GEOBENE

Will GEO Work? – An Economist's View

Alexey Smirnov

Michael Obersteiner

IIASA

33rd International Symposium on Remote Sensing of Environment (ISRSE-33)
4–8 May 2009, Stresa, Lago Maggiore, Italy

Background

- **GEO**
- **GEOSS**
  - G8 initiative to bring observing systems in line to address concerns of society
  - 9 Benefit Areas which a perfect GEO system should cover *(Disaster, Health, Energy, Climate, Water, Weather, Ecosystems, Agriculture and Biodiversity)*
- **GEO-BENE**
  - Assessment of economic, social and environmental benefits of improved information provided in the context of GEOSS in the short and long-term

Modeling

- Aggregated macroeconomic model of a society under the threat of extreme events (catastrophes)
- **GEOSS:**
  - Preventive measures to increase society’s welfare
- **Global Partnership:**
  - “Investment Game” in multi-society world

Model

Stylized neoclassical model of the development of an economy affected[1] by random natural hazards

Capital stock dynamics: $K_{i+1} = ((1-\delta)K_i + I_{i+1}) \cdot D_{i+1}, \quad i = 0,1,\ldots,\infty$

Here K_i – capital, D_i – extreme event (random variable),

I_i – investment, C_i – consumption

Production output $Y_{i+1} = \alpha K_i$

Step 1: $Y_1 = I_1 + C_1 + z$

Step $i>1$: $Y_{i+1} = I_{i+1} + C_{i+1}$

investment in the development of prevention measures

Social planner chooses consumption level in order to maximize the economy's utility, expected value of the social welfare

$$W(z) = \max_{C_i} E\left(\sum_{i=0}^{\infty} (1+\rho)^{-i} \ln C_{i+1} \right)$$

[1] Z. Chladna, E. Moltchanova, and M. Obersteiner, "Prevention of Surprise", in: S. Albeverio, V. Jentsch, H. Kantz (Eds.), Extreme Events in Nature and Society, Springer, vol. 352, pp. 295–318, 2006.

Model

Capital stock dynamics:

$$K_{i+1} = ((1-\delta)K_i + I_{i+1}) \cdot D_{i+1}, \quad i = 0,1,\ldots,\infty$$

Extreme event D_i occurs with probability q_i causing the loss of fraction d of the capital stock:

$$D_i = \begin{cases} 1-d, & \text{with probability } q_i \\ 1, & \text{with probability } 1-q_i \end{cases}$$

Probability q_i endogenously depends on the preventive measures z

$$q_i = \frac{q_0}{1+\kappa z}, \quad i = 1,2,\ldots$$

Here q_0 is the probability of disasters without any preventive measures, and κ is a given positive coefficient characterizing the efficiency of investment.

Optimal Welfare

Proposition[2]**.** *For every* $z \in [0, \alpha K_0)$ *, the optimal social welfare W(z) has the following form*

$$W(z) = \log(1 - s_0) + \frac{1}{\rho}\log\big((1-\delta)K_0 + s_0(\alpha K_0 - z)\big) + \log(\alpha K_0 - z) + \frac{1}{\rho}\log\rho + \frac{1+\rho}{\rho^2}\log\rho\left(\frac{\alpha+1-\delta}{1+\rho}\right)$$

where

$$s_0 = \begin{cases} \frac{\alpha K_0 - z - \rho(1-\delta)K_0}{(\alpha K_0 - z)(1+\rho)} & \text{if } z < (\alpha + \rho\delta - \rho)K_0, \\ 0 & \text{otherwise} \end{cases}$$

[2] A. Kryazhimskiy, M. Obersteiner, and A. Smirnov, “Infinite-horizon dynamic programming and application to management of economies effected by random hazards ”, Appl. Math. Comput., 205, pp. 609–620, (doi:10.1016/j.amc.2008. 05.042), 2008.

Optimal Preventive Measures

How big should be the investment *z* into preventive measures to provide the best value for the social welfare?

Optimal investment problem:

$$\text{Maximize } W(z) \text{ over all } z \in [0, \alpha K_0).$$

Proposition. *Optimal investment problem has the unique solution z*. If*

$$\kappa K_0 \left| q_0 \log(1-d) \right| \le \frac{\rho(1+\rho)}{1+\alpha-\delta},$$

then z=0, otherwise z* is positive (for exact formula see ([2]).*

[2] A. Kryazhimskiy, M. Obersteiner, and A. Smirnov, “Infinite-horizon dynamic programming and application to management of economies effected by random hazards ”, Appl. Math. Comput., 205, pp. 609–620, (doi:10.1016/j.amc.2008. 05.042), 2008.

Optimal Preventive Measures

Qualitative conclusion

- Economy refrains from investing in the prevention measures if its ability to cope with natural hazards (κK_0) is low, or the measure of danger, caused by natural hazards ($|q_0 \log(1-d)|$) is not high enough.

Investment Game

- Two independent economies both under the threat of natural disasters

- Each of the economies can make an investment (z^1, z^2) in common prevention measures aimed at mitigating the impact of natural hazards on both economies

- Each economy is subject the same dynamics as on the previous slides but with its own set of parameters (indicating by corresponding indexes).

Investment Game

Effect of joint investments is achieved by the modification of the rule how probability of the occurrence of natural hazards changes after the implementation of prevention measures

$$q_i = \frac{q_0}{1+\kappa^1 z^1 + \kappa^2 z^2}, \quad i = 1,2,\dots$$

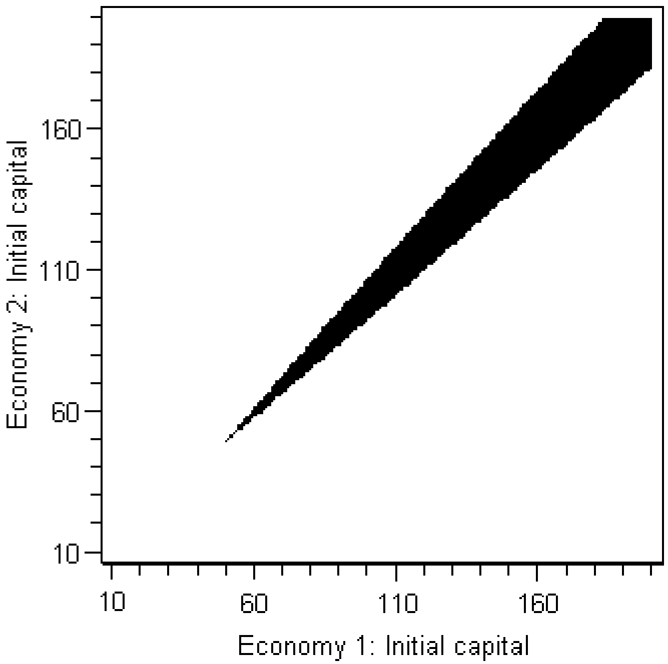
Each economy is maximizing its own welfare

$$\text{Maximize}\, W_1(z^1, z^2) \text{ over all } z^1 \in [0, \alpha^1 K_0^1).$$

$$\text{Maximize}\, W_2(z^1, z^2) \text{ over all } z^2 \in [0, \alpha^2 K_0^2).$$

Proposition. *Non-zero-sum game of preventive investments always has a unique Nash equilibrium solution (z^{1*}, z^{2*}).*

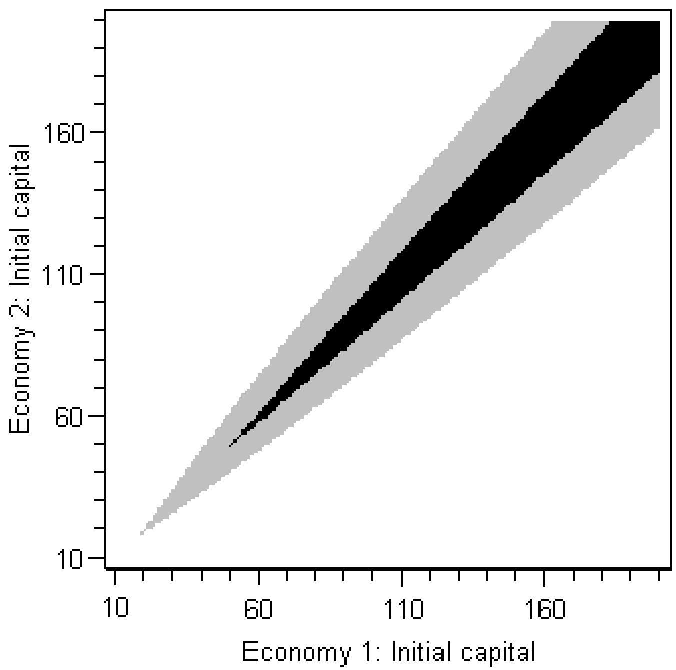
Investment Game



It can be shown that in the context of perfect knowledge about model's parameters the case when both economies invest (z^i*>0) into preventive measures (we call this **cooperative behavior**) happens only among similar economies.

Figure shows the example how narrow is the *"cooperation zone"* (economies' initial capitals must belong to the black area to reveal the cooperative behavior).

Investment Game: Role on Uncertainties



Taking into account uncertainties naturally existing in the model (parameters like probability of natural disasters, q_0 and their impact on capital stock, d) we found that for some of previously non-cooperative economies there will appear additional cooperative solutions.

Figure shows that 10% uncertainty in the probability (q_0) of occurring of natural disaster leads to the increasing of "cooperation zone" more than twice. Grey area on the figure describes the economies where cooperation becomes an option.

Conclusions

- Emergence of a joint GEOSS infrastructure as a Global Partnership is unlikely to materialize basing only on economical interests:
  - “Rich” always pays in its own interest
  - Involving “Poor” only under special cases
  - Free-rider problem to establish global infrastructure
- Uncertainty in risk valuing provides an incentive for cooperation
- Arising non-uniqueness of equilibrium solutions leads to necessity of additional negotiations between countries to set appropriate investments level