Risk, Insurance, and the Provision of Public Goods Under Uncertainty

Stephen Aultman*
Jay Coggins
Department of Applied Economics
University of Minnesota
*Email: aultm015@umn.edu

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Introduction

- Interested in examining economies where agents face risk of loss with some probability
- One example is a flood-prone community
- There may exist a public good that can affect the probability that the agents in a community experience a loss
- Examples include levies, dams

Pareto efficient provision of Public goods

- Identifying and implementing Pareto efficient levels of public goods under uncertainty is challenging for several reasons:
  - Often agents have incentive to misrepresent their preferences for the public good to attempt to free-ride.
  - Unaware of any mechanism design work focused on the provision of public goods under uncertainty
  - Need complete markets (insurance) to achieve Pareto efficiency.

Complexity of Insurance

- Insurance markets are traditionally handled in economic theory with Arrow-Debreu securities, one security for each unique set of endowments in the economy.
- Problem: With certain kinds of risk, number of states of the economy can grow unmanageably large as the number of agents increase. Real-life insurance bears little resemblance to Arrow-Debreu securities.

Risk: Definitions

- Suppose there is an economy with N agents and that there are M possible states of nature each agent can experience. The number of states of the economy will depend on N, M and the type of risk that is presents.

Types of Risks

- Joint Risk: All agents experience the same state of the world.
- Graduated Risk: Agents live in an ordered environment, a river valley for example, and the loss each agent suffers can be no greater than the agents in a lower state in the ordered environment.
- Idiosyncratic Risk: Each agent can experience any of the possible states of world. This doesn’t have to be a completely independent process, risks can be correlated, but there must be some element of idiosyncratic or individual risk involved.

Computational Complexity

- Joint Risk: M states. Does not depend on number of agents, just the states of nature M.
- Graduate Risk: Defined recursively as

$$S(M,N) = If(M == 2, Return[N+1]$$

$$Else$$

$$Return[\sum_{i=1}^{M} S(M-1, N-i)]$$

- Idiosyncratic Risk: $N*M^N$. Number of states of the economy grows exponentially with the number of agents

Limiting Behavior

- For graduated risk, the limiting behavior is such that the number of states of the economy increases in polynomial fashion with the order of the polynomial given by M-1. Thus, for M=2 the problem is linear. M=3 is quadratic etc.

Current practice

- Army Corp of Engineers is responsible for constructing most flood control projects
- Complex cost-benefit rules are used to determine which projects are undertaken.
- Flood insurance is provided via separate agency, part of the Federal Emergency Management Agency.

Desired alternative

- Would be useful if the insurance component of the problem and the public good component could be combined as the two decisions are related. Part of the demand for a levee could come from risk aversion. This would make flood an insurance and a levy substitutes. Insurer likely to have strong preferences over levee height as it affects premiums.

FEMA meets the Army Corp of Engineers

- What if we allowed a monopoly insurer to pick premiums for agents and allowed the insurer to provide the public good out money received from the premiums?
- Theory of the second best: with one market failure (public good) adding a second (market power) may be welfare improving

Rationale

- Insurer has strong incentive to provide and maintain the public good because it decreases the probability of having to pay out claims
- Only one price is necessary, so efficient with information
- Monopoly insurer can fund public good provision out of revenue from insurance premiums (ability to pay)

Single priced contracts

- We restrict the insurance company to selling single-priced contracts. That is, the premium an agent pays doesn’t not depend on the realizations experienced by other agents (not Arrow-Debreu). However, there is a risk that the insurance company will default and not pay your claim at all.

Default risk

- Tradeoffs with single priced contracts:
  - Limits number of prices in markets
  - Agents don't need to trust or verify claims made by other agents, only required to trust insurance company
- Disadvantages
  - In a sufficiently bad year, no way to avoid default
  - Assume there is a government regulator who sets maximum probability of default. Insurance companies must make decisions to ensure probability of default doesn't exceed threshold.

Simple example

- Insurer surprises agents with public good
- Future work to look at mechanism design
- To simplify mathematical model, assume agents face idiosyncratic risk

Problem details

- Logarithmic utility: $u = \ln(c)$
- Each agent has endowment of 1
- Loss of 0.5 with probability $p(\delta) = .1 - .05\,\delta^{.5}$
- Cost function is $C(\delta) = 5\,\delta^2$
- Limit on default risk, α, is the exogenous parameter

Agents' problem

$$\max_I (1-\alpha)\big(p * u(e - c * I + I - d) + (1-p)u(e - c * I)\big) + \alpha(p * u(e - c * I - d) + (1-p)u(e - c * I))$$

- Alpha is probability of default
- P is probability of loss
- C is insurance premium
- I is quantity of insurance purchased
- D is loss due to bad outcome occuring

Insurer's problem

- Maximize profit subject to a default constraint
- With idiosyncratic risk, probability of paying out a given number of claims is governed by binomial distribution
- Breakeven point:

$$N * c * I(c) - c(\delta) - X * I(c) = 0$$

Insurer's problem cont

- Solvency constraint is given by

$$1 - BinomialCDF(N, p(\delta), X) \leq \alpha^*$$

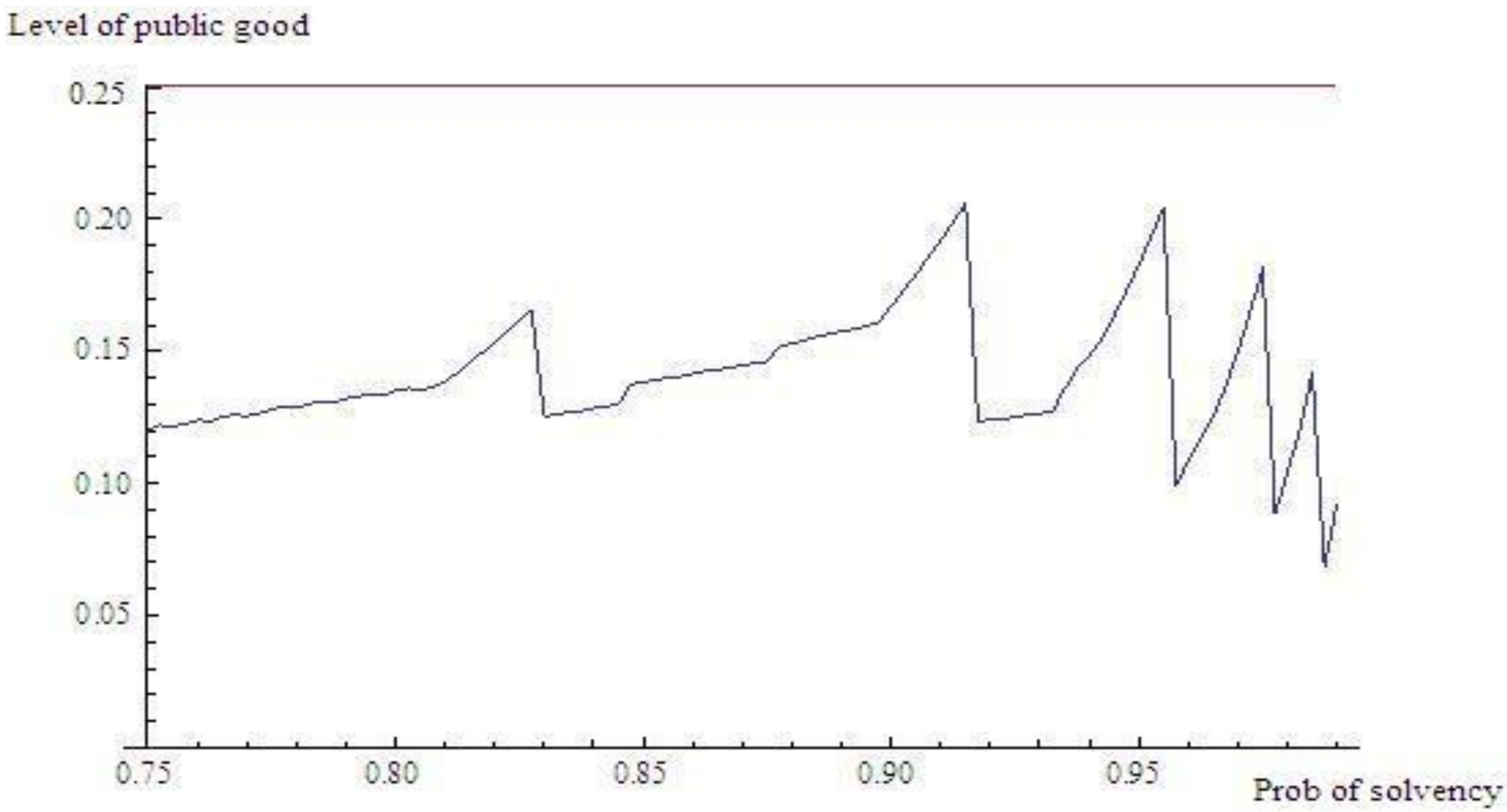
Insurer's problem cont

$$\max_{c,\delta} \sum_{i=0}^{N} \left(\frac{N!}{i!\,(N-i)!} p(\delta)^i \left(1 - p(\delta)\right)^{N-i} \right) * N * c * I(c) - c(\delta) - i * I(c)$$

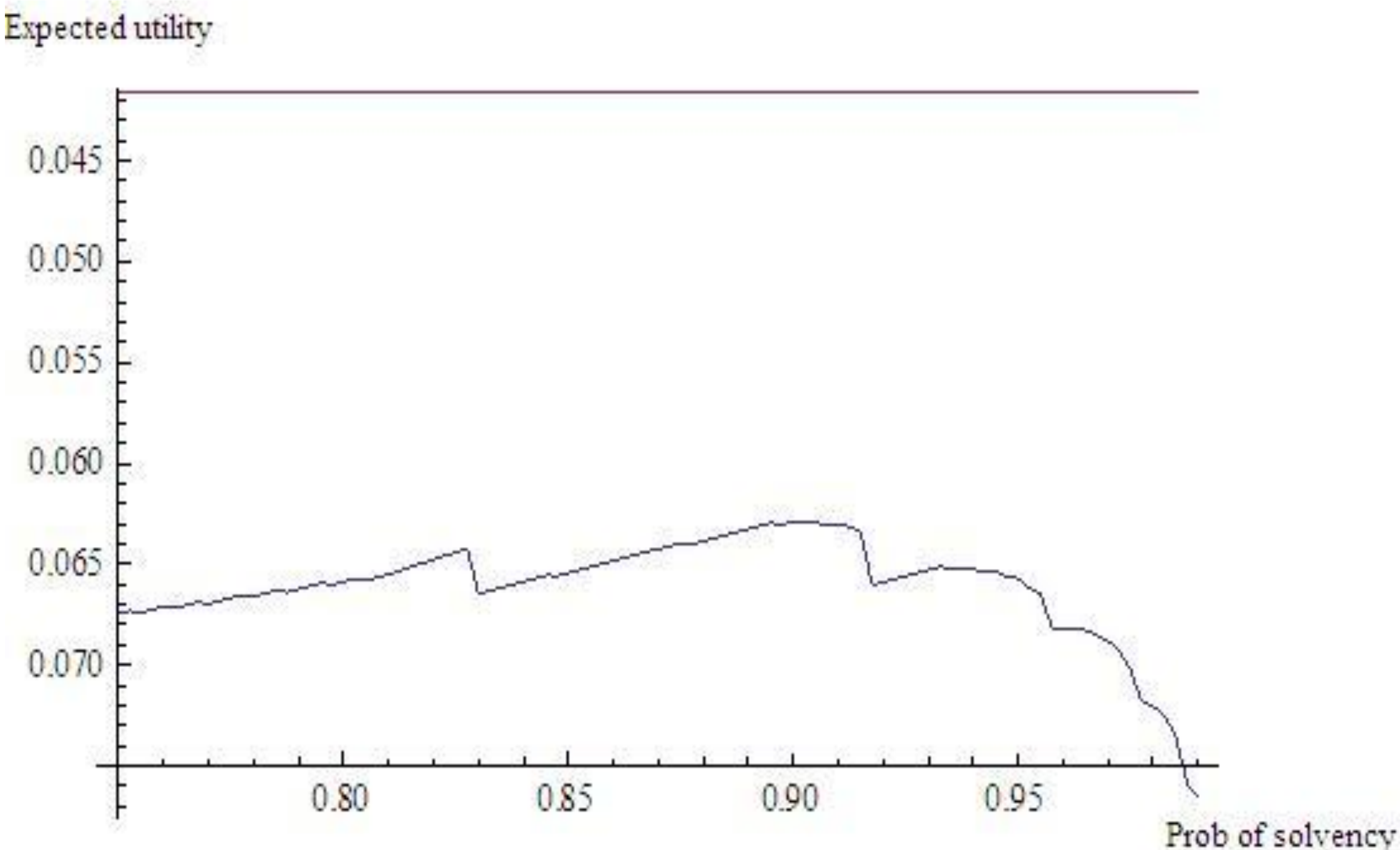
s.t.

$$1 - \sum_{i=0}^{Floor\left(\frac{N*c*I(c)-c(\delta)}{I(c)}\right)} \frac{N!}{i!\,(N-i)!} p(\delta)^i (1 - p(\delta))^{N-i} \leq \alpha^*$$

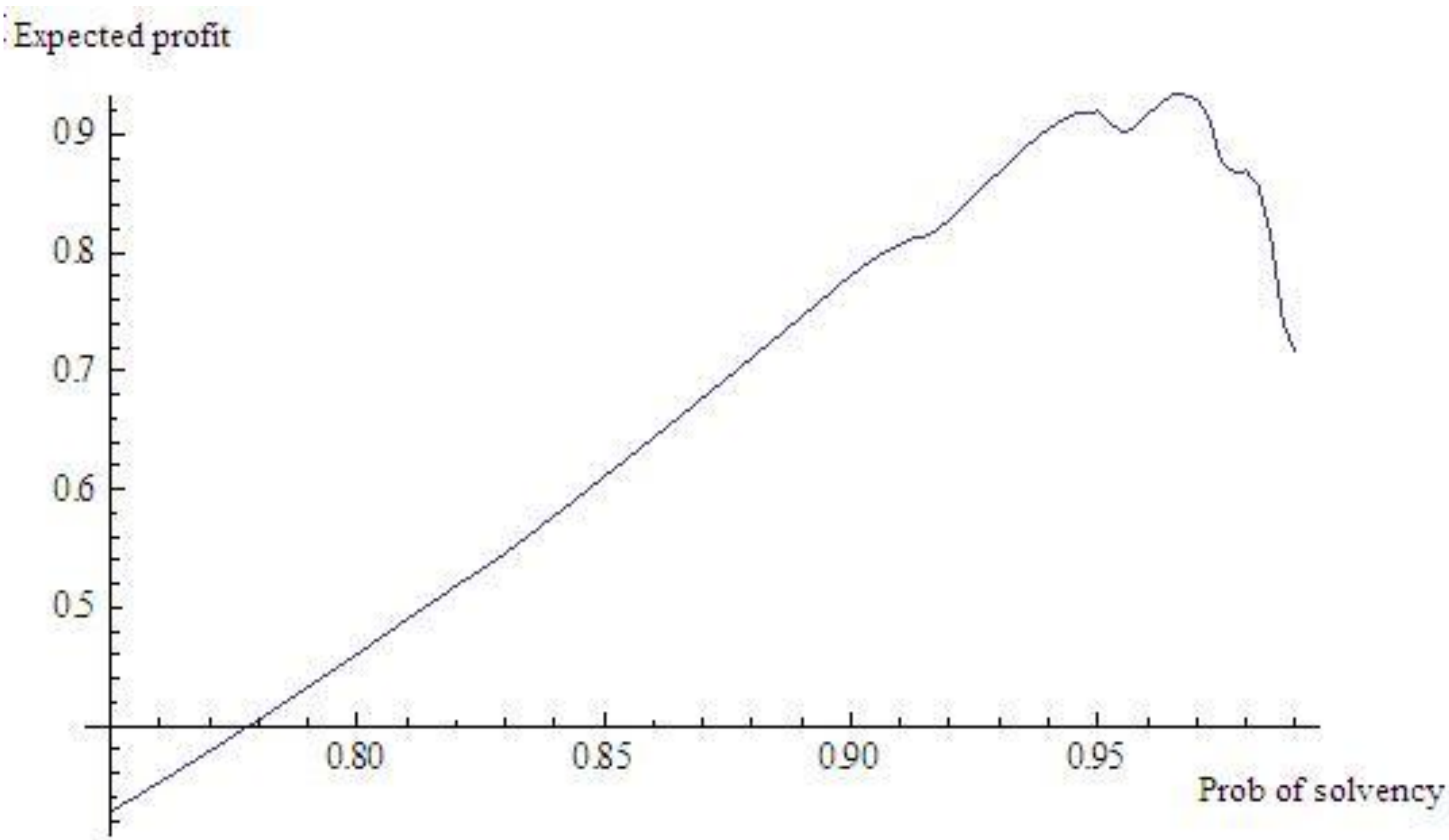
Public good as a function of α



Utility as a function of α



Expected profit as a function of α



Conclusion

- Provision of public goods under uncertainty presents both mechanism design and computational challenges
- Only a limited literature exists in this area
- Numerical simulations indicate a tradeoff between solvency and utility.