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# Insurance Risk Classification

How much is socially optimal?

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Indian Statistical Institute, August 2015

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- 1 Introduction
- 2 Why do people buy insurance?
- 3 What drives demand for insurance?
- 4 How much of population losses is compensated by insurance?
- 5 Which regime is most beneficial to society?
- 6 Conclusions

# Insurance Risk Classification

## Insurance – Pooling of risk

- Everybody is exposed to **risks**, but only a few suffer a **loss**.
- **Insurers** compensate **insureds** if a particular loss occurs.
- Insurers charge a **premium** for their services.
- Why is insurance possible at an affordable premium? **Pooling**.

## Insurance risk classification

- Homogeneous risk: Charge the same premium for all.
- Heterogeneous risk: Contentious issue of **adverse selection**.

# Adverse Selection

## What is adverse selection?

No commonly accepted standard definition of *adverse selection*.

## Definition (Actuarial perspective)

Insurer faces **loss** due to risk not factored in at the time of sale due to **asymmetric information** between the insurer and the insured.

## Definition (Economic perspective)

An individual's **demand for insurance** (the propensity to buy insurance and the quantity purchased) is **positively correlated** with the individual's **risk of loss** (higher risks buy more insurance).

## Question:

Why is this a **bad outcome** and **for whom**?

# Theory and Practice

## Traditional theory:

If insurers cannot charge **risk-differentiated** premiums, then:

- higher risks buy more insurance, lower risks buy less insurance,
- raising the **pooled** price of insurance,
- lowering the demand for insurance,

usually portrayed as a bad outcome, both for **insurers** and for **society**.

## In practice:

Policymakers often see merit in restricting insurance risk classification

- EU ban on using gender in insurance underwriting.
- Moratoria on the use of genetic test results in underwriting.

## Question:

How can we reconcile theory with practice?

# Agenda

## We ask:

- **Why** do people buy insurance?
- **What** drives demand for insurance?
- **How much** of population losses is compensated by insurance (with and without risk classification)?
- **Which** regime is most beneficial to society?

## We find:

**Social welfare** is maximised by maximising **loss coverage**.

## Definition (Loss coverage)

**Expected population losses compensated by insurance.**

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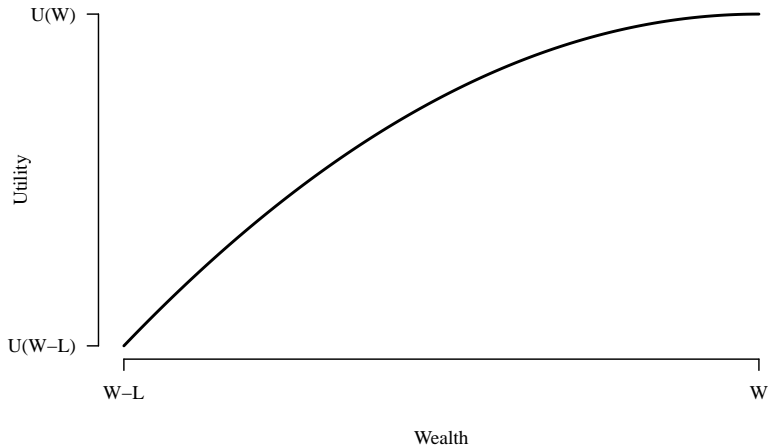
# Why do people buy insurance?

## Assumptions

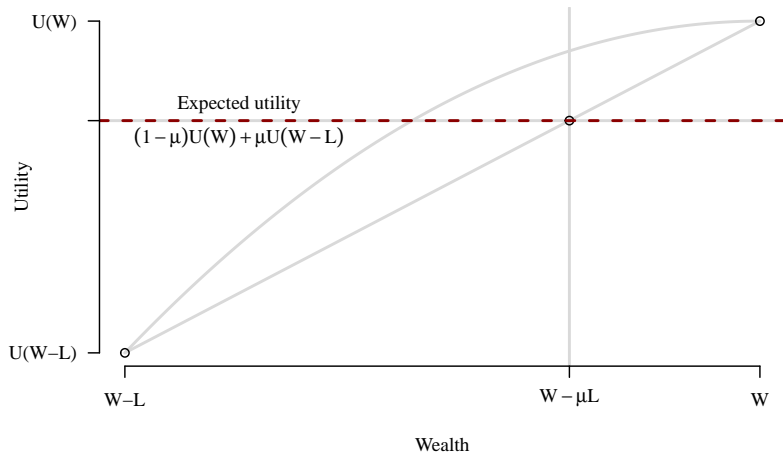
Consider an individual with

- an initial wealth  $W$ ,
- exposed to the risk of loss  $L$ ,
- with probability  $\mu$ ,
- utility of wealth  $U(w)$ , with  $U'(w) > 0$  and  $U''(w) < 0$ ,
- an opportunity to insure at premium rate  $\pi$ .

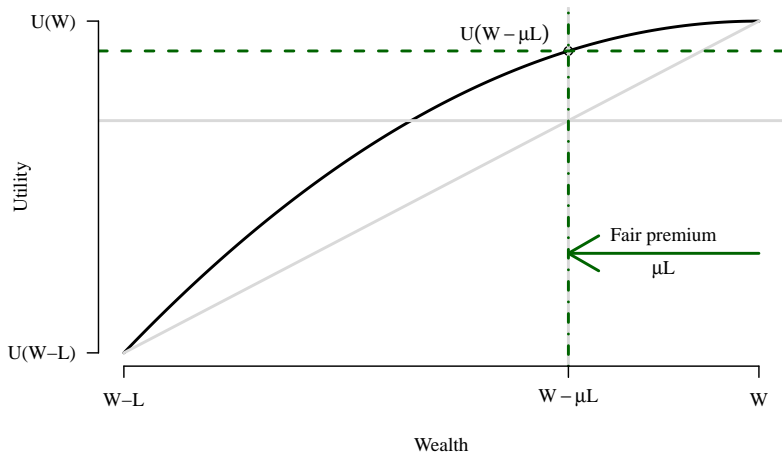
# Utility of wealth



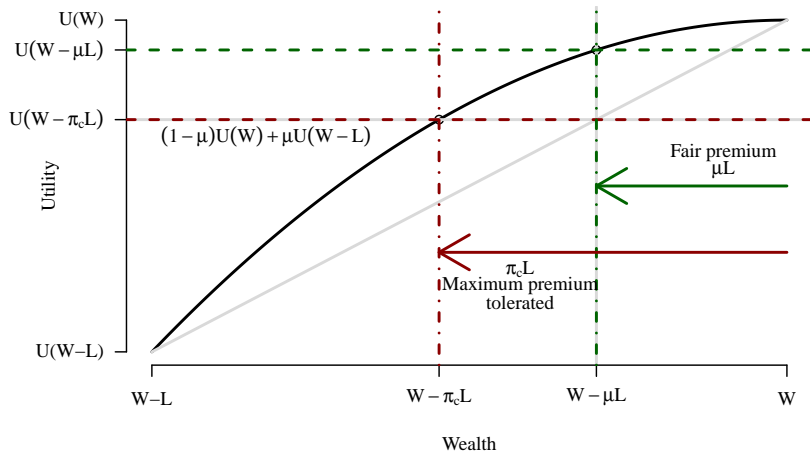
# Expected utility: Without insurance



# Expected utility: Insured at fair actuarial premium



# Maximum premium tolerated: $\pi_c$



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# Modelling demand for insurance

## Simplest model:

Based on the given set-up:

- All will buy insurance if  $\pi < \pi_c$ ;
- None will buy insurance if  $\pi > \pi_c$ .

**Reality:** Not all will buy insurance even at fair premium. **Why?**

## Heterogeneity:

- Individuals are homogeneous in terms of underlying risk.
- Individuals can be heterogeneous in terms of **attitude to risk**.

## Utility as a Random Variable

$[U(w)](v)$  is utility of wealth  $w$  for an individual  $v$  chosen at random.

- $[U(w)](v)$ : (non-random) utility function of wealth for individual  $v$ .
- $\widetilde{U(w)}$  is a random variable for a specific wealth  $w$ .

## Demand is a survival function

### Condition for buying insurance:

Given premium  $\pi$ , individual  $v$  chosen at random will buy insurance if:

$$\underbrace{[U(W - \pi L)](v)}_{\text{With insurance}} > \underbrace{(1 - \mu) \times [U(W)](v) + \mu \times [U(W - L)](v)}_{\text{Without insurance}}.$$

### Standardisation

Suppose all individuals within the risk-group are standardised so that:

$$\begin{aligned} [U(W)](v) &= 1, \\ [U(W - L)](v) &= 0. \end{aligned}$$

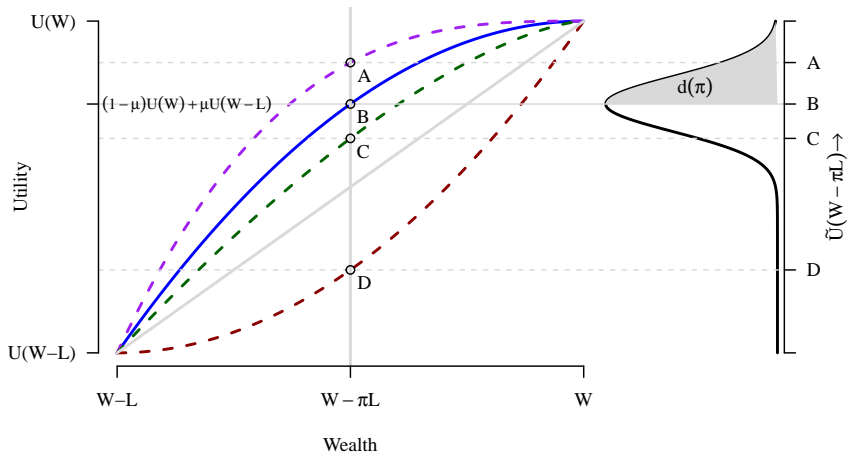
### Demand as a survival function:

Given premium  $\pi$ , insurance demand,  $d(\pi)$ , is the survival function:

$$d(\pi) = \text{Prob}[U(\widetilde{W - \pi L}) > (1 - \mu)U(W) + \mu U(W - L)].$$



# Demand is a survival function



## Illustrative example: $W = L = 1$

Power utility function:

$$\widetilde{U}(w) = w^{\tilde{\gamma}}.$$

Heterogeneity in risk preferences: Distribution of  $\tilde{\gamma}$ :

$$\text{Prob}[\tilde{\gamma} \leq x] = \begin{cases} 0 & \text{if } x < 0 \\ k x^\lambda & \text{if } 0 \leq x \leq (1/k)^{1/\lambda}, k > 0, \lambda > 0, \\ 1 & \text{if } x > (1/k)^{1/\lambda}. \end{cases}$$

Demand for insurance:

$$d(\pi) = \text{Prob}[U(\widetilde{W} - \pi L) > (1 - \mu)U(W) + \mu U(W - L)],$$

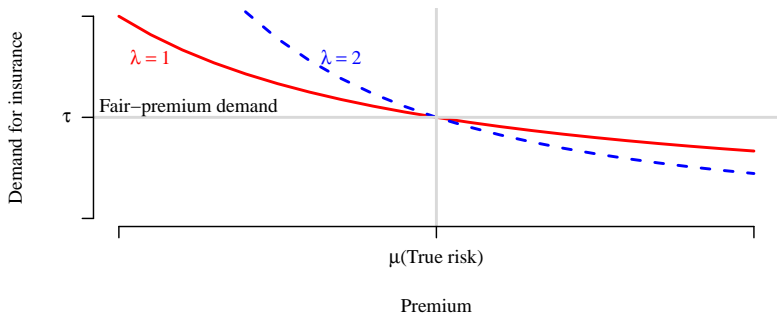
$$d(\pi) \approx \text{Prob}[\tilde{\gamma} < \frac{\mu}{\pi}] = k \left(\frac{\mu}{\pi}\right)^\lambda.$$

$$d(\pi) \propto \pi^{-\lambda}.$$

# Illustrative example: $W = L = 1$

## Demand elasticity (Iso-elastic demand):

$$d(\pi) \propto \pi^{-\lambda} \Rightarrow \epsilon(\pi) = \left| \frac{\frac{\partial d(\pi)}{d(\pi)}}{\frac{\partial \pi}{\pi}} \right| = \lambda.$$



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## Risk classification

Consider a population of individuals with the same:

- initial wealth  $W = 1$ ;
- potential loss  $L = 1$ ;
- form of iso-elastic demand function  $d(\pi) \propto \pi^{-\lambda}$ ; and
- demand elasticity  $\lambda$ .

Suppose the population can be divided into 2 risk-groups, with:

- risk of losses:  $\mu_1 < \mu_2$ ;
- population proportions:  $p_1$  and  $p_2$ ;
- fair premium demand:  $d_1(\mu_1) = \tau_1$  and  $d_2(\mu_2) = \tau_2$ , i.e.

$$d_i(\pi) = \tau_i \left( \frac{\pi}{\mu_i} \right)^{-\lambda}, \quad i = 1, 2.$$

# Risk-differentiated premium

## Equilibrium:

If risk-differentiated premiums  $\pi_1$  and  $\pi_2$  are allowed,

- Total premium:  $\sum_i p_i d_i(\pi_i) \pi_i$ .
- Total claims:  $\sum_i p_i d_i(\pi_i) \mu_i$ .

Equilibrium is achieved when insurers break even, i.e.  $\pi_i = \mu_i$ .

## Adverse Selection:

No losses for insurers. No (actuarial/economic) adverse selection.

## Loss coverage (Population losses compensated by insurance):

$$\text{Loss coverage} = \sum_i p_i d_i(\mu_i) \mu_i = \sum_i p_i \tau_i \mu_i.$$

# Pooled premium

## Equilibrium:

If only a pooled premium  $\pi_0$  is allowed,

- Total premium:  $\sum_i p_i d_i(\pi_0) \pi_0$ .
- Total claims:  $\sum_i p_i d_i(\pi_0) \mu_i$ .

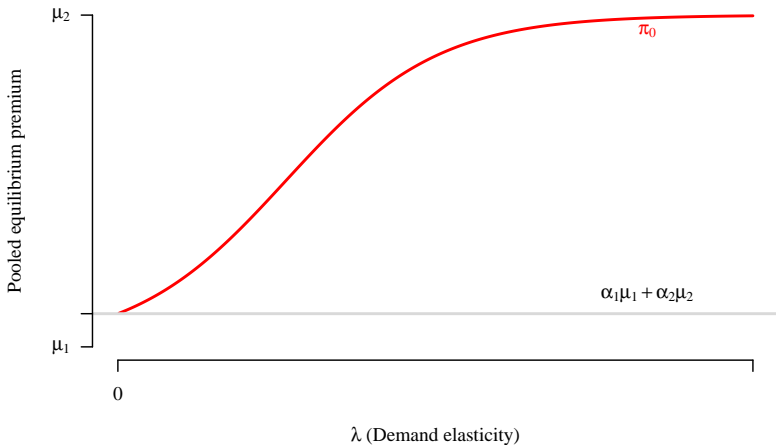
Equilibrium is achieved when insurers break even, i.e.

Total premium = Total claims,

$$\Rightarrow \sum_i p_i d_i(\pi_0) \pi_0 = \sum_i p_i d_i(\pi_0) \mu_i,$$

$$\Rightarrow \pi_0 = \frac{\alpha_1 \mu_1^{\lambda+1} + \alpha_2 \mu_2^{\lambda+1}}{\alpha_1 \mu_1^\lambda + \alpha_2 \mu_2^\lambda}, \text{ where } \alpha_j = \frac{\tau_j p_j}{\tau_1 p_1 + \tau_2 p_2}.$$

# Pooled premium: Adverse selection





# Pooled premium: Adverse selection

## Adverse selection: Summary

- The pooled equilibrium is greater than the average premium charged under full risk classification:

$$\pi_0 > \alpha_1 \mu_1 + \alpha_2 \mu_2 \Rightarrow \text{(Economic) adverse selection.}$$

- No losses for insurers!  $\Rightarrow$  No (actuarial) adverse selection.

Adverse selection is not useful to measure social efficacy of insurance.

# Loss coverage ratio

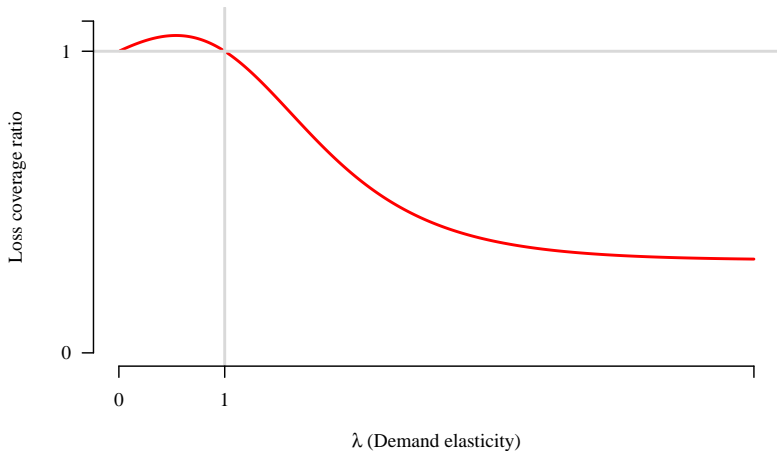
Loss coverage (Population losses compensated by insurance):

$$\text{Loss coverage} = \sum_i p_i d_i(\pi_0) \mu_i.$$

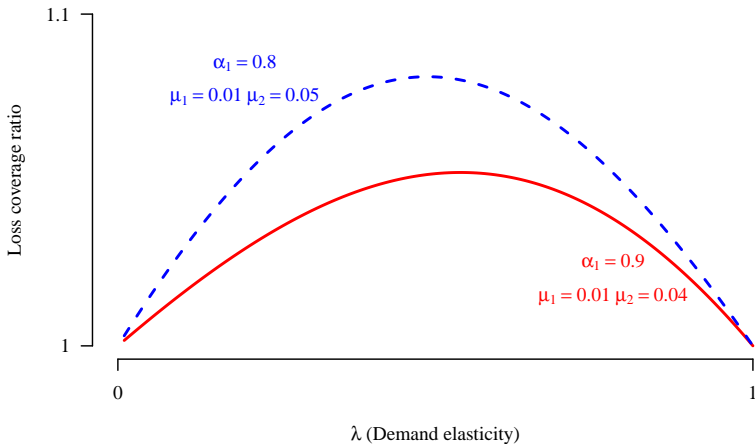
Loss coverage ratio:

$$\begin{aligned} C &= \frac{\text{Loss coverage for pooled premium}}{\text{Loss coverage for risk-differentiated premium}}, \\ &= \frac{\sum_i p_i d_i(\pi_0) \mu_i}{\sum_i p_i d_i(\mu_i) \mu_i}, \\ &= \frac{1}{\pi_0^\lambda} \frac{\alpha_1 \mu_1^{\lambda+1} + \alpha_2 \mu_2^{\lambda+1}}{\alpha_1 \mu_1 + \alpha_2 \mu_2}. \end{aligned}$$

# Loss coverage ratio



# Loss coverage ratio



# Loss coverage ratio: Summary

## Summary

- $\lambda < 1 \Rightarrow$  Loss coverage is more when risk classification is banned.
- $\lambda = 1 \Rightarrow$  Loss coverage is the same in both risk classification regimes.
- $\lambda > 1 \Rightarrow$  Loss coverage is more when full risk classification is used.
- Empirical evidence suggests  $\lambda < 1$ , providing justification for restricting risk classification.
- The maximum value of loss coverage ratio depends on the relative risk and relative size of the risk groups.
- A pooled premium might be highly beneficial in the presence of a small group with very high risk exposure.

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# Social welfare

## Definition (Social welfare)

Social welfare,  $G$ , is the sum of all individuals' expected utilities:

$$G = \sum_i p_i \left[ \underbrace{d_i(\pi_i) U^*(W - L\pi_i)}_{\text{Insured population}} + \underbrace{(1 - d_i(\pi_i)) \{(1 - \mu_i) U(W) + \mu_i U(W - L)\}}_{\text{Uninsured population}} \right],$$

where  $U^*(W - L\pi_i)$  is the expected utility of the insured population.

## Linking social welfare to loss coverage

Setting  $U(W - L) = 0$  and assuming  $L\pi_i \approx 0$  gives:

$$G = U(W) \sum_i p_i d_i(\pi_i) \mu_i + \text{Constant},$$

$$= \text{Positive multiplier} \times \mathbf{\text{Loss coverage}} + \text{Constant}.$$

Loss coverage provides a good proxy (which depends only on observable data) for social welfare (which depends on unobservable utilities).

**Result: Maximising loss coverage maximises social welfare.**

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# Conclusions

## Adverse selection need not be adverse

### Restricting risk classification

- will always increase adverse selection;
- increases loss coverage if  $\lambda < 1$ .

## Summary

**Loss coverage provides a better metric than adverse selection in measuring social welfare.**

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