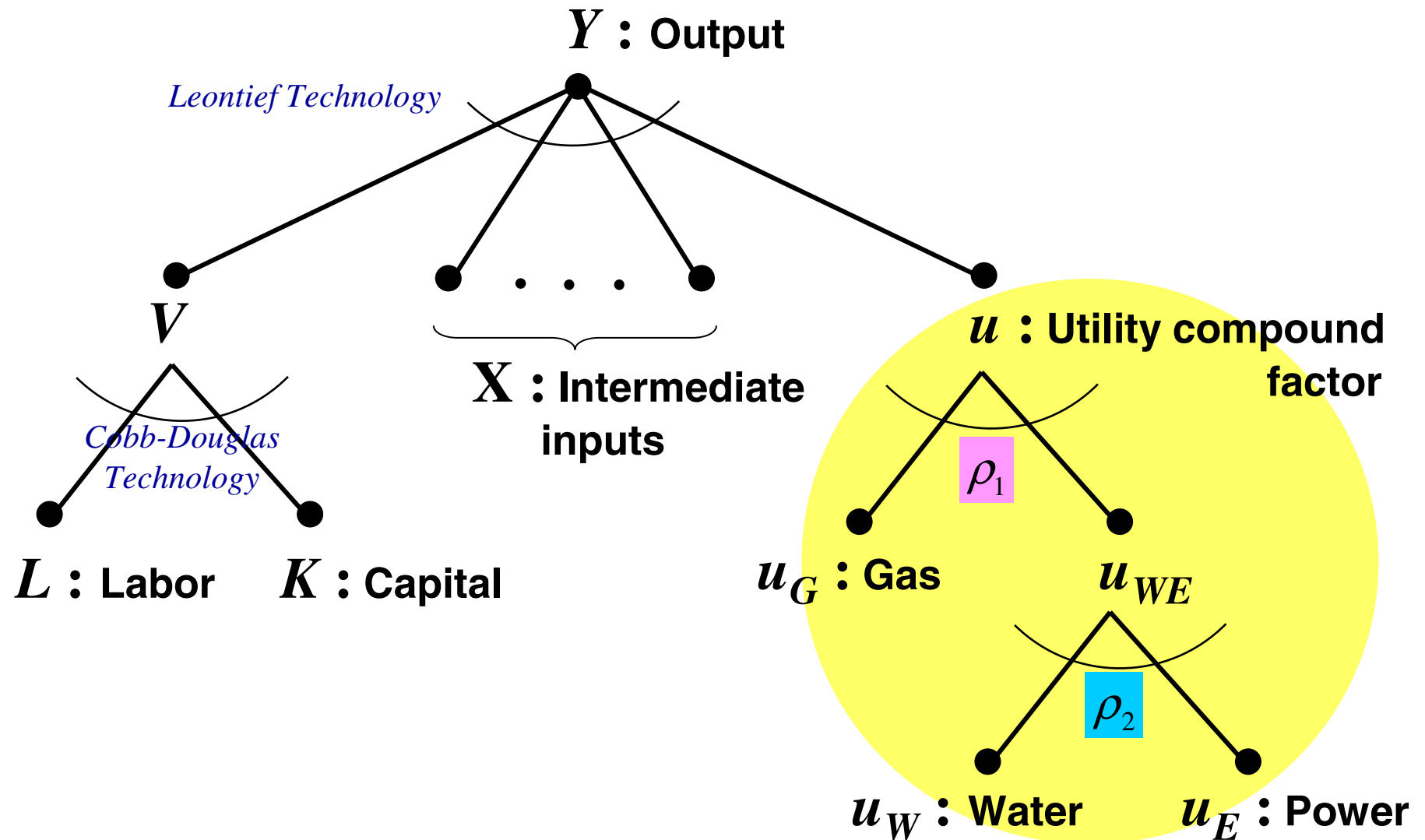
# CGE Model -2

## Regional Economic System



# CGE Model -3

## Nested CES Production Function



# Deriving Estimate Equation from CES Production Function

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$$X = \left\{ \beta_1 (x_1)^\rho + \beta_2 (x_2)^\rho \right\}^{\frac{1}{\rho}}$$



$$\left( \frac{X'}{X} \right)^\rho = \frac{\beta_1 (x_1')^\rho + \beta_2 (x_2')^\rho}{\beta_1 (x_1)^\rho + \beta_2 (x_2)^\rho}$$

Some steps



$$(r_X)^\rho = \frac{a_1 (r_{x_1})^\rho + a_2 (r_{x_2})^\rho}{a_1 + a_2}$$

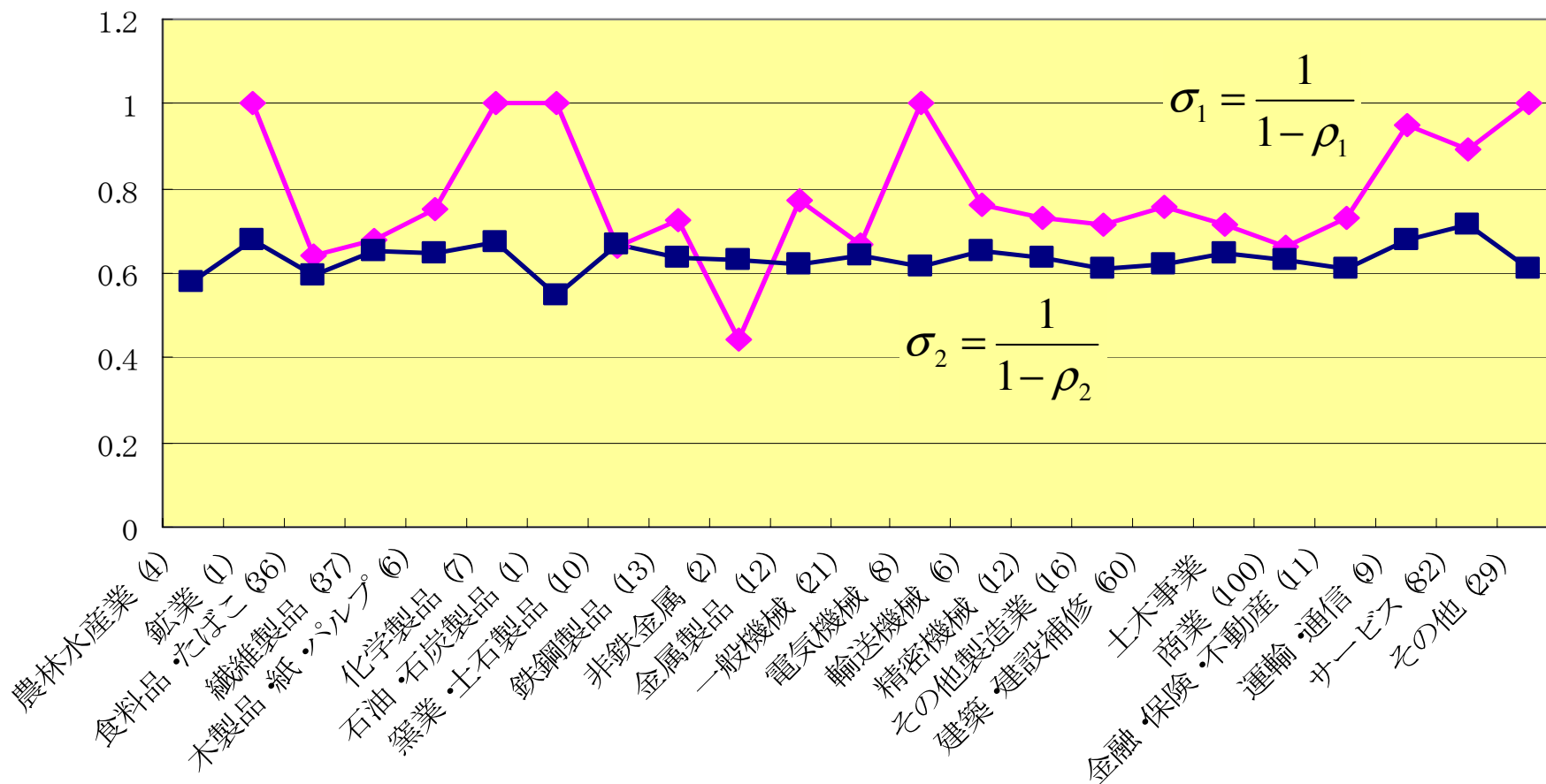
$$\underbrace{a_1}_{\bullet \text{---} \bullet} + \underbrace{a_2}_{\bullet \text{---} \bullet}$$

**Input Coefficient  
in I-O analysis**

# Data: Resiliency Factor (Kajitani et al.)

	Ex W <sup>o</sup> G <sup>o</sup>	E <sup>o</sup> W <sup>x</sup> G <sup>o</sup>	E <sup>o</sup> W <sup>o</sup> G <sup>x</sup>	E <sup>o</sup> W <sup>x</sup> G <sup>x</sup>	Ex W <sup>o</sup> G <sup>x</sup>	Ex W <sup>x</sup> G <sup>o</sup>	Ex W <sup>x</sup> G <sup>x</sup>	Sample #
Food	<u>0.0429</u>	0.4323	0.6302	0.3883	0.0372	0.0106	0.0000	51
Aparrel & Textile	0.0776	0.7241	0.8276	0.7328	0.1121	0.0776	0.0690	29
Wood & Wooden Prodt	0.0625	0.9063	1.0000	0.9063	0.0625	0.0625	0.0625	11
Glass Stone Clay	0.0345	0.4196	0.5862	0.3534	0.0862	0.0259	0.0172	30
Paper-Pulp	0.0313	0.5938	0.7969	0.5938	0.0167	0.0156	0.0156	17
Chemicals	0.0786	0.3571	0.7353	0.3286	0.0571	0.0588	0.0500	35
Refinary-Coal	0.1818	0.7045	1.0000	0.7045	0.1818	0.0000	0.0000	11
Metal Product	0.0381	0.6519	0.7219	0.6088	0.0424	0.0216	0.0212	61
Steel	0.0000	0.5000	0.6964	0.4107	0.0000	0.0000	0.0000	15
Non-Ferrous	0.0500	0.4211	0.6947	0.3684	0.0526	0.1053	0.0526	21
General Machinery	0.0417	0.6067	0.8636	0.6113	0.0109	0.0000	0.0000	25
Precision Machinery	0.0417	0.6875	0.9167	0.6667	0.0625	0.0208	0.0083	12
Elec. & Electron	0.0662	0.7353	0.8897	0.7059	0.0303	0.0441	0.0368	34
Transport Eq	0.0313	0.5426	0.5573	0.4427	0.0208	0.0213	0.0104	49
Misc. Manufact	0.0708	0.4750	0.6653	0.4083	0.0833	0.0805	0.0410	62
Total	0.0533	0.5533	0.7235	0.5093	0.0537	0.0387	0.0260	469

# Parameter Estimation: Results



1) Figures in ( ) : #sample

2)  $c_1(\rho_1)$  : substitution between gas and E-W ,  $c_2(\rho_2)$  : between power and

# Simulation Results

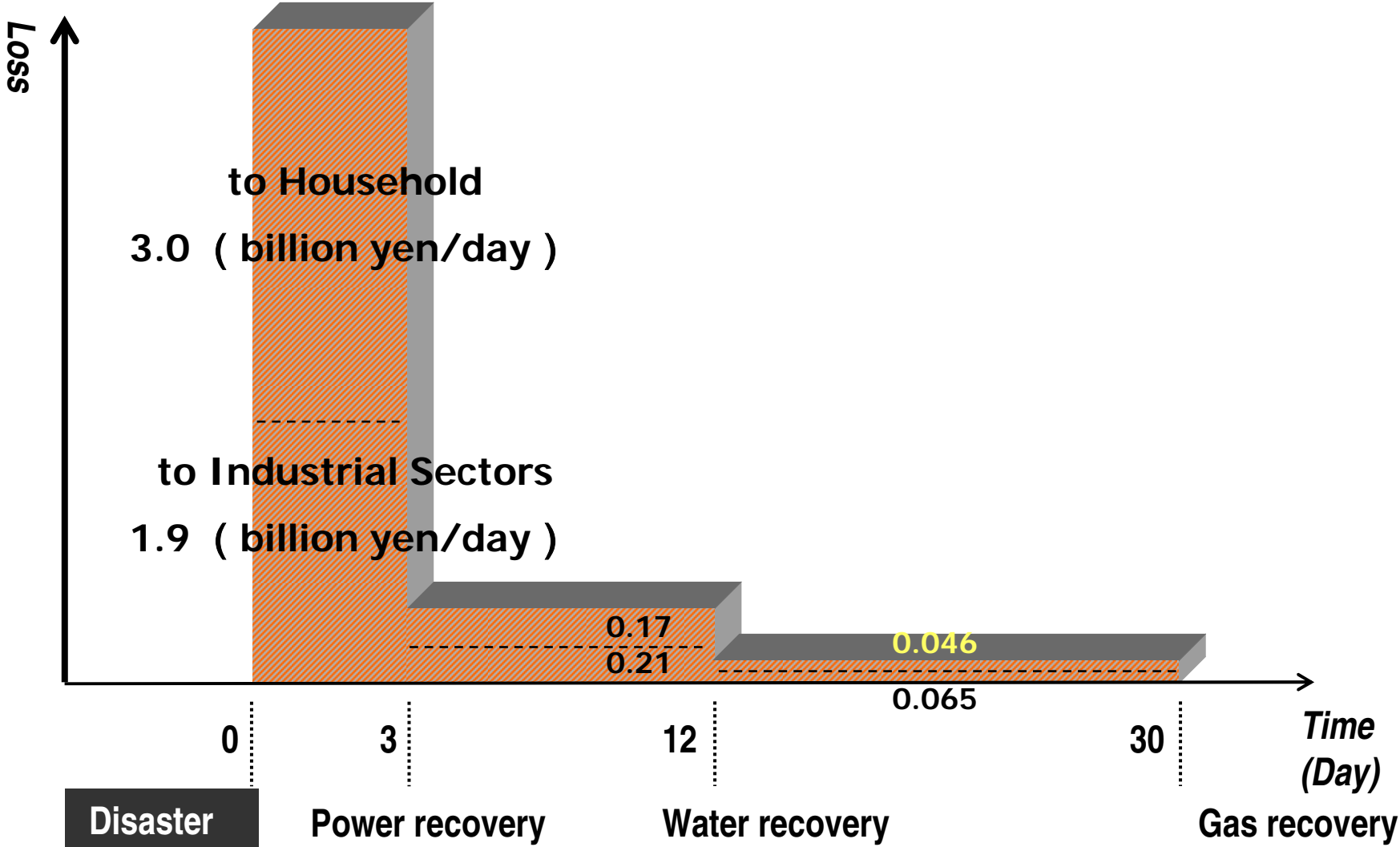


# Data

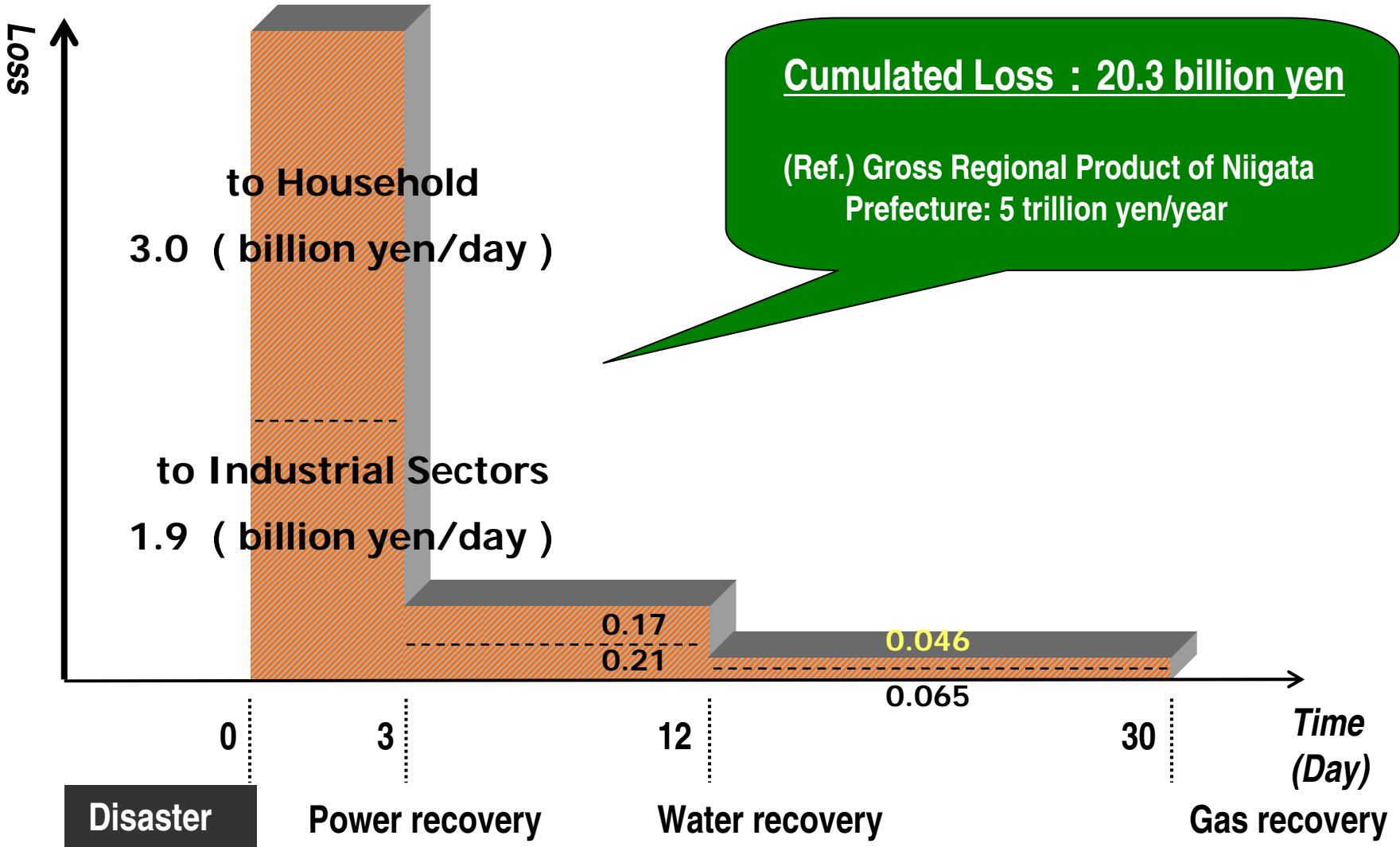
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- National/Regional Input-Output tables (2000)
  - cover all endogenous variables and most of parameters to be calibrated in CGE
  
- The remaining parameters
  - from [references](#): Substitution on commodity consumption (household), Substitution of region on commodity purchase
  - from [survey](#): Elasticity of substitution on utility inputs

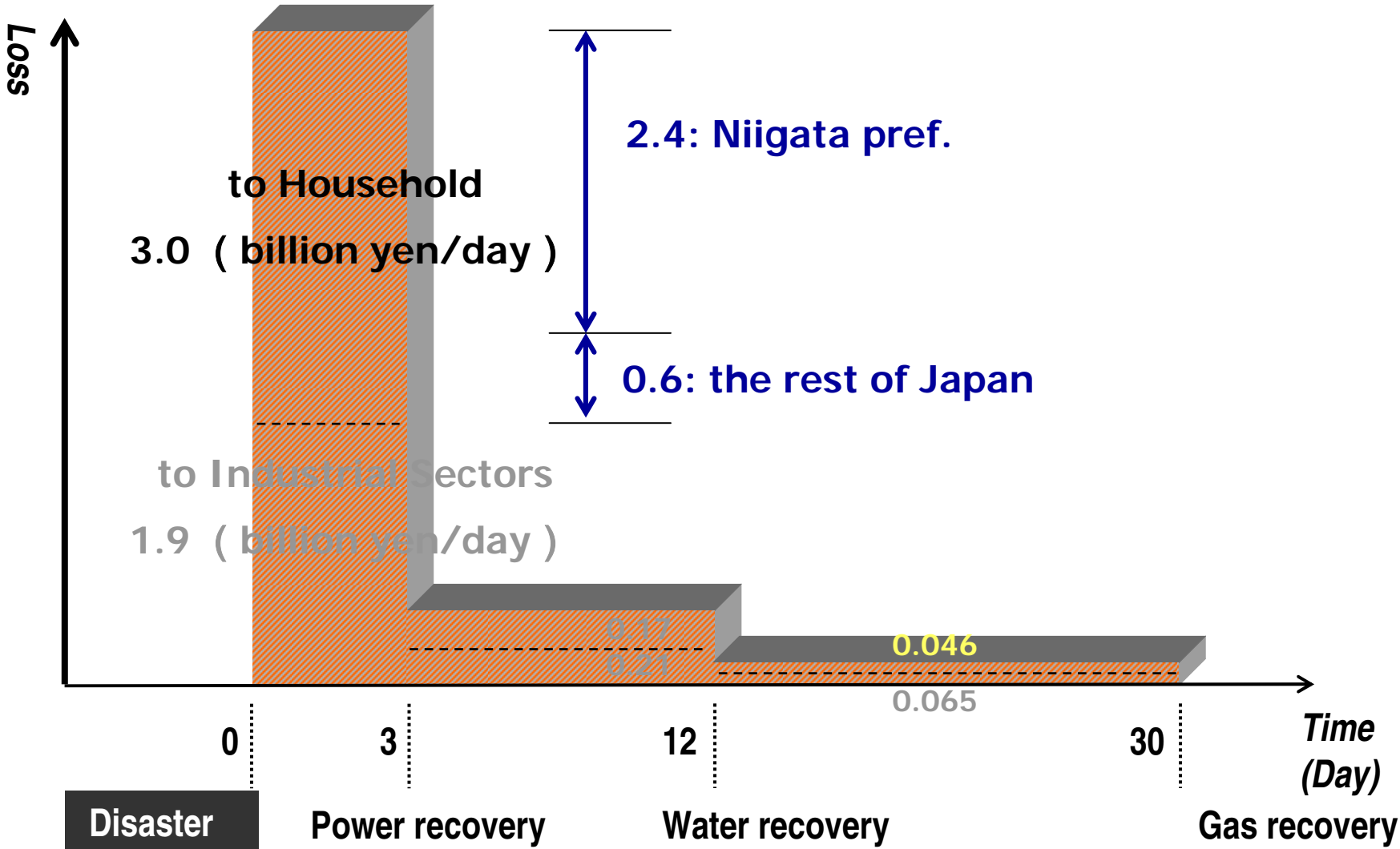
# Estimated Loss Induced by Lifeline Disruption



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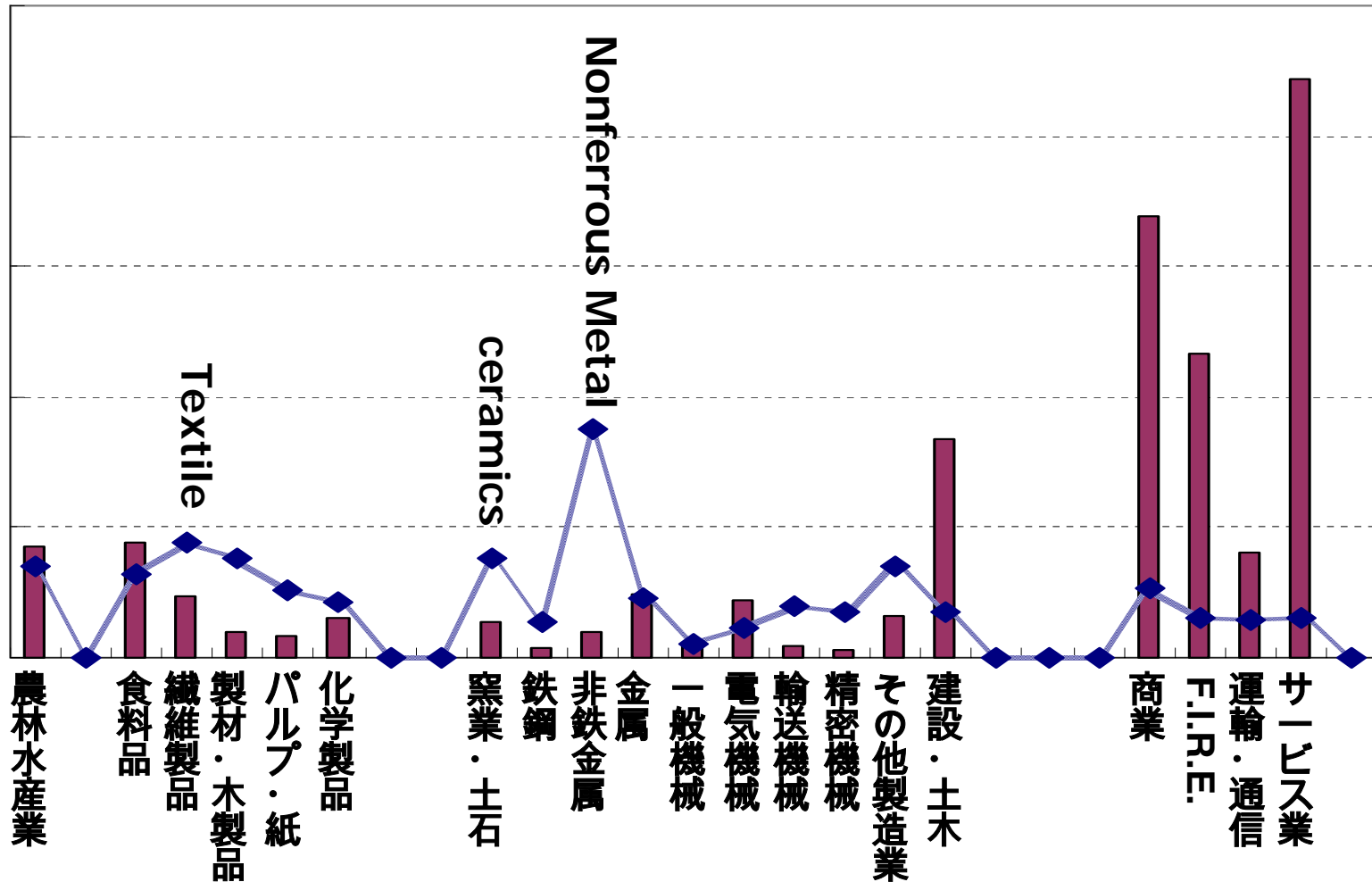
# Estimated Loss Induced by Lifeline Disruption



# Loss to Industrial Sectors

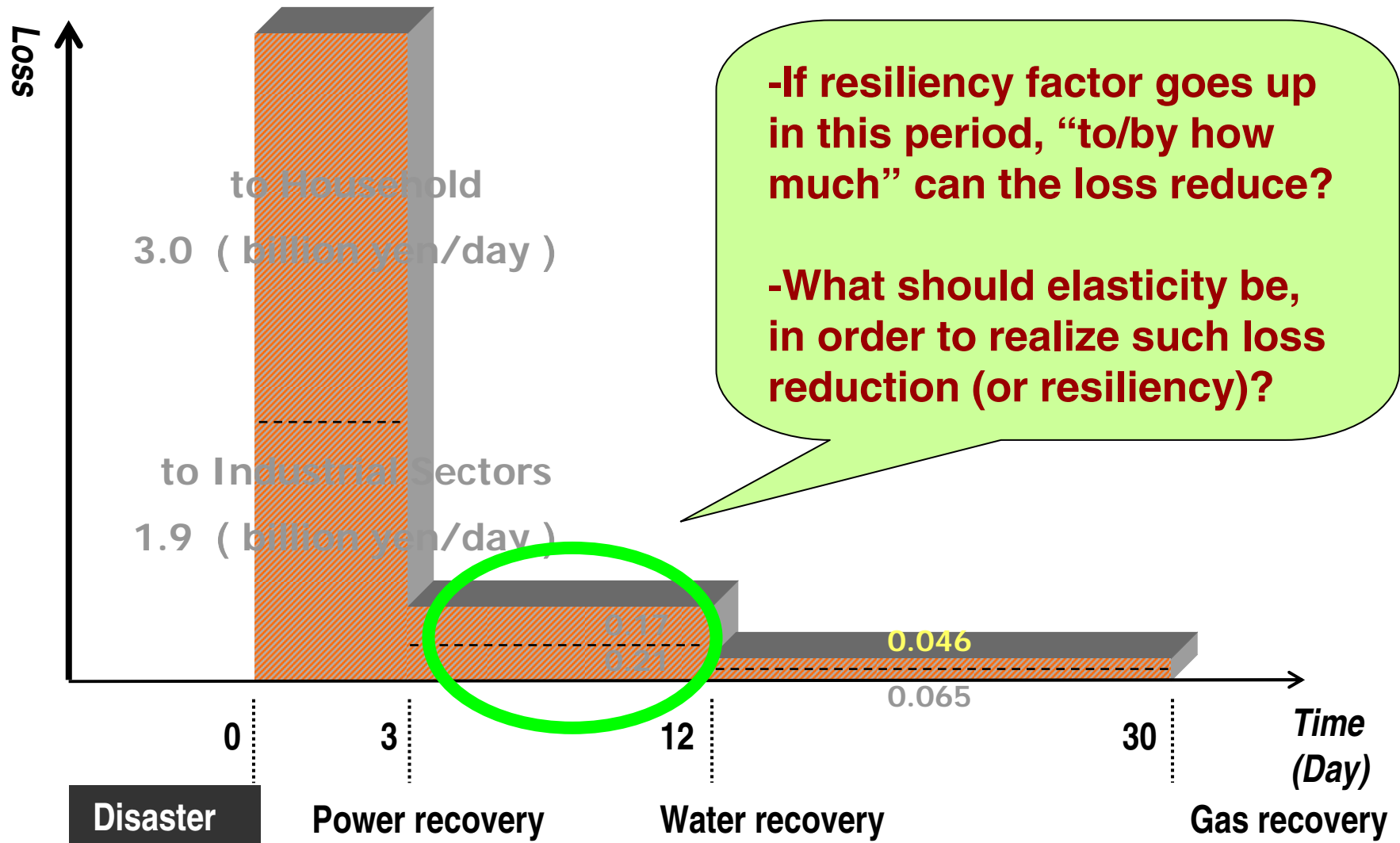
Loss (10<sup>-1</sup>\*billion yen)

25.0  
20.0  
15.0  
10.0  
5.0  
0.0



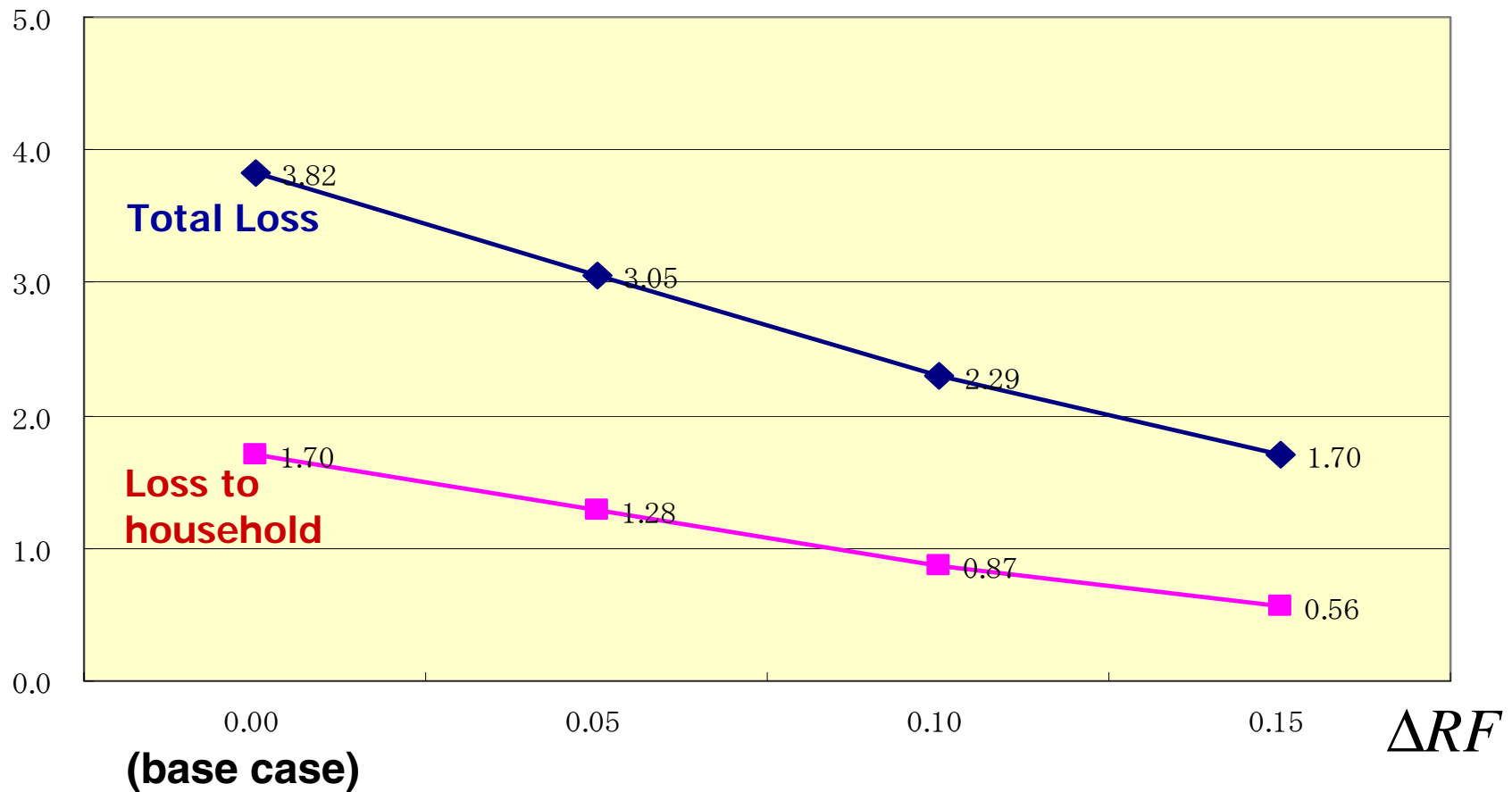
( % )  
1.0  
0.5  
0.0

# Policy Implication -1



# Policy Implication -2

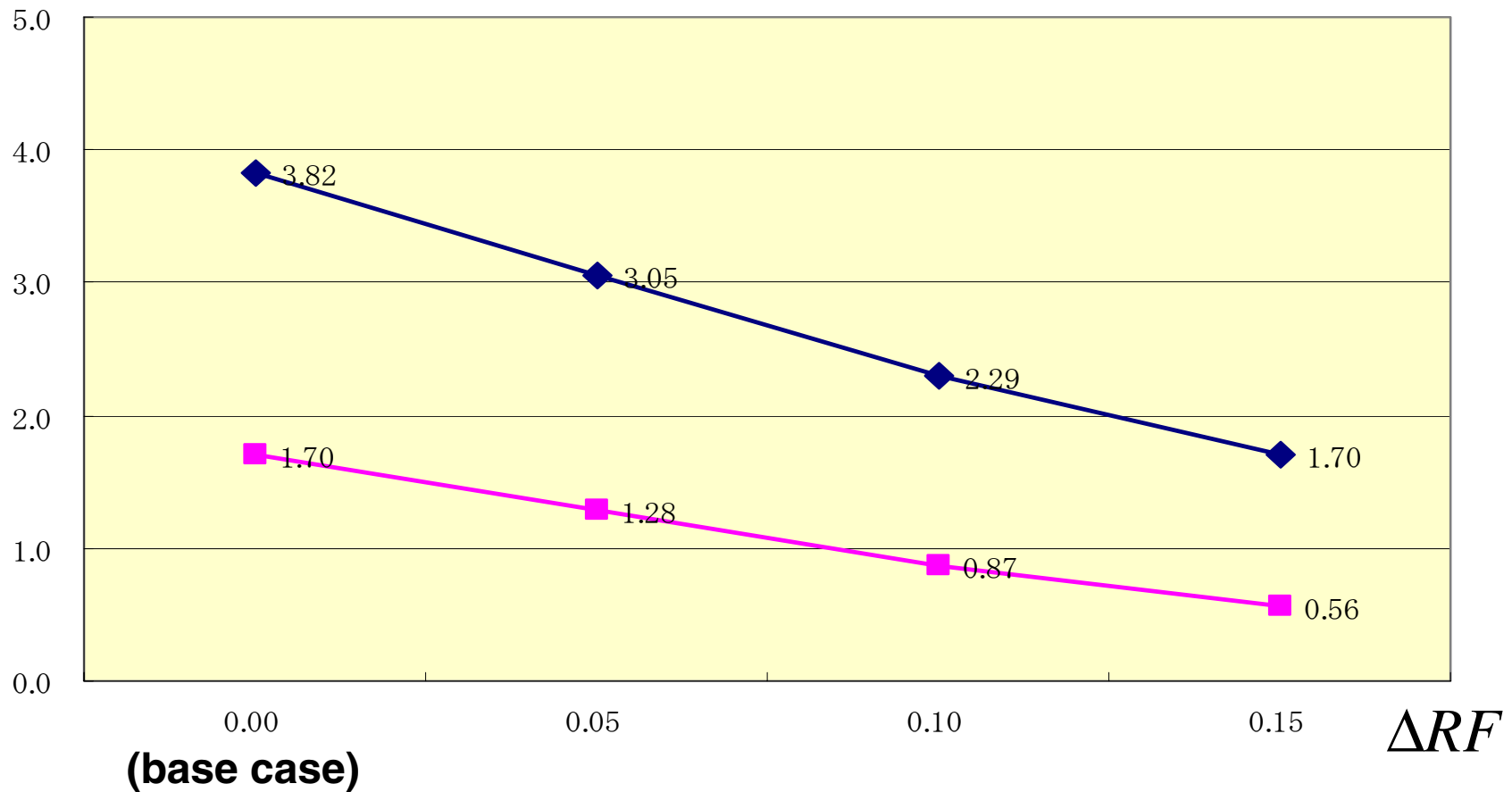
Loss  
( $10^{-1}$ \*billion yen/day)



# Policy Implication -3

Loss  
( $10^{-1}$ \*billion yen/day)

to realize  $\Delta RF$ , what should elasticity go up to?



# Policy Implication -3

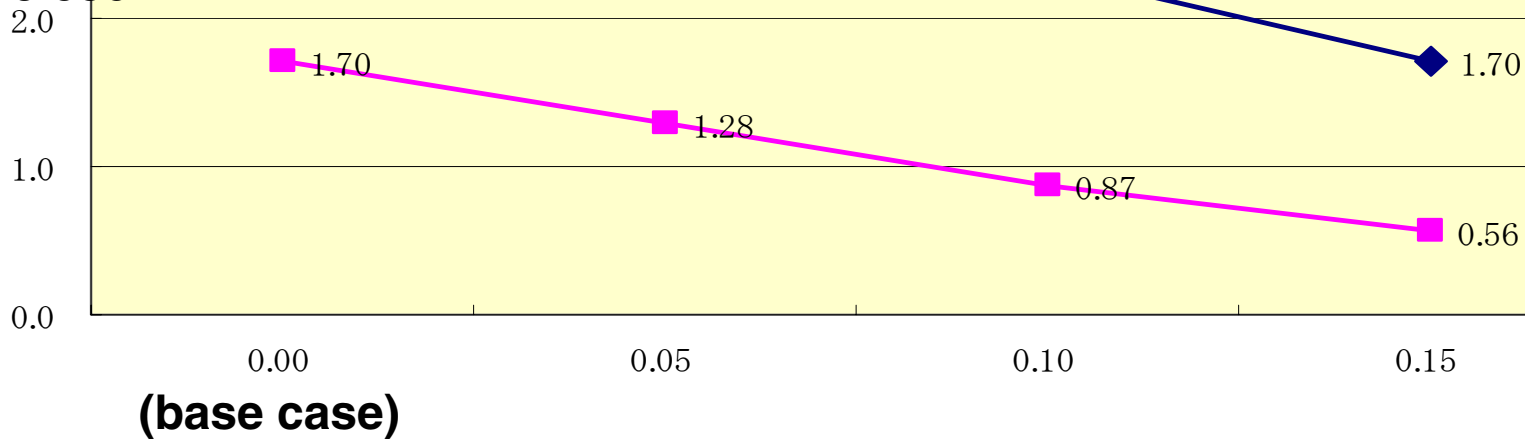
Loss  
( $10^{-1}$ \*billion yen/day)

to realize  $\Delta RF$ , what should elasticity go up to?

**Textile**

$c_1$  : 0.678  $\rightarrow$  0.687  $\rightarrow$  0.696  $\rightarrow$   
**0.707**  
 $c_2$  : 0.652  $\rightarrow$  0.655  $\rightarrow$  0.657  $\rightarrow$

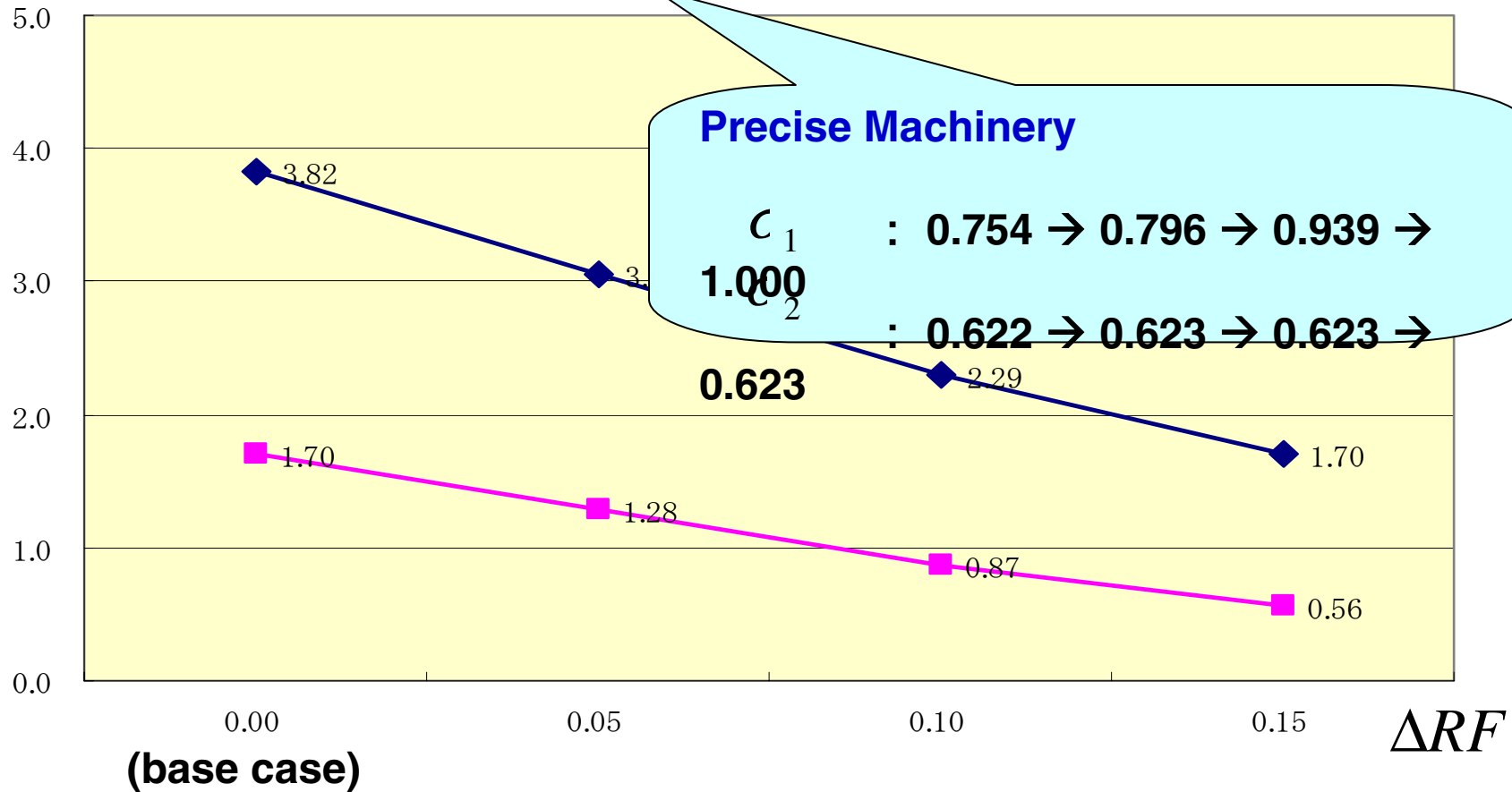
**0.659**



# Policy Implication -3

Loss  
(10<sup>-1</sup>\*billion yen/day)

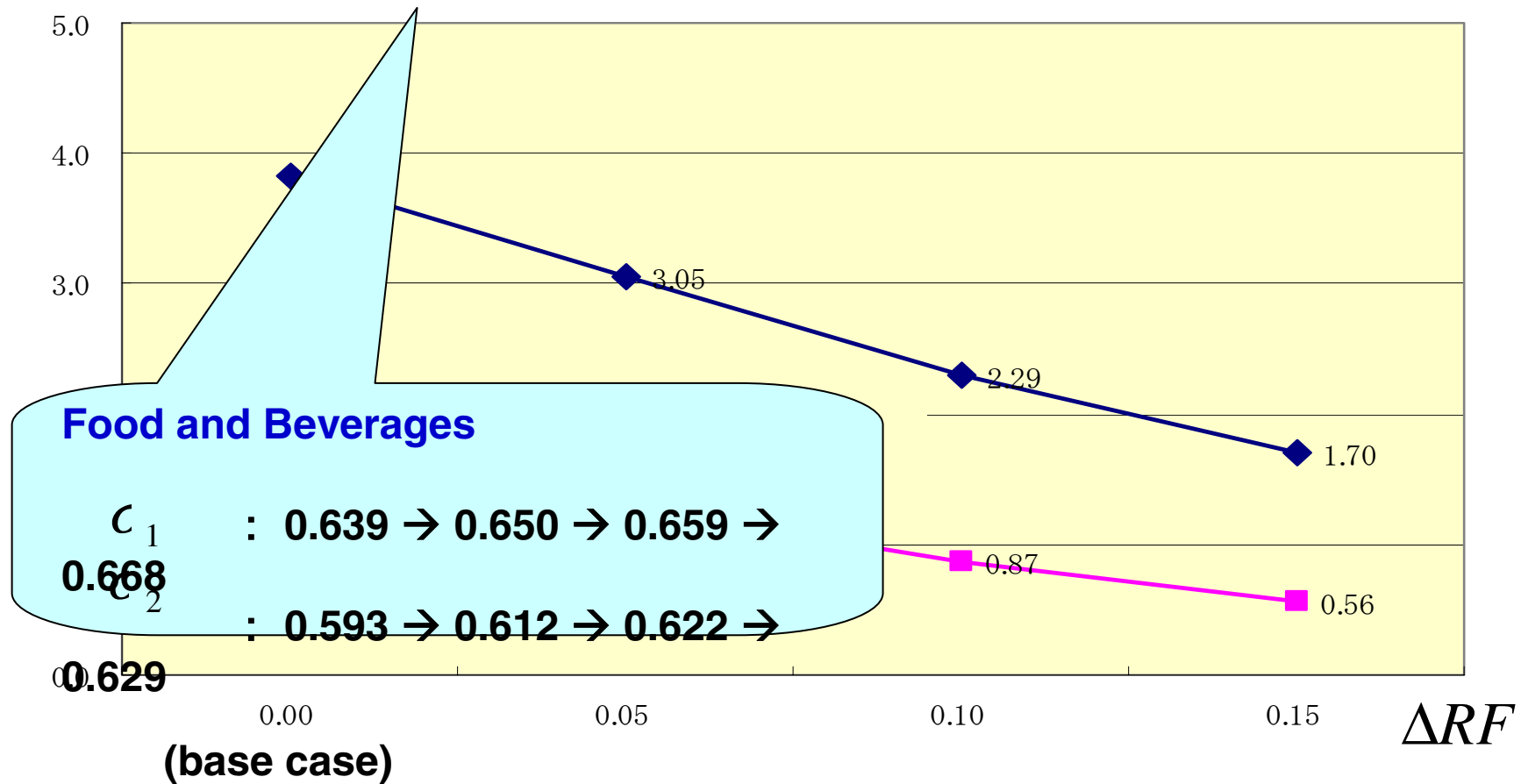
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# Policy Implication -3

Loss  
(10<sup>-1</sup>\*billion yen/day)

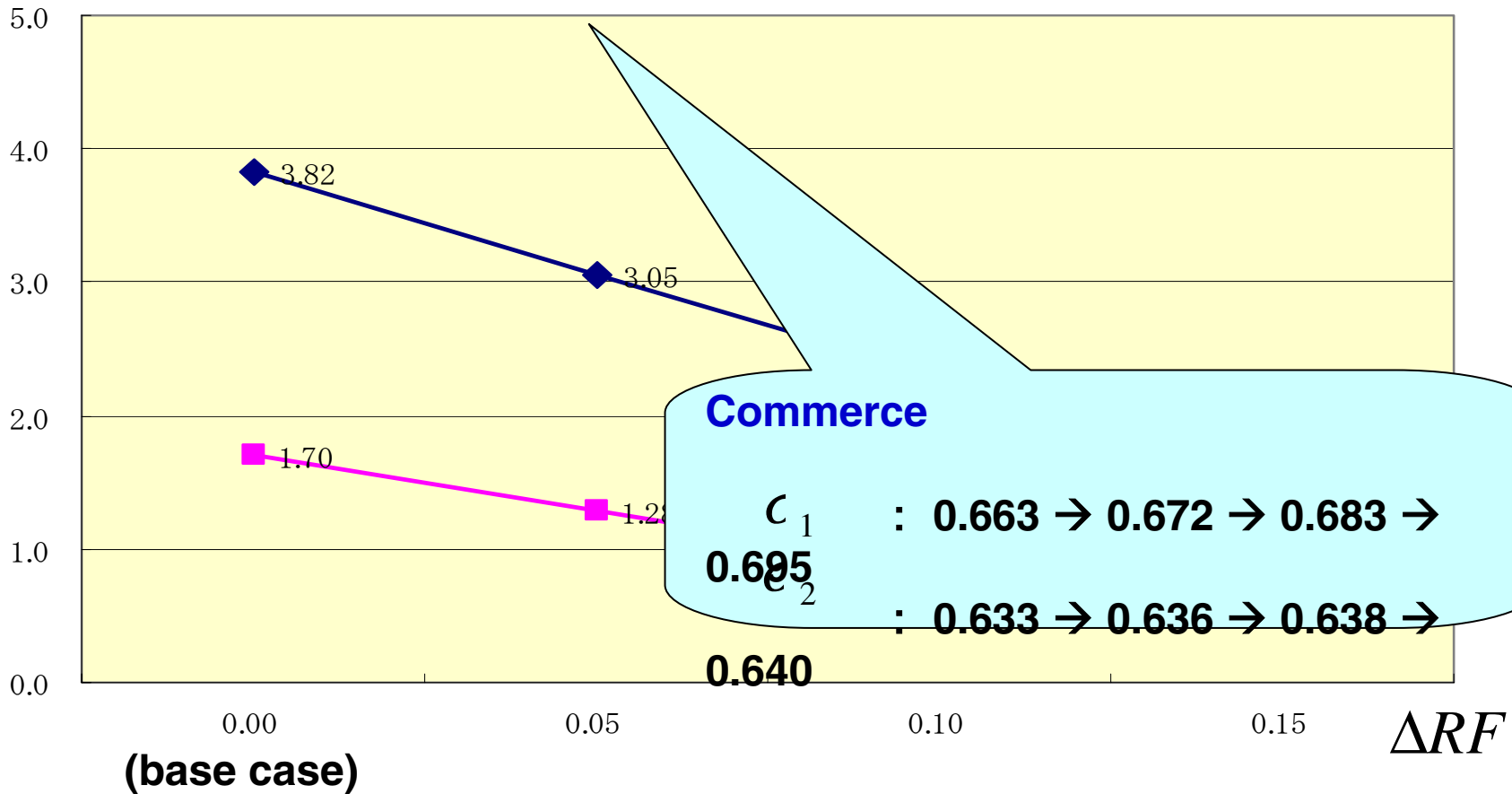
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# Policy Implication -3

Loss  
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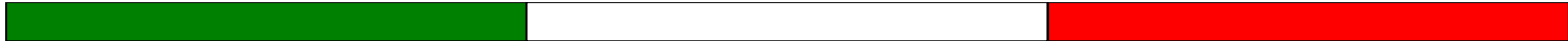


# Summary

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- Loss Estimation Framework due to Lifeline Disruption
  - Resiliency factor is incorporated into substitution parameters of production function in CGE model
  
- Case Study: Niigata-Chuetsu Earthquake (2004)
  - The substitution parameters were estimated with survey data
  - Our CGE estimated the loss: 20.3 billion yen
  - Policy implication: find “to/by how much” can the potential loss can reduce by building more resilience

**Thank you very much.**



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