Measuring Economic Impact of a Disaster without Double Counting Based on Multi-Sector Economic Growth Models

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Backgrounds and Motivations

- Measuring economic impact of disaster is important for cost-benefit analysis for risk management countermeasures.
- “Double counting” must be avoided. Rose(2004)
- ->It is important to find the way to estimate total economic losses.

In the past studies,

- Total economic loss

=opportunity cost caused by both of "the disaster" and "restoration actions".

- To measure it, "foregone profit + restoration cost" is a consistent measure.
- The cost can also measured by the difference of discounted cashflows with/without disaster.

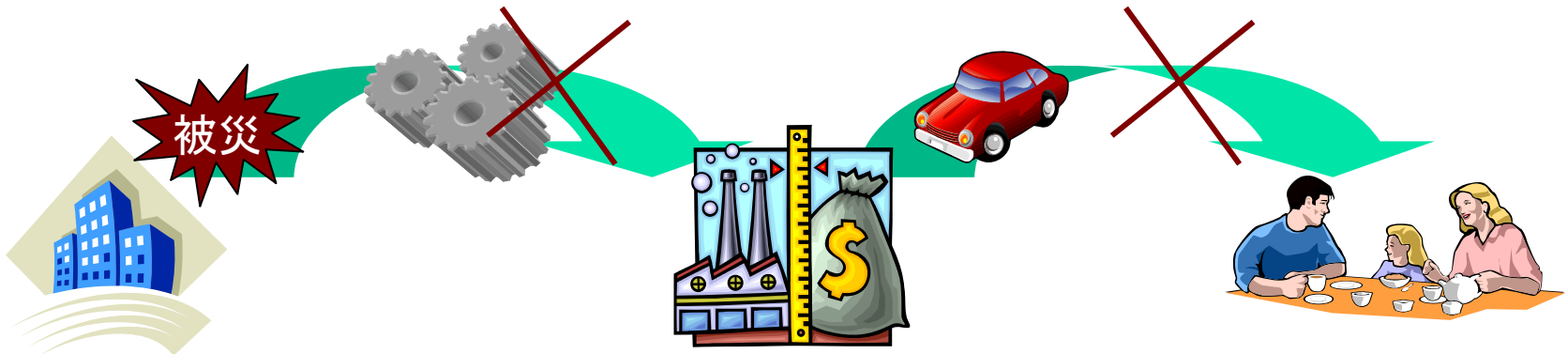
Tatano et.al. 2000, 2006

This paper

- investigates the measure of the total economic loss in an entire economy which includes industrial sectors and households in a open economy.
- ―＞economic growth theory
- We focused on the “cascade effect” in the context of substitutability conditions.

Cascade Effect

- is a spillover effect of economic loss under a mutual relationship between industrial sectors.
- is a factor enlarging economic impact.

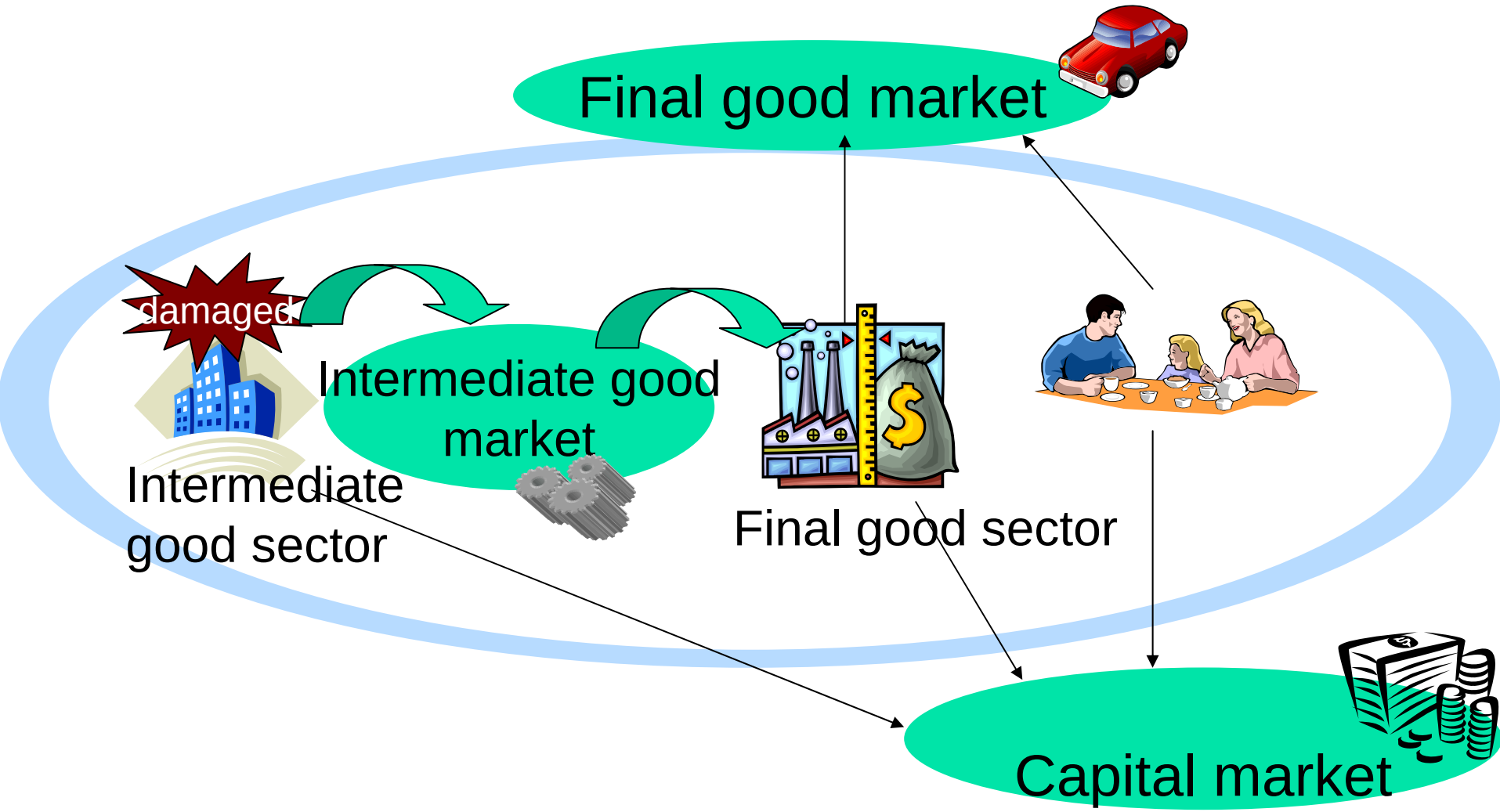


Intermediate good sector

Final good sector

Household

The model


Final good market
damaged
Intermediate good market
Intermediate good sector
Final good sector
Capital market

Formulation of firms

Intermediate good sector

$$\max \int_0^{\infty} (qF(K_1, L_1) - I_1(1 + T(I_1 / K_1)) - wL_1) e^{-rt} dt$$

Production

Investment (adjustment cost)

Labor

s.t.

$$\dot{K}_1 = I_1$$

Capital accumulation equation

$$K_1(0) = given$$

Final good sector

$$\max \int_0^{\infty} (pH(K_2, Z_1^2, L_2) - I_2 - qZ_1^2 - wL_2) e^{-rt} dt$$

Production

Investment

Intermediate input

Labor

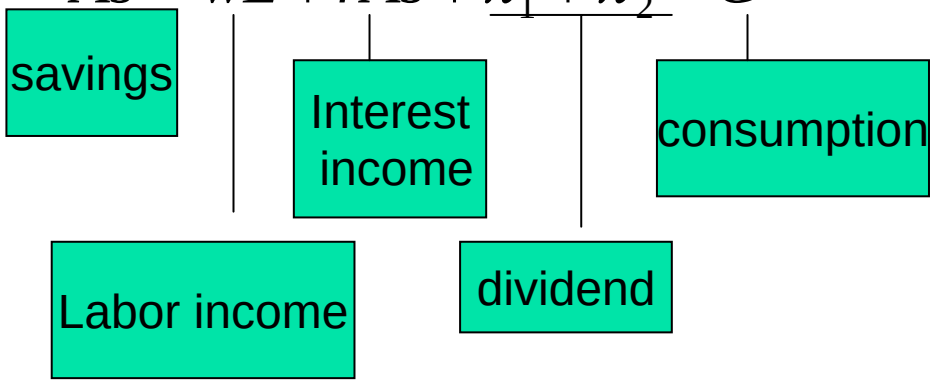
$$\dot{K}_2 = I_2$$

$$K_2(0) = given$$

Formulation of household

$$\max \int_0^{\infty} u(C)e^{-\rho t}dt$$

s.t. $A\dot{s} = wL + rAs + \pi_1 + \pi_2 - C$ ->budget constraint equation

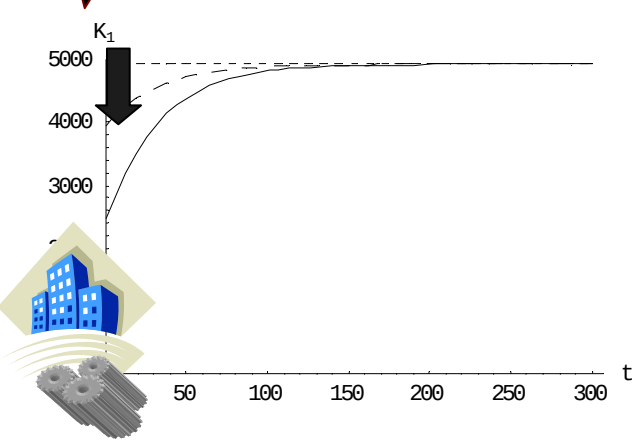


Representation of a Disaster

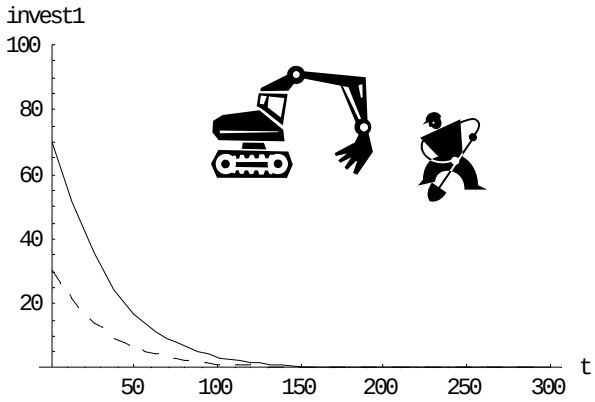
- Assumption: discount factor=interest rate $\rho = r$
- In this model, economy converges to a steady state, in which the economic growth rate is zero.
- A disaster brings about downward jump of capital of intermediate goods industry from the steady state.
- Final good sector will suffer indirect loss because of the decrease of factor input from intermediate good sector.
  - Assumption: The intermediate good market is assumed closed and no other means for purchasing intermediate good except for the damaged domestic industry.
- Households borrow money from international capital market and invest for the industry. (Recovery investment)

Economic impact in the intermediate good sector

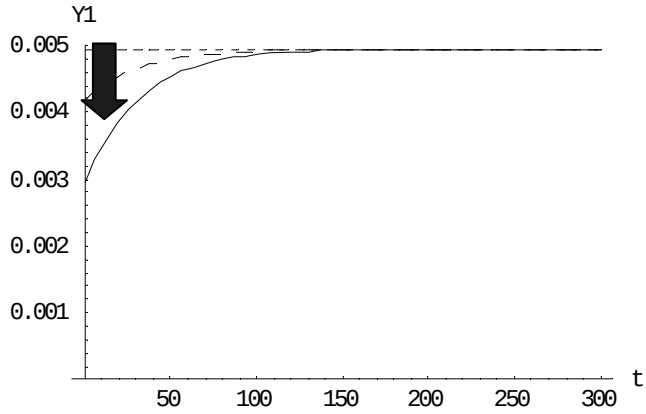
damage



Capital recovery process



Recovery investment



Production recovery process

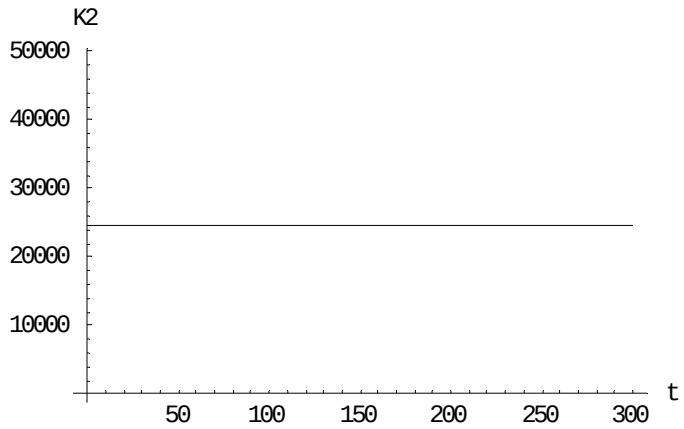
$$\int_{\tau}^{\infty} (q^{*}Y_1^{*} - \hat{q}\hat{Y}_1 + \hat{I}_1(1+T(\hat{I}_1/\hat{K}_1))e^{-r(t-\tau)}dt = \int_{\tau}^{\infty} (\pi_1^{*} - \hat{\pi}_1)e^{-r(t-\tau)}dt$$

Foregone revenue

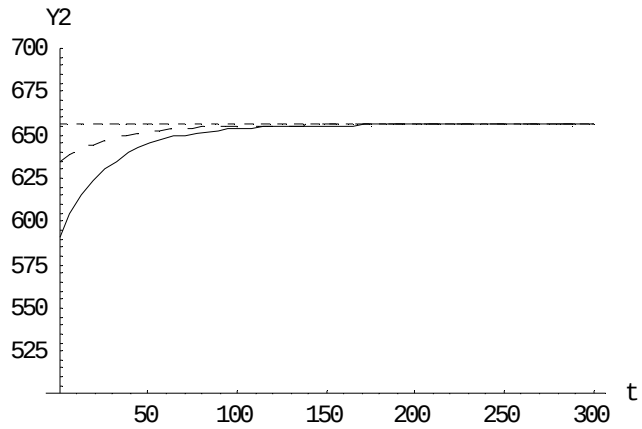
Recovery investment

Present value of difference of cashflows

Economic impact in the final good sector



No capital damage



Production recovery process (caused by the decrease of intermediate input)

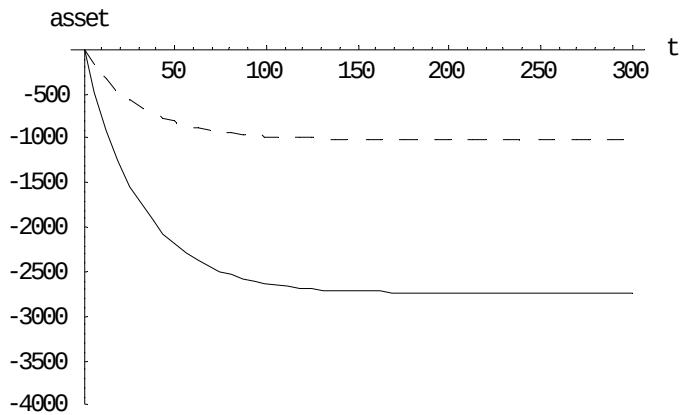
$$\int_{\tau}^{\infty} (pY_2^* - q^*(Z_1^2)^* - (p\hat{Y}_2 - \hat{q}\hat{Z}_1^2))e^{-r(t-\tau)}dt = \int_{\tau}^{\infty} (\pi_2^* - \hat{\pi}_2)e^{-r(t-\tau)}dt$$

Foregone Added Value

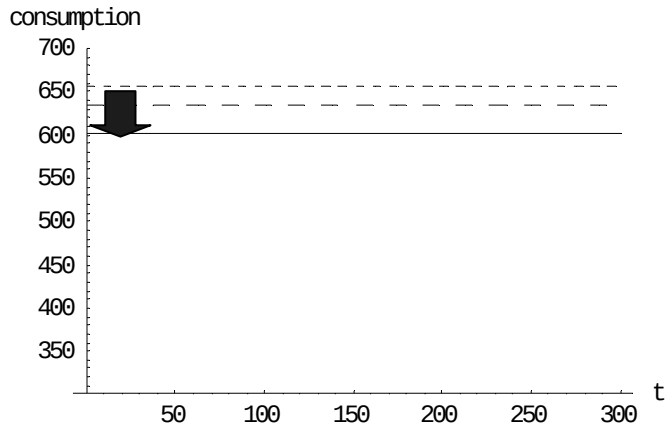
Present value of difference of cashflows

Economic impact in the household sector

【increase of debt】



【decrease of consumption】



Decline of utility in each period measured by CV

$$r\int_{\tau}^{\infty}(\pi_1^{*}-\hat{\pi}_1+\pi_2^{*}-\hat{\pi}_2)e^{-r(t-\tau)}dt$$

Economic loss of household is measured by

$$\int_{\tau}^{\infty}(\pi_1^{*}-\hat{\pi}_1+\pi_2^{*}-\hat{\pi}_2)e^{-r(t-\tau)}dt$$

Table of loss measured in each sector

Industry	Household
Intermediate good sector Foregone revenue $\int_{\tau}^{\infty}(q^{*}Y_{1}^{*}-\hat{q}\hat{Y}_{1})e^{-r(t-\tau)}dt$ Restoration investment $\int_{\tau}^{\infty}\hat{I}_{1}(1+T(\hat{I}_{1}/\hat{K}_{1}))e^{-r(t-\tau)}dt$	Decline of utility $V_{1}^{*}-V_{1}^{-}+V_{2}^{*}-V_{2}^{-}$
Final good sector Foregone value added $\int_{\tau}^{\infty}(AV_{2}^{*}-A\hat{V}_{2})e^{-r(t-\tau)}dt$	
total $V_{1}^{*}-V_{1}^{-}+V_{2}^{*}-V_{2}^{-}$	total $V_{1}^{*}-V_{1}^{-}+V_{2}^{*}-V_{2}^{-}$

Findings:

If a disaster only brings about capital loss,

Total loss in the economy

≠ Total loss in industrial sectors

+ total loss in household sector

We should not sum up losses in households and industries!

Total loss in the economy

= Total loss in industrial sectors

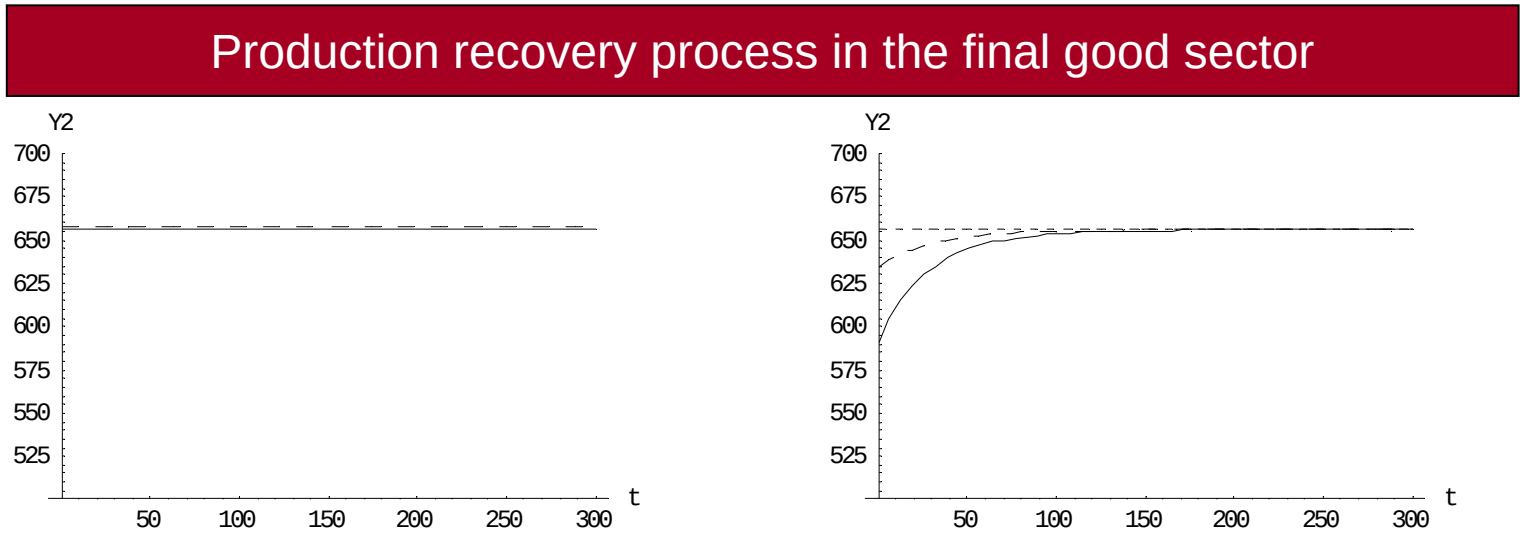
= Total loss in household sector

How to Measure the Cascade Effect Separately

- If the intermediate good can be obtained at the same price as the equilibrium price before the disaster, then as long as the final goods sector does not damaged, the demand for the intermediate input would be unchanged. Thus, production of the final goods would not be affected.

Comparison of restoration process between the case which Intermediate good market is Open and Close

Cascade effect is induced when the intermediate good market is closed.



Open

Close

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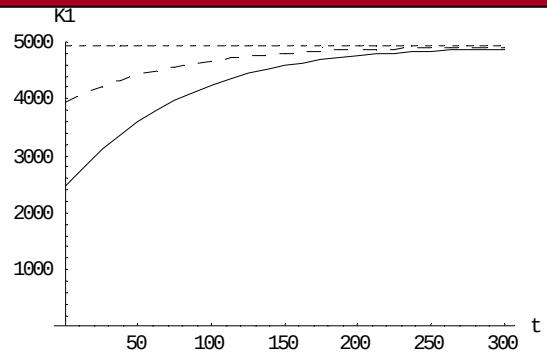
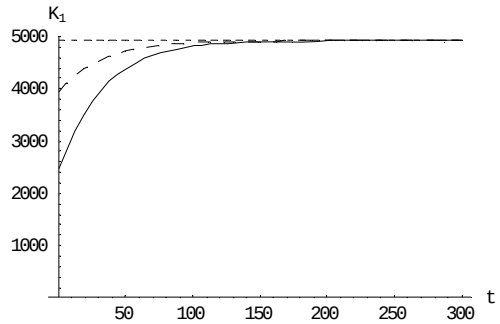
Comparison of restoration process between the case which Intermediate good market is Open and Close

capital recovery process in the intermediate good sector

Open

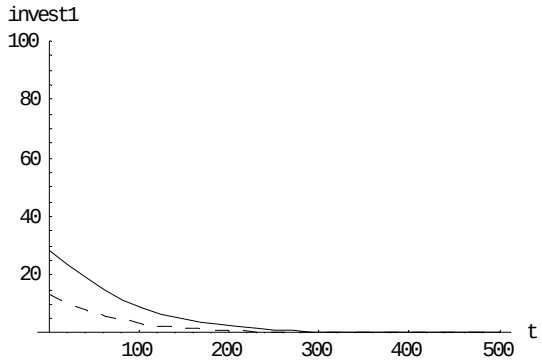


Close

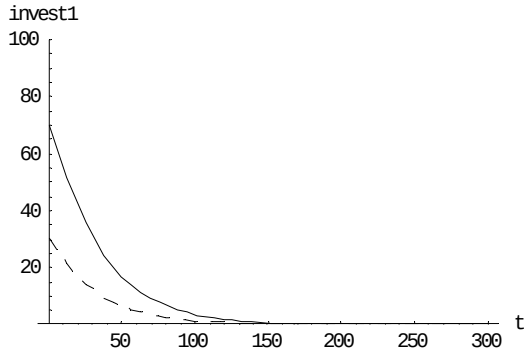


Recovery investment in the intermediate good sector

Open



Close



How to Measure the Cascade Effect Separately

- Difference of economic loss between the cases of open and closed intermediate good market.
- Actural case – Completely substitutable case

Table of loss in each sector when cascade effect is measured separately

industry	Household
Intermediate goods sector Foregone Revenue (Cascade Effect) $\int_{\tau}^{\infty}(q^{*}\tilde{Y}_1-\hat{q}\hat{Y}_1)e^{-r(t-\tau)}dt$ Foregone Revenue (Primary Effect) $\int_{\tau}^{\infty}q^{*}(Y_1^{*}-\tilde{Y}_1)e^{-r(t-\tau)}dt$ Restoration Investment (Cascade Effect) $\int_{\tau}^{\infty}(\hat{I}_1(1+\hat{T})-\tilde{I}_1(1+\tilde{T}))e^{-r(t-\tau)}dt$ Restoration Investment (Primary Effect) $\int_{\tau}^{\infty}\tilde{I}_1(1+\tilde{T})e^{-r(t-\tau)}dt$	Decline of Utility (Cascade Effect) $\tilde{V}_1-V_1^{-}+V_2^{*}-V_2^{-}$ Decline of Utility (Primary Effect) $V_1^{*}-\tilde{V}_1$
Final goods sector Foregone Added Value (Cascade Effect) $\int_{\tau}^{\infty}(AV_2^{*}-A\hat{V}_2)e^{-r(t-\tau)}dt$	
Total $V_1^{*}-V_1^{-}+V_2^{*}-V_2^{-}$	Total $V_1^{*}-V_1^{-}+V_2^{*}-V_2^{-}$

Summary

- The sum of the net present value of the difference of the cash flows between with and without the disaster over industrial sectors is the consistent total economic losses of the entire economy, if capital stock of an industrial sector is decreased in a discrete way by a disaster.
- Total losses in household sector is identical to industrial sector if the losses only occurs as a decrease of production capital.
- Cascade effects are brought about the economy because of the low substitutability of factor inputs. Hence, cascade effects can be measured by substituting total loses in the completely substitutable case from total losses in actual case.
- The cascade effects are shown to be estimated and to affect both foregone profit and recovery investment.

Thank you for your attention!

Total loss in the economy

$\neq$ Total loss in industrial sectors + total loss in household sector

Total loss in the economy

= Total loss in industrial sectors

= Total loss in household sector