Economic Valuation of Catastrophic Disaster Risk

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Research Interest

1. Methodological research of economic valuation of disaster risk
   - Valuation in efficient catastrophic risk market.
   - Valuation under liquidity constraint.
2. Macroeconomic dynamics under disaster risk
   - Stochastic macroeconomic growth
   - Recovery process after great disaster
   - Inter-sectoral allocation of risk in market

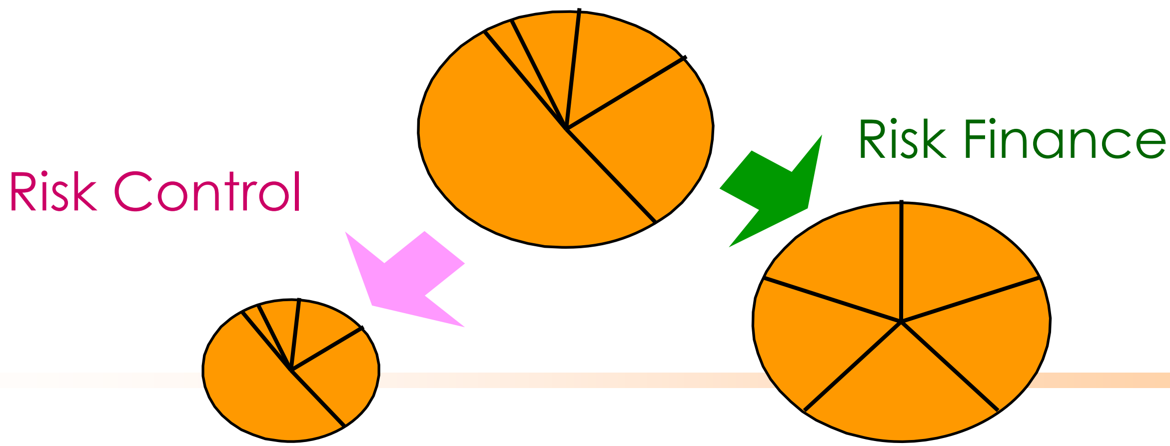
Technology of risk management

Risk control: Mitigation of total losses in society

Provision of dyke, dam, floodway. Seismic retrofit.
Management and operational skills of traffic system, communication system, etc.
Management skill of recovery projects.

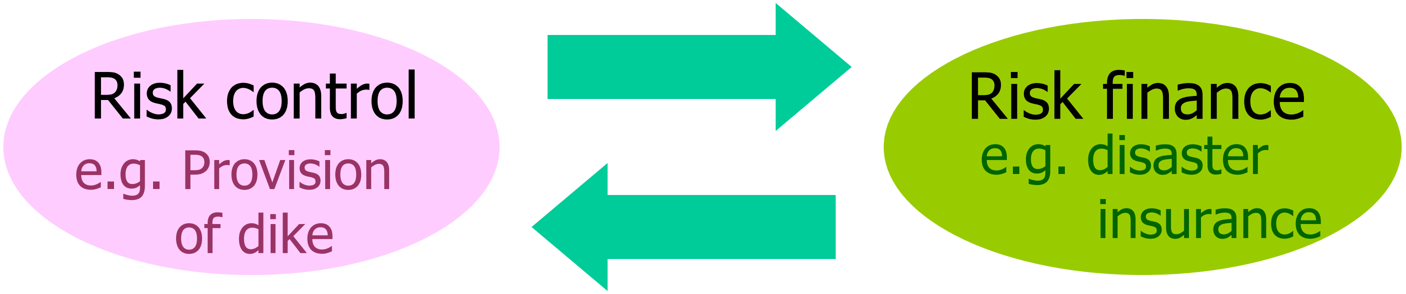
Risk finance: Redistribution of losses among individuals

Market insurance, derivatives, etc.
Governments compensation, national debts, etc.



Interdependency between risk control (mitigation) and risk finance

- Mitigation of collective risks.
- Increase in insurability. ➡ Decrease in premium.



-Procurement of resource for recovery.
-Adjusting the level of premium so as to reflect risks and motivating households to retrofit.

Integrated Disaster Risk Management system should be composed of optimal combinations of RC and RF.

Refinement of economic valuation of insurance and mitigation

	Value of insurance	Value of mitigation
Present rule in practice: Independent small risks	Risk aversion: Pooling independent small risks	Expected-losses-reduction
Refinement 1: Spatial and collective Risks (Kobayashi and Yokomatsu, 2000)	Risk aversion: Diversification of collective risk with security type of D. insurance (e.g. CAT bond)	Reduction of risk premium
Refinement 2: Households' liquidity constraint	Liquidity supplement	Reduction of Liquidity damage

Present rule in practice

Benefit of disaster risk mitigation

=Expected-losses-reduction

↑

Assumption:

- Small independent risks
- Fair insurance premium and full-coverage insurance contract

➡ Disregarding CATASTROPHE of disaster !!

Refinement 1:
Kobayashi and Yokomatsu (2000)

Assumption:
- ➢Catastrophe: low probability and high consequence
- ➢Collective risk: synchronized arrivals

➡ First-best disaster insurance system

composed of contingent security and mutual insurance.

➡ Damages are still not fully covered...

Benefit of disaster risk mitigation

= Risk premium × Expected-losses-reduction

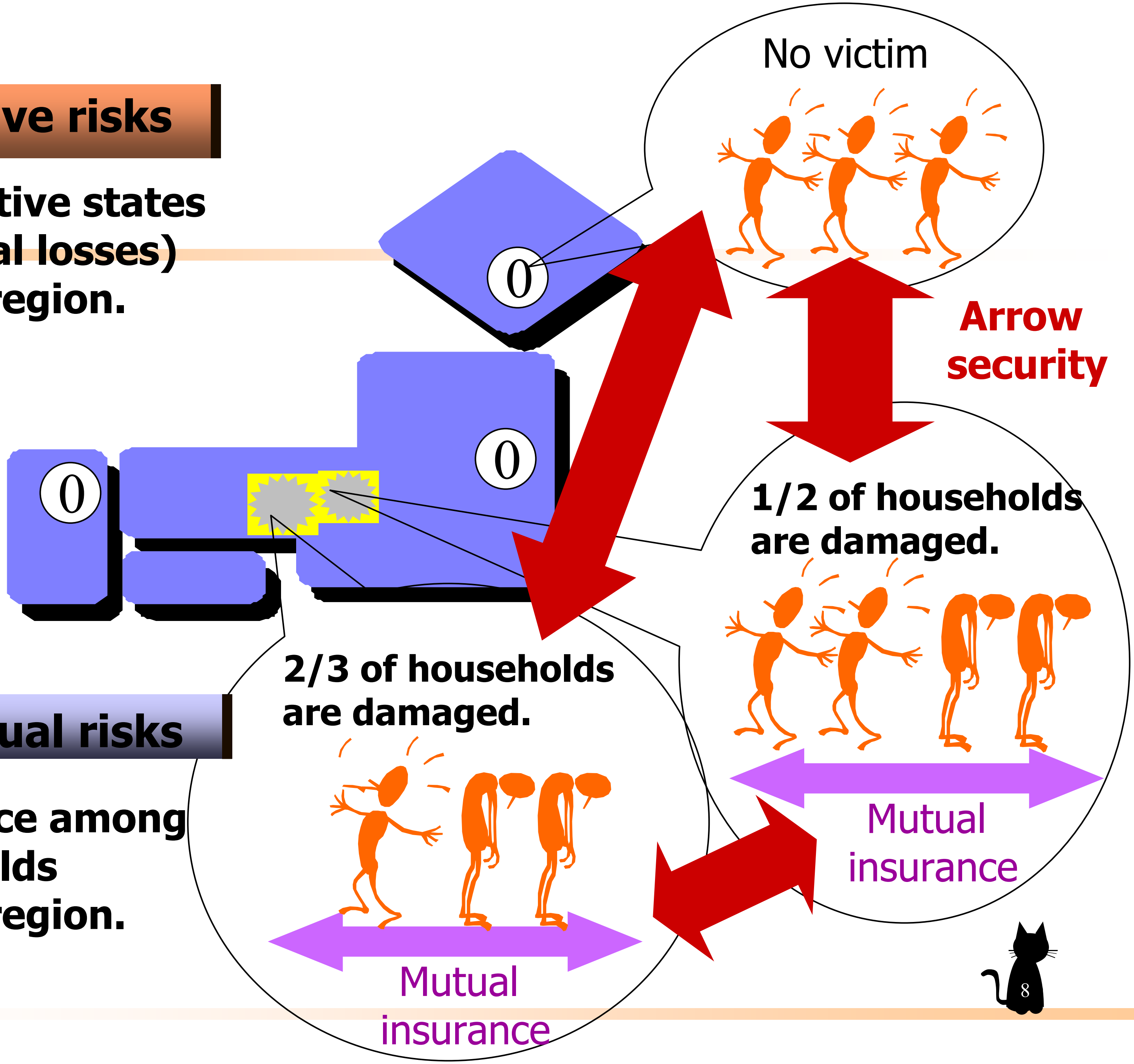
Mark-up ratio of premium in disaster insurance market (>1)

Collective risks

Aggregative states (e.g. total losses) of each region.

Individual risks

Difference among households in each region.



Composition of catastrophic disaster insurance

Premium $$c_h = \sum_t \{p^*(t)a_h^*(t) + \sum_s \pi_h(s|t)m_h^*(s,t)\}$$

Diversifying collective risks

Diversifying individual risks

Insurance money $$R(s,t) = a_h^*(t) + m_h^*(t) + \sum_{t' \underline{\angle} t}\sum_s \pi_h(s|t)m_h^*(s,t)$$

Repayment of premiums of mutual insurance

Achieving Pareto efficient allocation of risks!

Economic valuation of disaster mitigation

Willingness-to-pay (WTP) for reduction in disaster risks born by households who purchase the catastrophic disaster insurance

Inclusive of benefits from mitigation of catastrophe.

Compensating option price: OP_h^C

$$E[v(\boldsymbol{x}_h^{*1} - OP_h^C) : \boldsymbol{\pi}_h^1] = E[v(\boldsymbol{x}_h^{*0}) : \boldsymbol{\pi}_h^0]$$

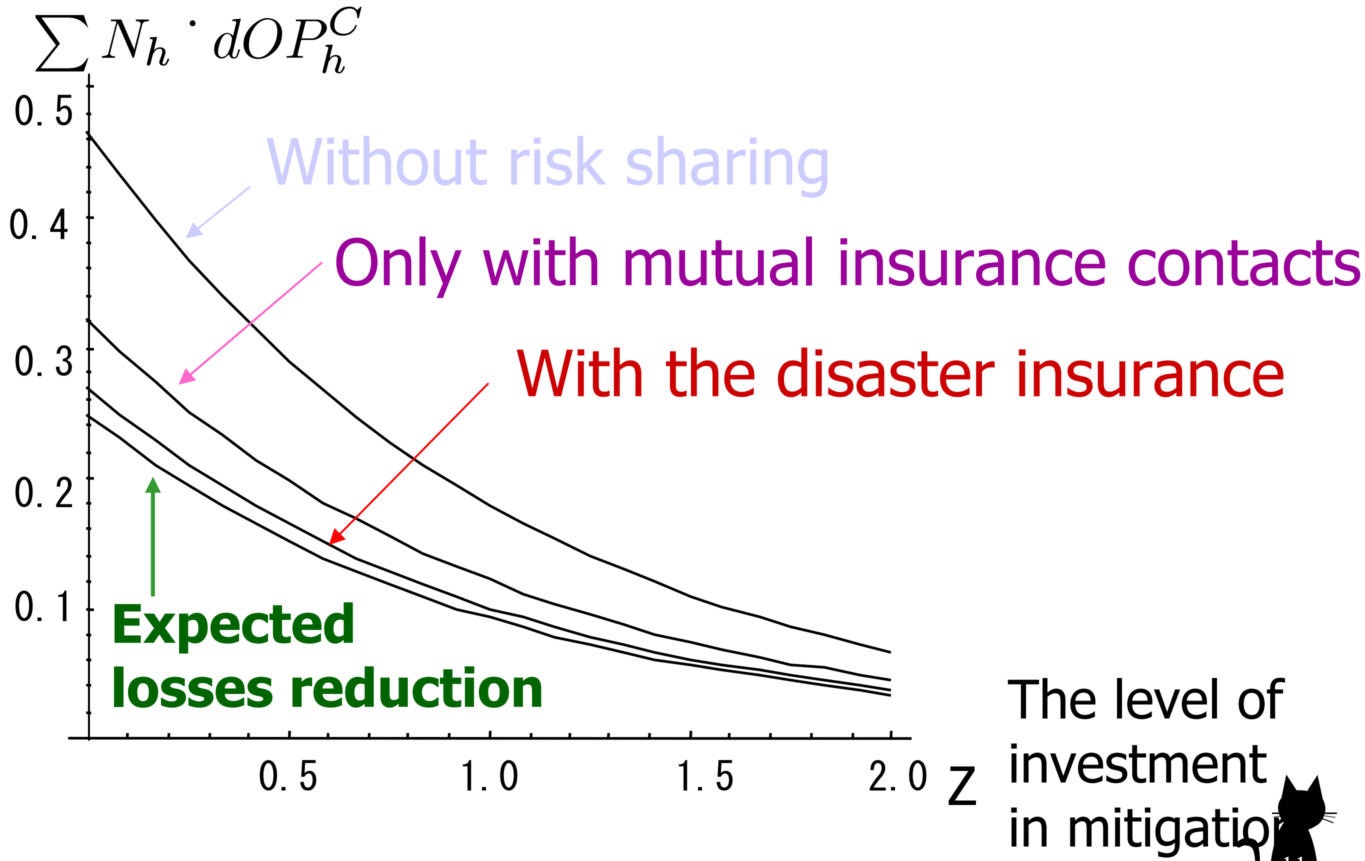
$$dOP_h^C = \frac{1}{\lambda_h^1} \sum_{t=0}^{T} \frac{\partial \pi^1(t)}{\partial z} v(\hat{x}_h^{*1}(t)) \cdot (-dz)$$

Expected marginal utility

$$\lambda_h^1 = \sum_{t=0}^{T} \pi_h^1(t) \frac{\partial v_h(\hat{x}_h^{*1}(t))}{\partial \hat{x}_h^1(t)}$$

Risk finance means and benefits of investment in disaster mitigation (Numerical example)

WTP for marginal investment



The conventional valuation underestimates the benefits.

Refinement 2:
Yokomatsu, Kobayashi and Wakigawa (2006)

First-best disaster insurance system presumes perfect Arrow=Debrue market,
including perfect credit market,
which is inconsistent with
delay of recovery in reality, because of ･･･

Liquidity constraint

Household’s (and firm’s) inability
to borrow money
(although it can repay with future income.)

↑

Asymmetry of information

resulting in household’s inability
to shift the timing of consumption in its life.

How come households are liquidity constrained after disaster?

1. Loss of house often involves
   1) loss of mortgage collateral,
   2) repayment obligation of outstanding loan.

2. Household is forced to change its job owing to damage of productive facility and/or physical ability, resulting in uncertainty of future income.

➡ Lending agency rejects provision of multiple consumer loans.

Liquidity constrained household can not recover the state of the physical assets as soon as possible.

How come delay of recovery occurs?

If a household can go into sufficient debt…

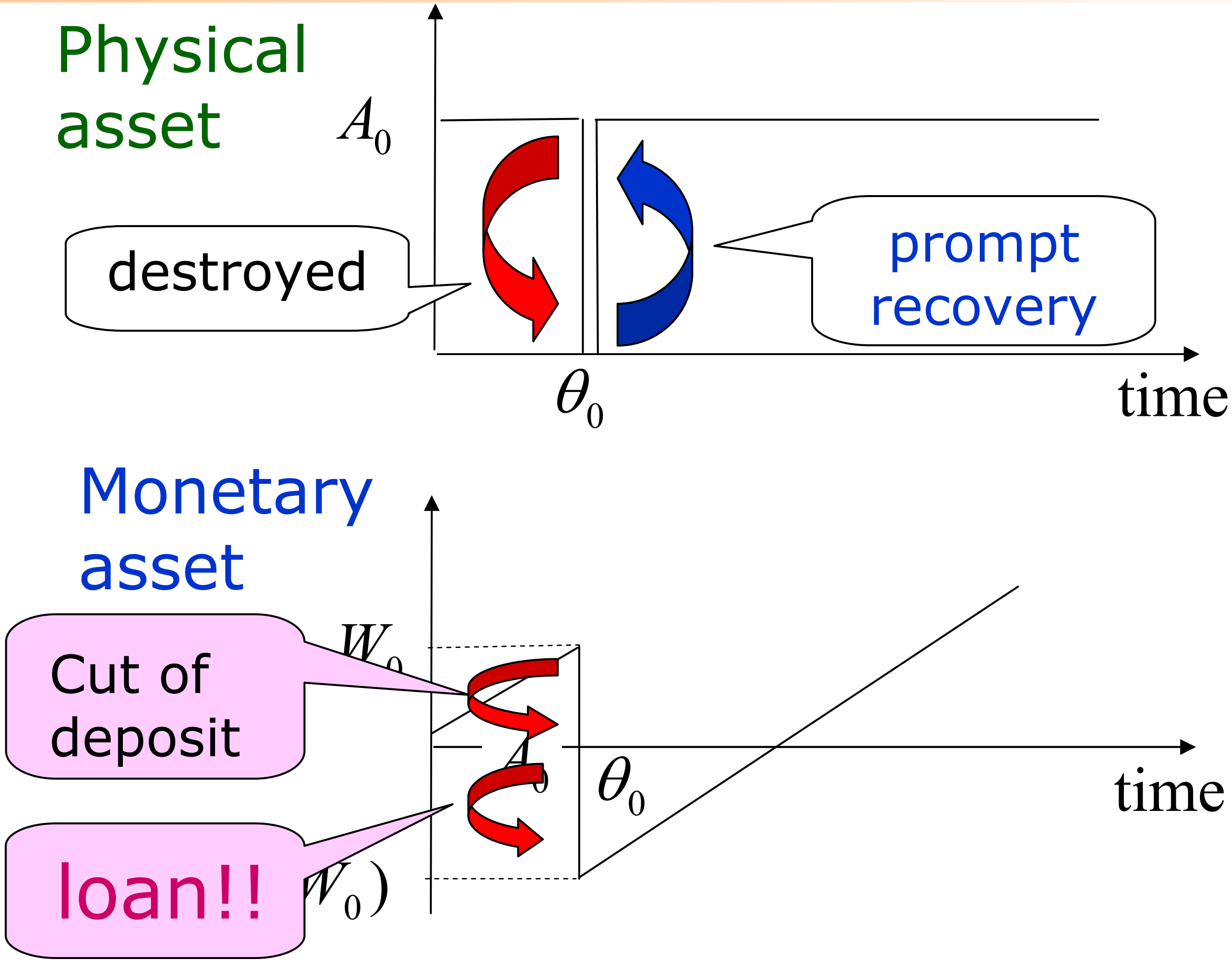
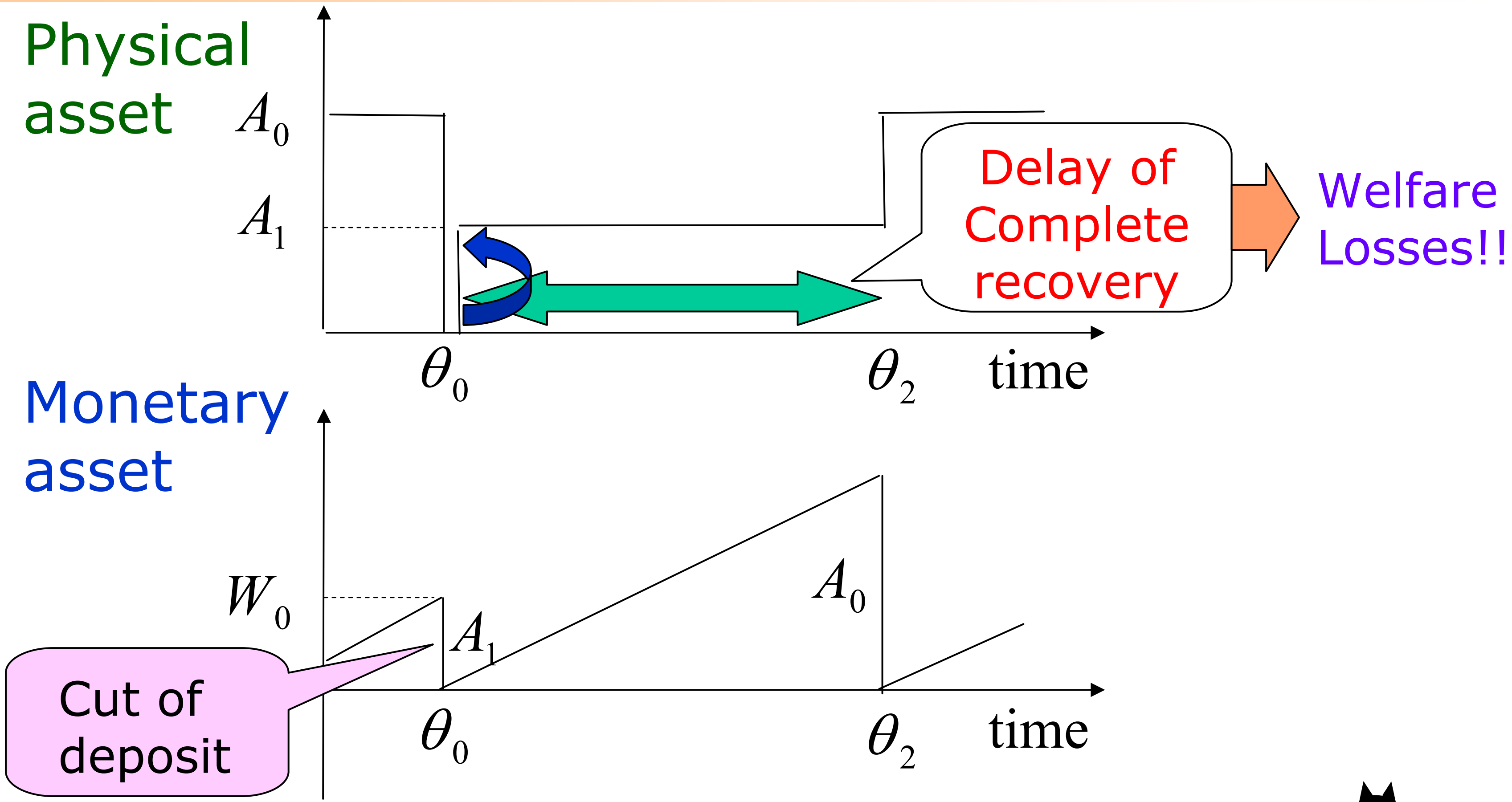


Figure 1. Recovery process without liquidity constraint

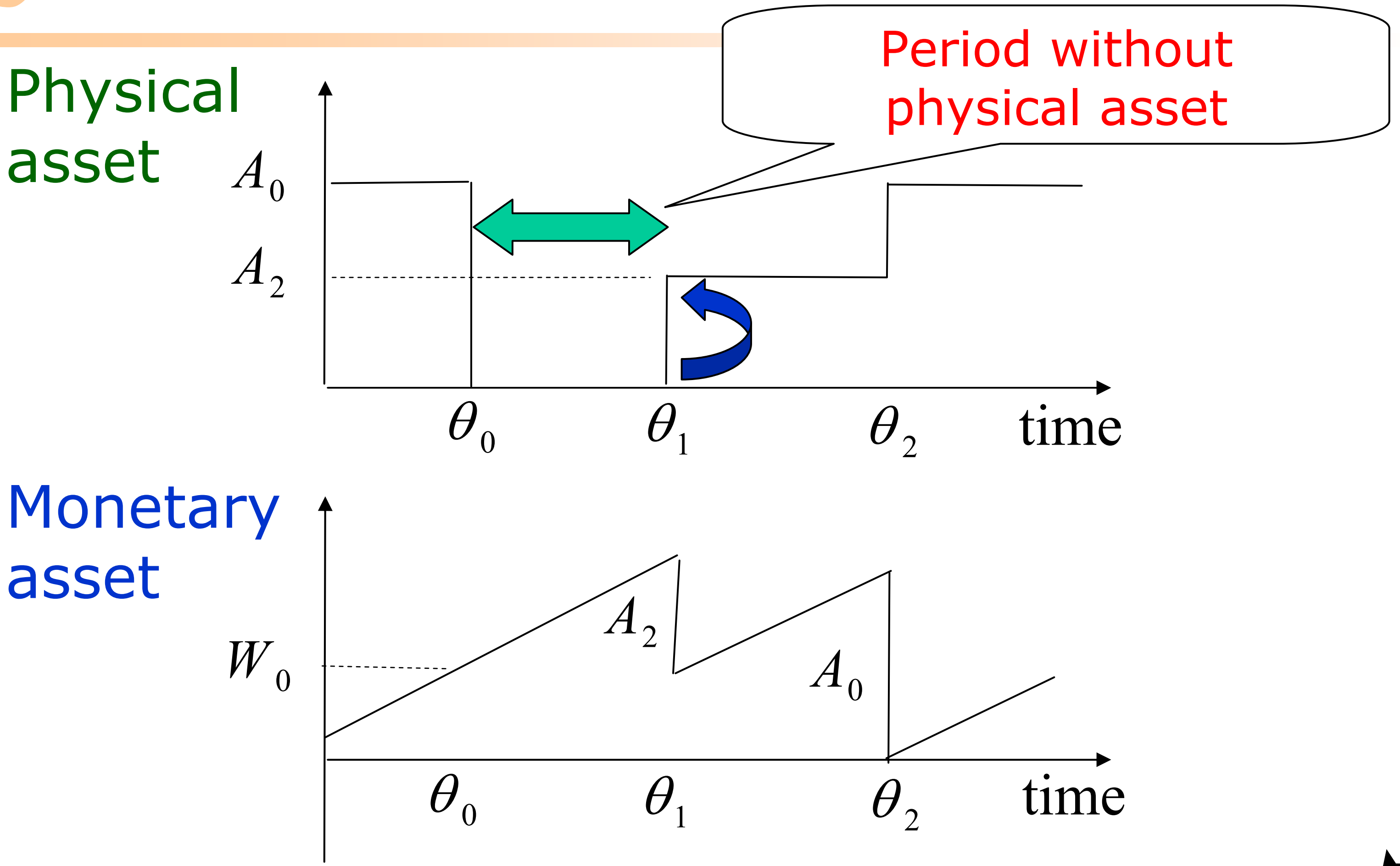
If a household can not go into debt at all…



a) Immediate partial-recovery

Figure 2. Recovery process with liquidity constraint

If a household can not go into debt at all…



b) Delayed partial-recovery

Figure 2. Recovery process with liquidity constraint

Refinement 2:
Objective of the study

1. Identify damage caused by liquidity constraint, “Liquidity damage”.
2. Figure out a function of insurance, “Liquidity supplement”.
3. Introduce economic valuation of disaster mitigation under liquidity constraint.

Assumptions

- Utility function in each periods $i(=1,2,\cdots)$

$$u_i(z_i,c_i)=v(z_i)+c_i$$

$$v(0)=0,\quad v'(z_i)>0,\quad v''(z_i)<0$$

z_i : Physical assets

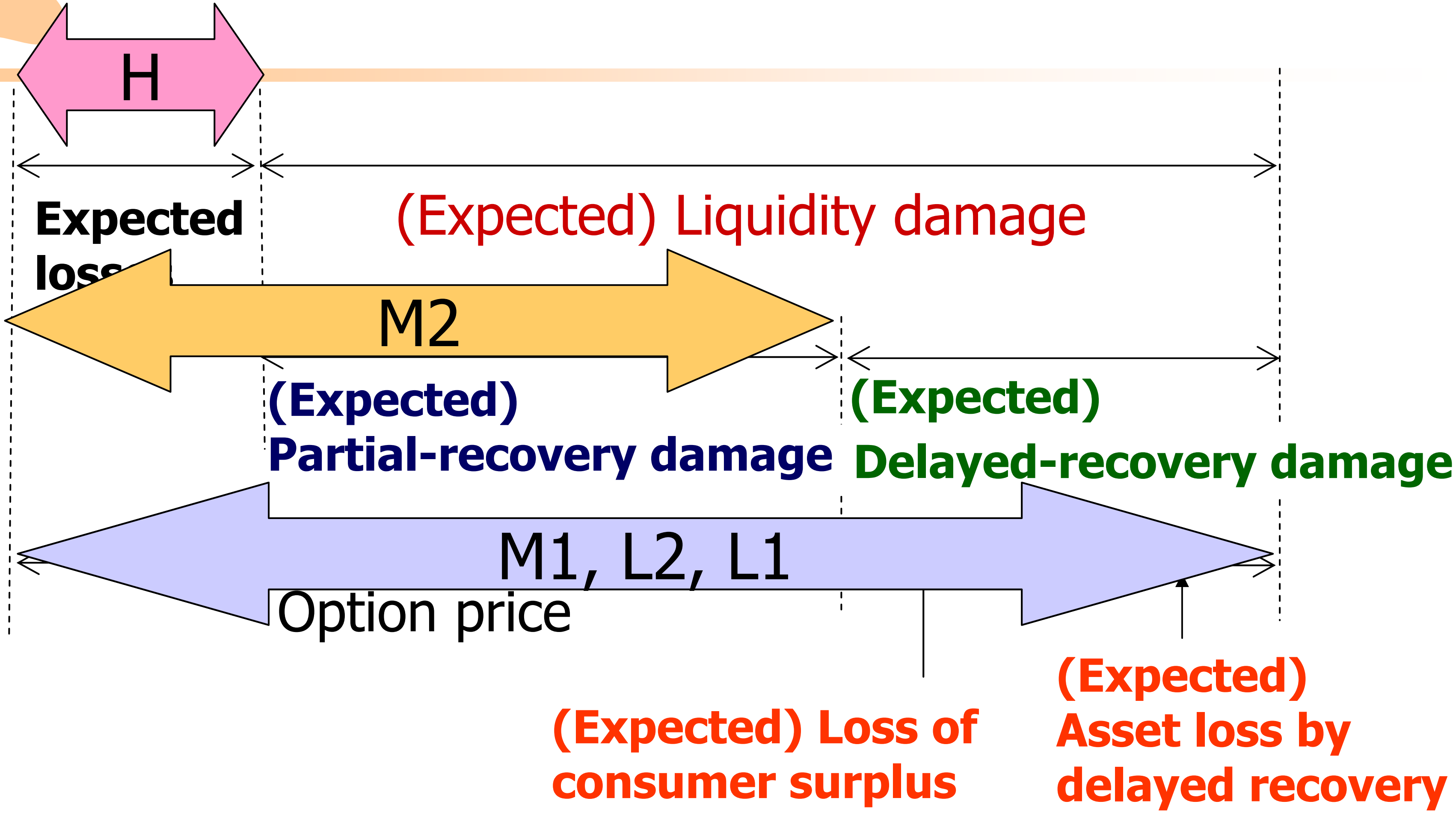
Durable for two periods

Replacement cycle

Optimal level, z^* : $\quad v'(z^*)=\dfrac{1}{2}$

c_i : Consumption

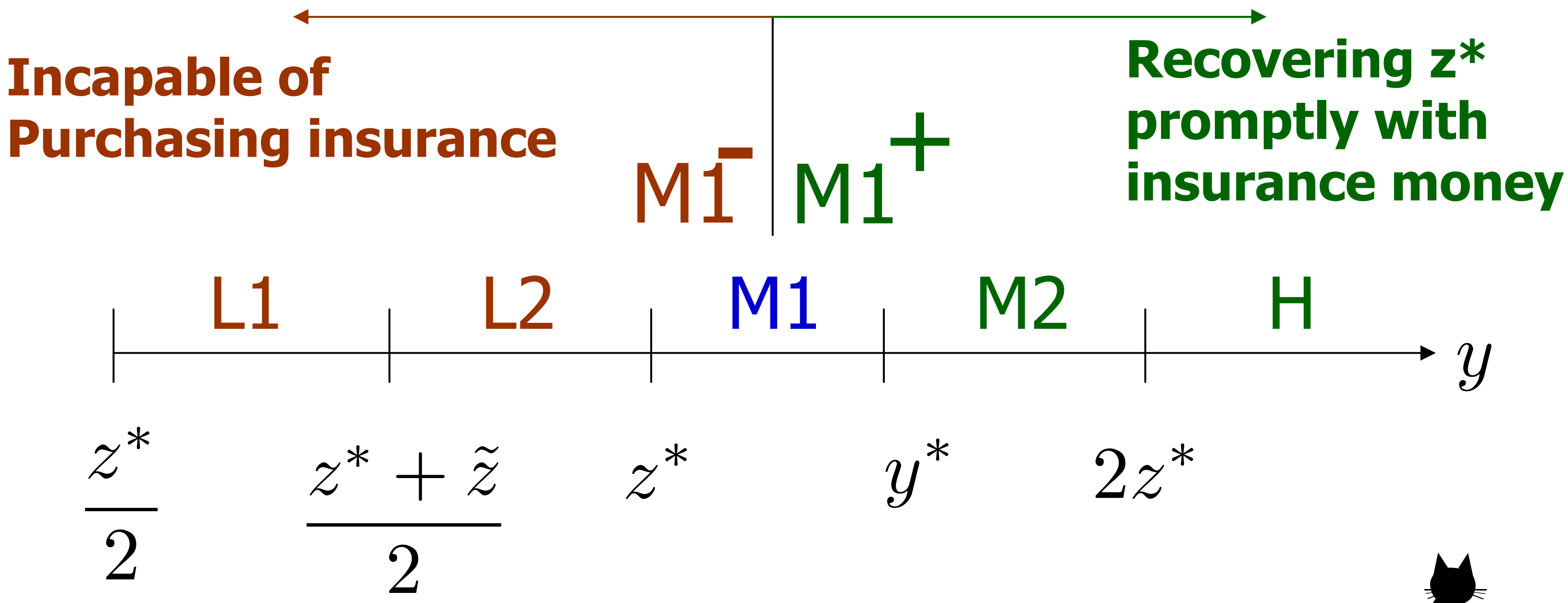
Composition of damage



Disaster prevention investment can mitigate every term of damage.

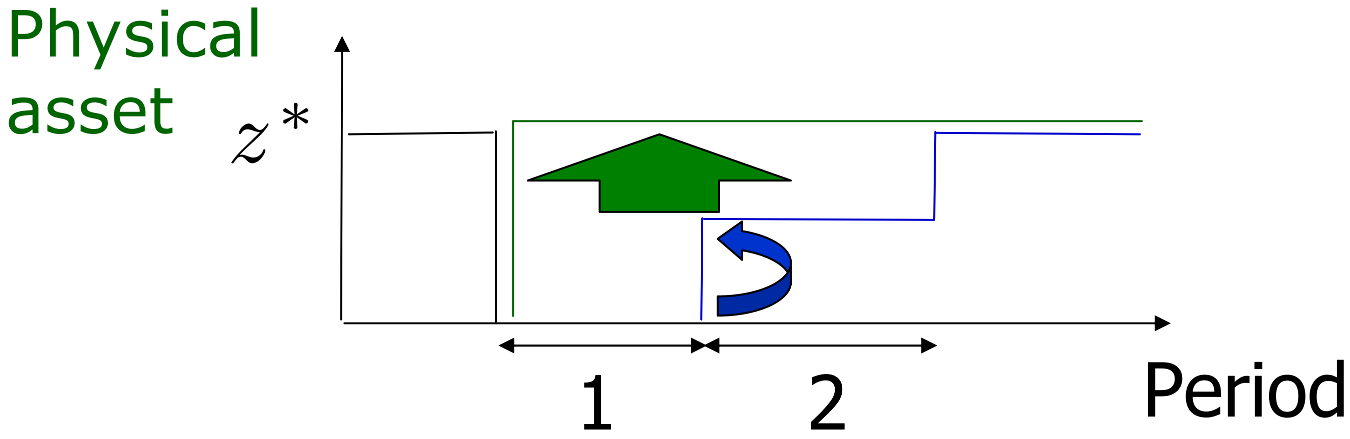
Disaster insurance

- Full-coverage insurance with fair premium, pz^*.



Value of insurance

Income class M1^{+}



Value of insurance

$$\phi(M_1^+) = p\Delta\tilde{C}(\tilde{z}) + pv(\tilde{z})$$

Expected partial-recovery damage   **Expected delayed-recovery damage**

= Liquidity damage

Value of insurance

Value of insurance = Liquidity damage

$$\phi(M_2) = p\Delta\tilde{C}(y - z^*)$$

Expected partial-recovery damage

$$\phi(H) = 0$$

(i.e. only conventional value based on risk aversion)

Value of insurance

Property

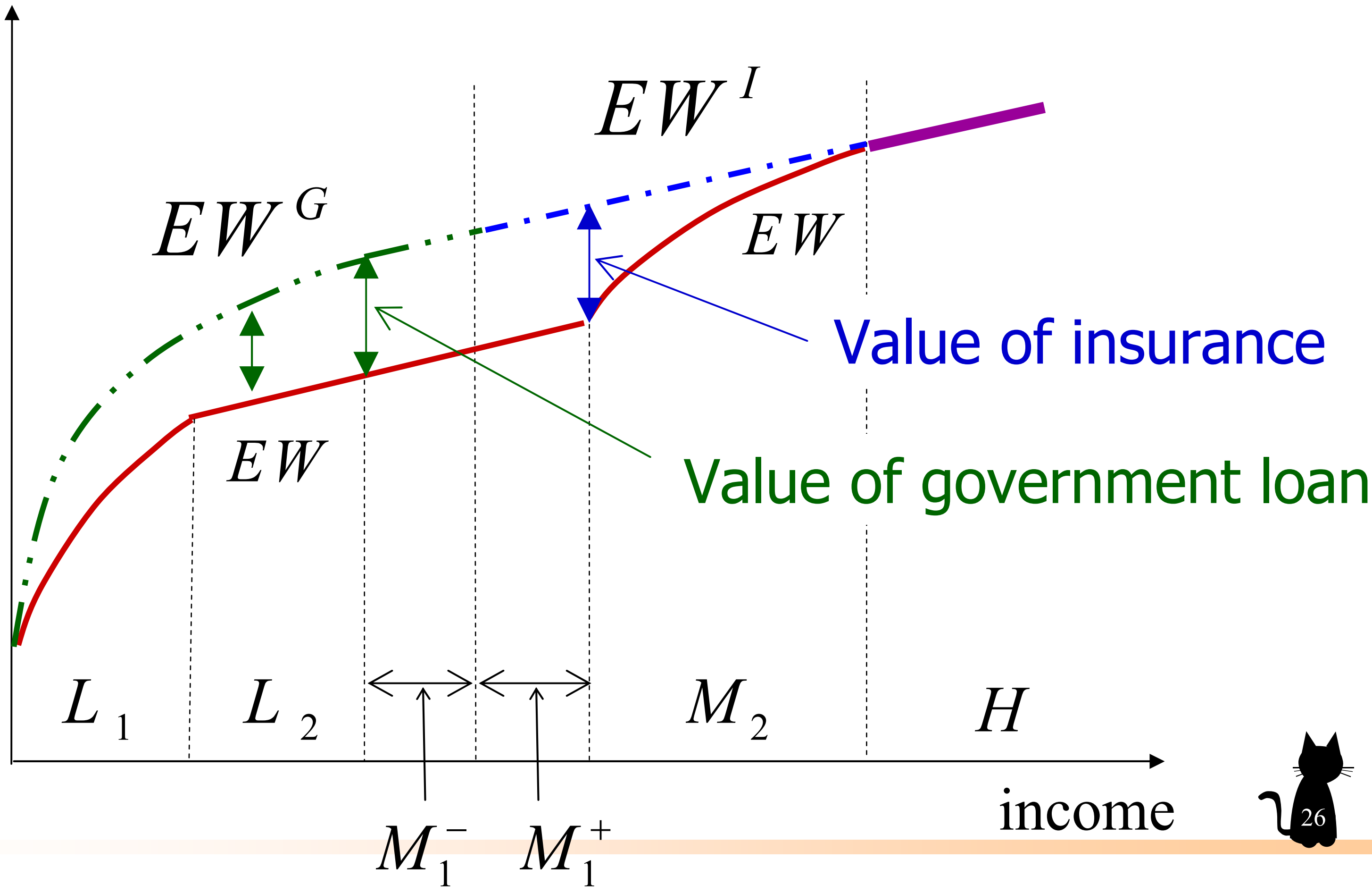
- With insurance, M1+ and M2 households can avoid Liquidity damage.
- As long as one can purchase insurance, value of insurance is higher in households with lower income.
- L1, L2 and M1- households can not purchase insurance.

(Conventional view)
Risk premium

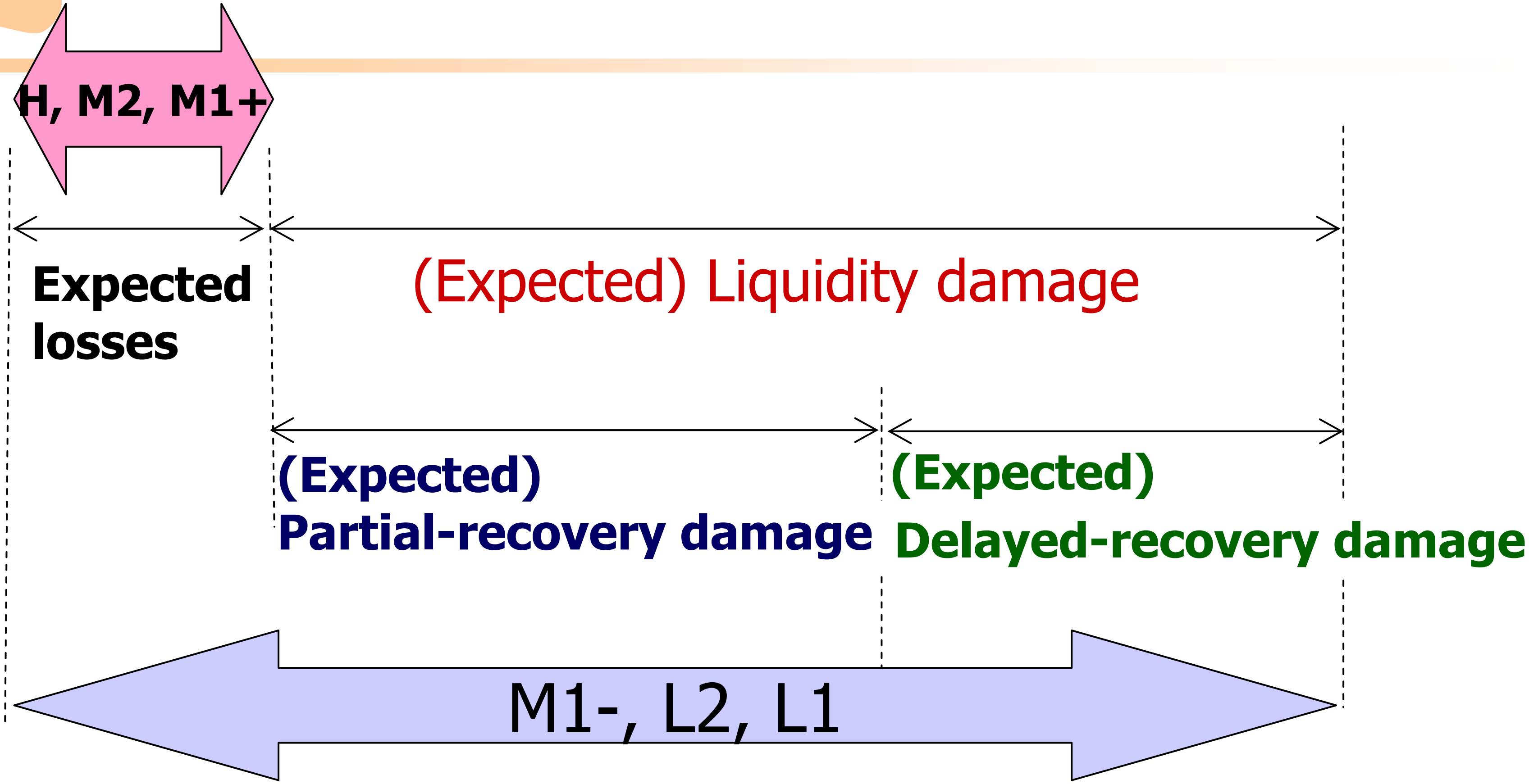
+"Liquidity premium"

Effect of insurance and government loan

Expected utility: *EW*



Economic valuation of mitigation



Disaster prevention investment can mitigate every term of damage. Moreover…

Since mitigation decreases the expected losses and insurance premium, it makes some M1- households capable of buying insurance.

⇒ Mitigation complements insurance function of "Liquidity supplement".

Conclusion

It is more beneficial to get durable assets as early as possible.

"Liquidity damage"

=Damage caused by liquidity constraint

Time required for accumulating money to purchase back the asset

➡ Losses caused by "money sleeping in drawer" for a while

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The Multi-Sector Open-Economy Model with Stochastic Energy Price

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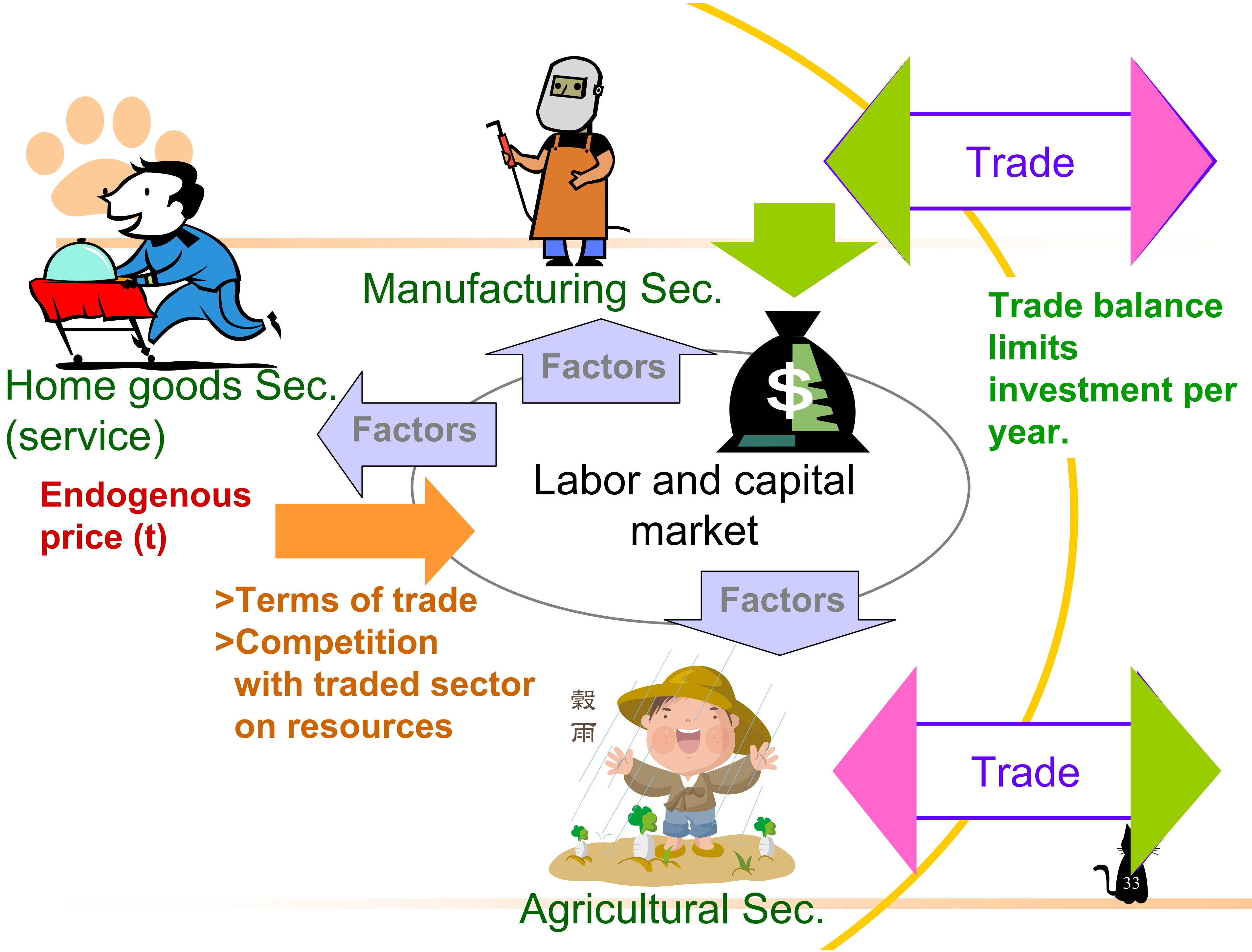
Kyoto University / University of Tokyo
On results working with Terry Roe and Rodney Smith,
University of Minnesota

International Seminar on Urban Infrastructure Management
March 25th, 2009, University of Tokyo

Four-sector open economy model:
Manufacture, Agriculture, Service and Energy

- Essential structure of economic growth is illustrated with the three-sector model.
- This study adds an energy sector as forth sector, whose price follows exogenous stochastic process.
- We investigate risk sharing among sectors and factors, and their resilience against shocks in growing process.


Trade
Manufacturing Sec.
Trade balance limits investment per year.
Home goods Sec. (service)
Factors
Factors
Labor and capital market
Endogenous price (t)
Factors
>Terms of trade
>Competition
with traded sector
on resources
穀雨
Trade
Agricultural Sec.

The process of energy price

- Geometric Ornstein-Uhlenbeck process with mean-reverting property

  (Bessembinder et al.(1995), Pindyck (1999))

$$\frac{dp_4}{p_4} = \gamma(\mu - p_4) \cdot dt + \underline{\sigma \cdot dz}$$

Mean 0
Variance $\sigma^2 dt$

$p_4(t)$: world energy price

μ : long-run expected equilibrium price

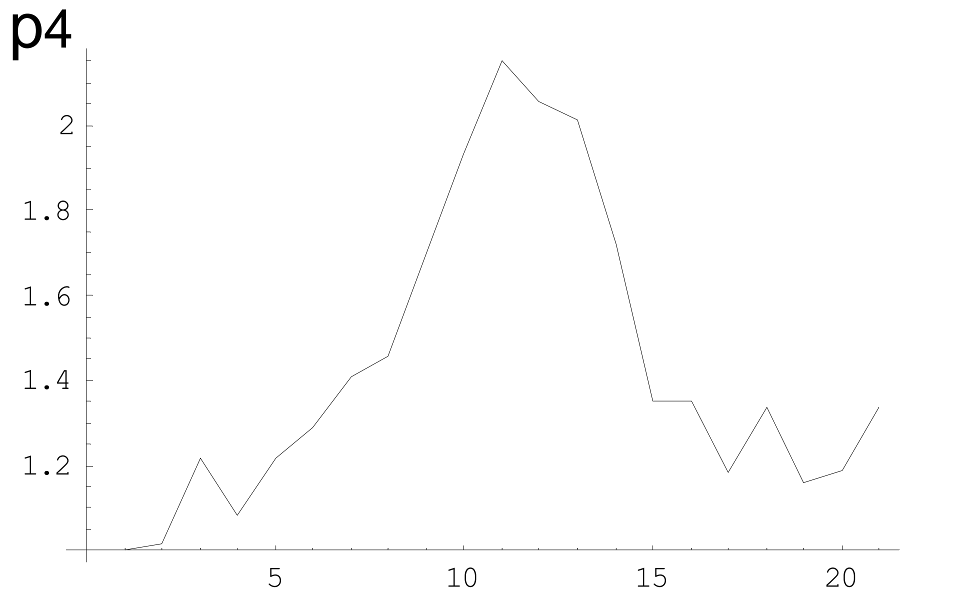
γ : reversion speed (>0)

σ : size of the variance of p4

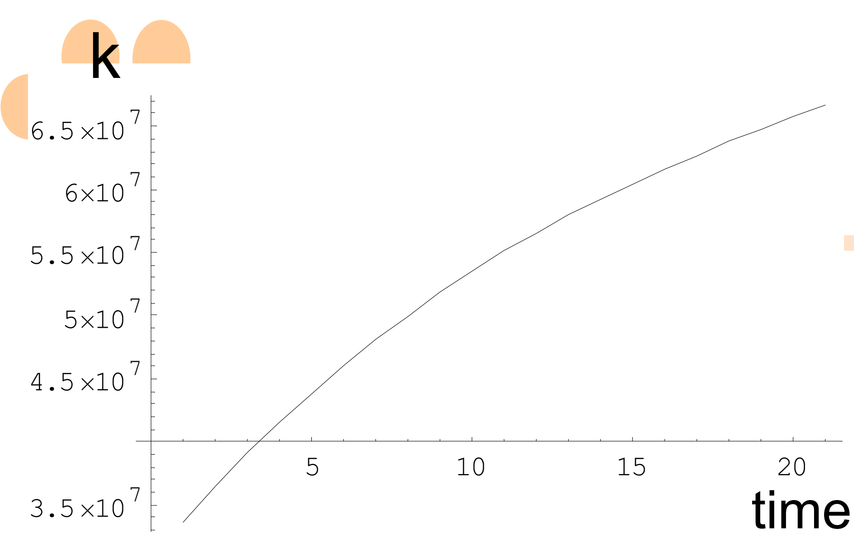
$dz(t)$: the standard Wiener increment

Simulation results

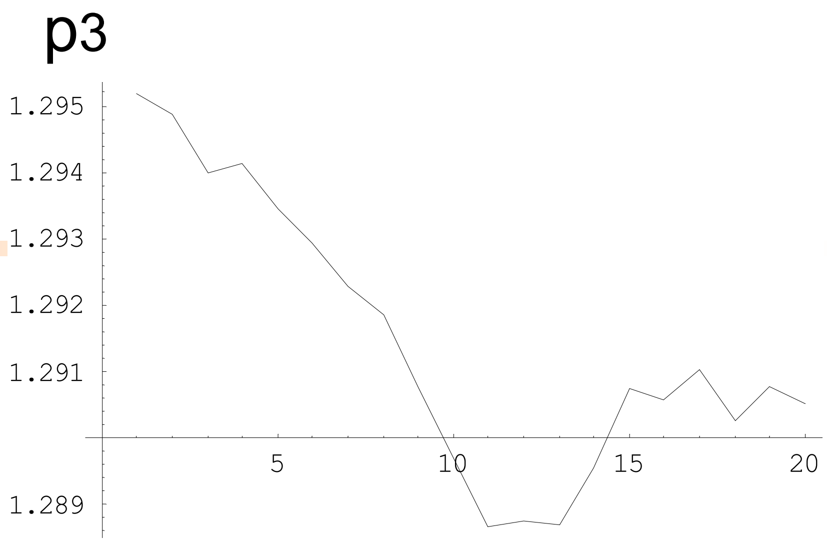
- Reversion speed, $\gamma = 0.03$ in the basic case



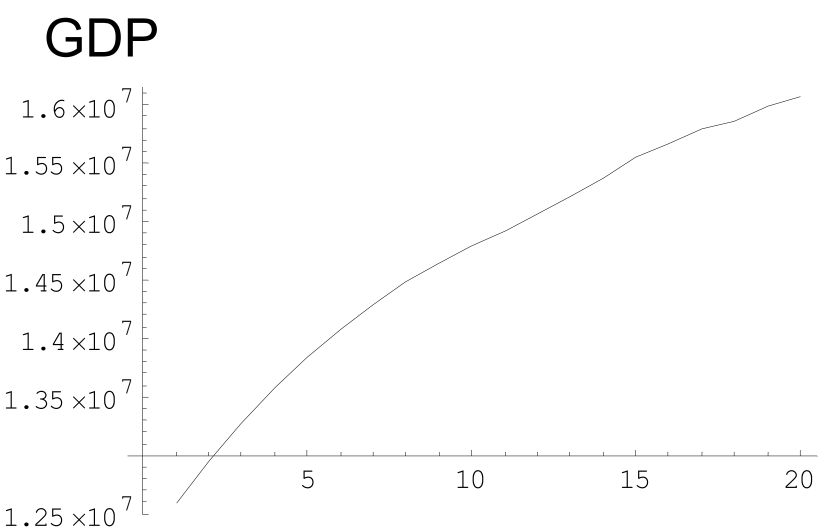
Sample path of energy price



Capital stock



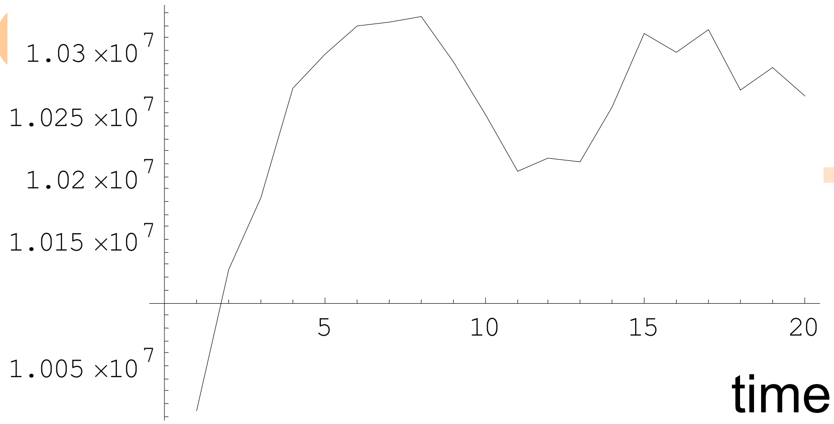
Price of service



GDP

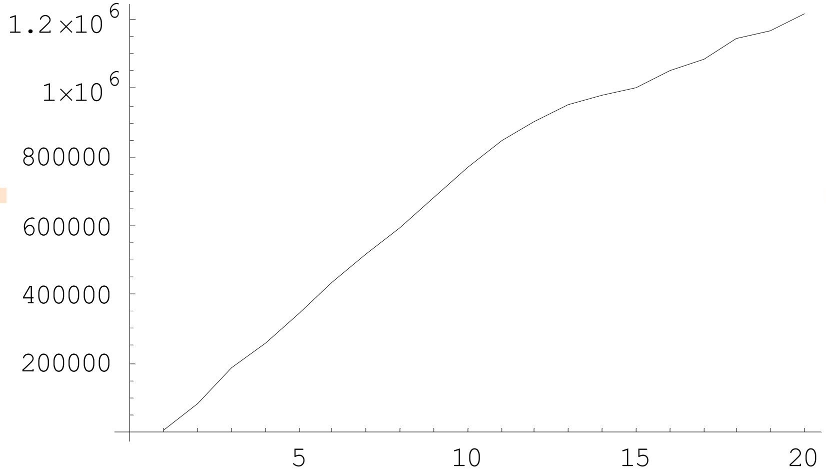
Serv. sector is capital intensive.

y1



Production of Mnf. sector

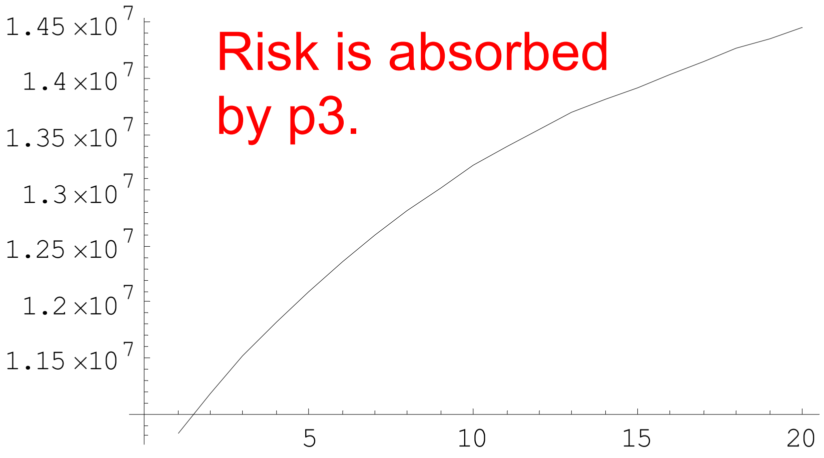
y2



Production of Ag. sector

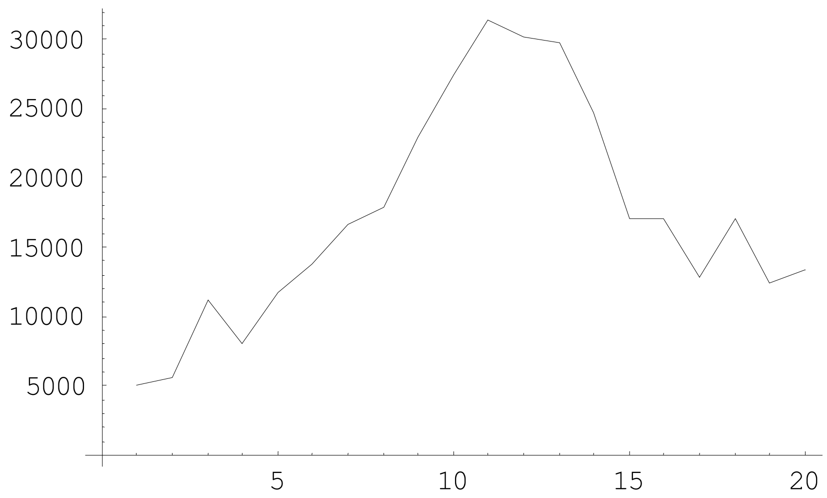
y3

Risk is absorbed by p3.

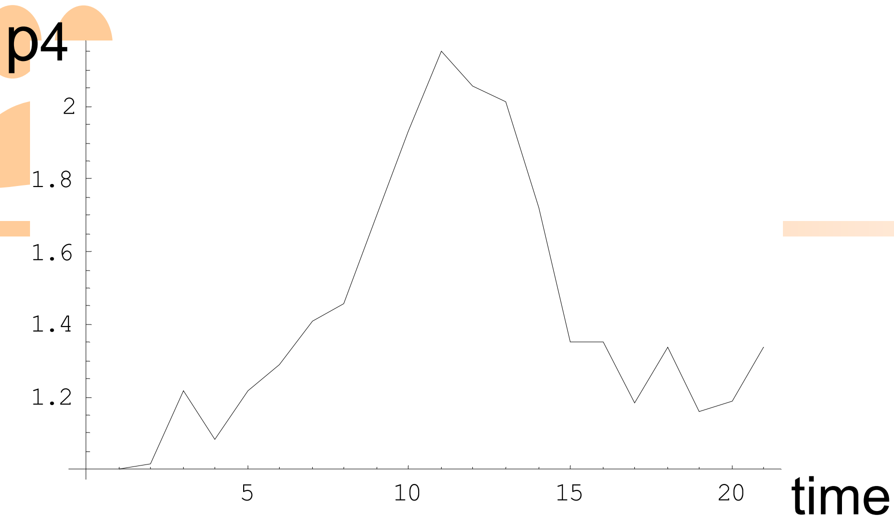


Production of Serv. sector

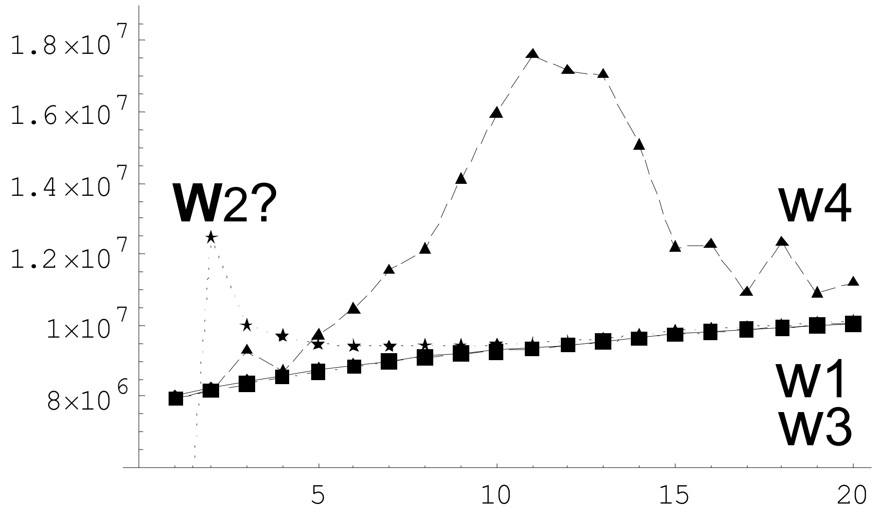
y4



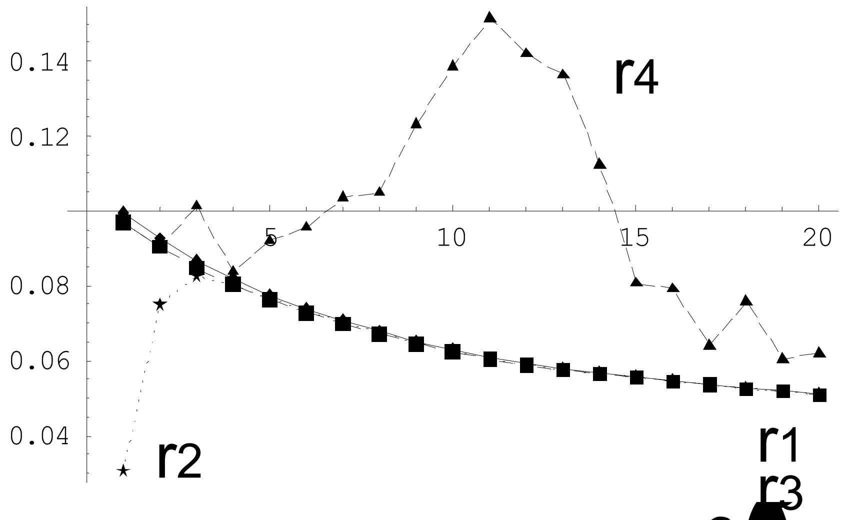
Production of Engy. sector



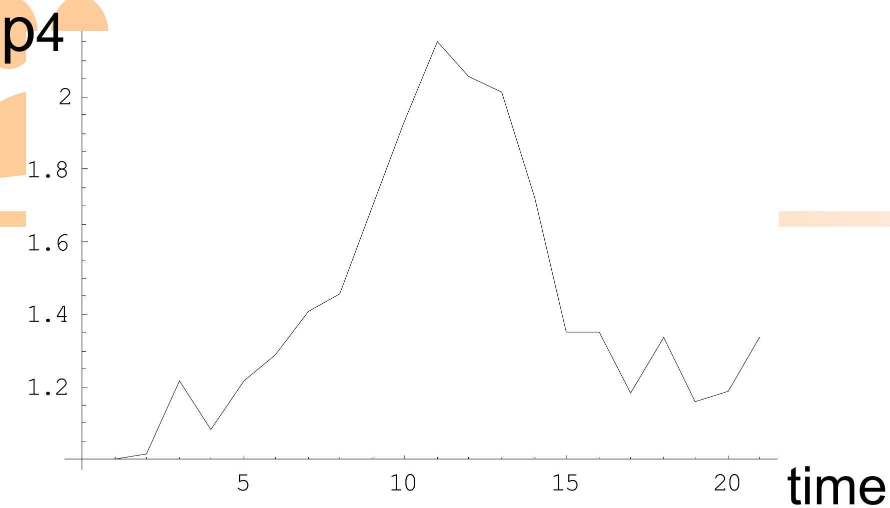
Sample path of energy price



Expected wage rates



Expected interests

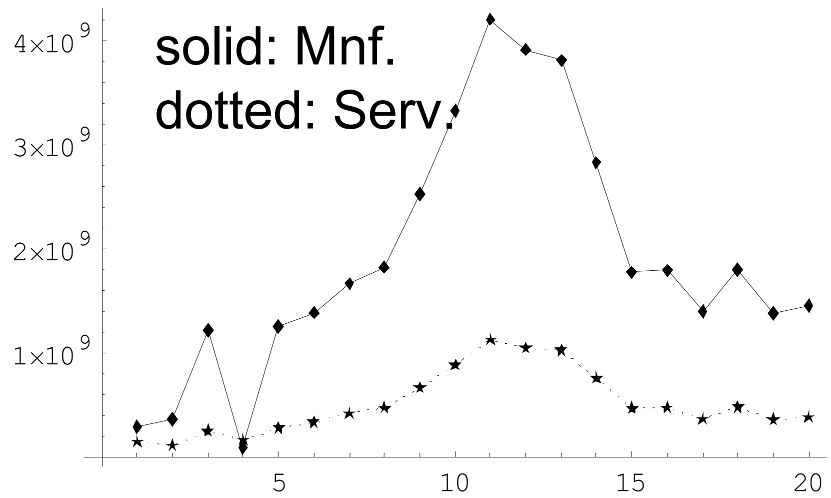


Sample path of energy price

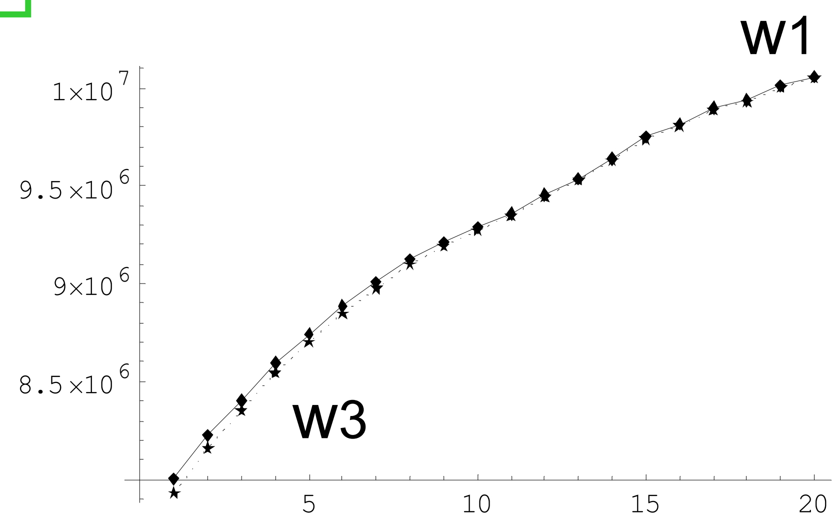
1. Wage in Mnf. sector is higher-risk-and-higher-return.

2. Variance of wage is correlated with the energy price.

3. Variance of Mnf. wage is more sensitive to fluctuation of p4.



Variance of wage rates of Mnf. and Serv. sec.



Expected wage rates of Mnf. and Serv. sec.