inverse selection

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NBER Insurance Meeting
Insurers Want to Know How Many Steps You Took Today

The cutting edge of the insurance industry involves adjusting premiums and policies based on new forms of surveillance.

By Sarah Jeong
Ms. Jeong is a member of the editorial board.

April 10, 2019
Google to Store and Analyze Millions of Health Records

The tech company’s deal with Ascension is part of a push to use artificial intelligence to aid health services.

Google, like other big tech companies, is aggressively trying to get a bigger piece of the health care industry. Jeff Chiu/Associated Press
the seed of a question

- advent of big data, machine learning and ai
  - significant increase in data storage and computing powers.
- insurance companies *statistically infer* things ‘we’ can’t.
- **inversion of info advantage** in classical screening contracts?
- how we model insurance contracts/industry?
a perspective on insurance models

- first generation:
  - asymmetric information matters for markets,
  - markets can unravel, so role for market design.

- second generation:
  - asymm info is multidimensional– advantageous selection.
  - heterogeneity in risk aversion.

- third generation(?):
  - big data changes the notion of asymm info.
  - ”who knows what” needs an update.
moving on…

- a question of our times:
  with big data, should we think of information here differently?

- in terms of modeling:
  once insurer knows some basic information about you, statistical inference allows it to know more about risks. **selection inverts the info advantage**
roadmap

- model setup with 2-dimensional asymmetric info
  - agent has partial **hard information** advantage
  - principal has **statistical information** advantage
- 3 cases: principal’s informational advantage
  - no $\Rightarrow$ Rothschild-Stiglitz
  - yes and agents are gullible (“gutgläubig”)
  - yes and agents are rational
- regulation:
  - nationalize statistical information analysis
  - force to reveal statistical info
- welfare
model setup: a cara-gaussian version

▶ risk neutral insurer (principal):
  ▶ maximizes profit.
  ▶ offers contract: \( c = \{p, x\} \), \( p \) = premium, \( x \) = fraction of coverage.

▶ risk averse insuree (agent):
  ▶ maximizes \( u(z) = -\exp(-\gamma z) \),
  ▶ initial wealth \( w \) and realized loss/damage \( \ell \),
  ▶ \( \ell \sim \mathcal{N}(\mu, \sqrt{\nu}) \), where \( \mu \equiv \mu_\theta \).
  ▶ \( \theta = (\theta_1, \theta_2) \) and \( \mu \in \{\mu_{LL}, \mu_{HL}, \mu_{LH}, \mu_{HH}\} \).
  ▶ \( \theta \) jointly distributed according to \( q \).
joint distribution

\[
\begin{array}{c|cc|c}
\theta_1 & L & H & \theta_2 \\
\hline
L & q_{LL} & q_{LH} & q_1 \\
H & q_{HL} & q_{HH} & 1 - q_1 \\
\hline
q_2 & 1 - q_2 & \\
\end{array}
\]
Joint distribution

- Distribution is parametrized by \((q_1, q_2, \rho)\).

- The standard deviation is \(\sigma = \sqrt{q_1(1-q_1)} \sqrt{q_2(1-q_2)}\).
key departure from existing model(s)

- **priors:** $q_1, q_2$ and $\rho \sim F$ on $[\underline{\rho}, \bar{\rho}]$, publicly known.

- **agent’s hard info** advantages: $\theta_1$.

- **principals’ statistical info** advantage: $\rho$.
  - $\rho$ is data collection exogenous to the model.
  - an endogenous approach would determine $\rho$ in “equilibrium”.
  - first step in pushing insurance models to data considerations...

- agent’s info and principal’s info interacts.
structure of “game” and timing

mediator proposes:

- message rule, $r : [\rho, \bar{\rho}] \rightarrow \Delta(M)$,
- mechanism, $c^m = (p^m, x^m)$ s.t. $p^m, x^m : \{H, L\} \rightarrow \mathbb{R}$.

<table>
<thead>
<tr>
<th>stage 1</th>
<th>stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>▶ nature draws $\rho \sim F, \theta \sim q_{\rho}$</td>
<td>▶ menu $(c^m_H, c^m_L)$ is offered.</td>
</tr>
<tr>
<td>▶ seller learns $\rho$ and reports it.</td>
<td>▶ buyer learns $\theta_1$ and reports it.</td>
</tr>
<tr>
<td>▶ $r$ generates message $m$.</td>
<td>▶ contract $c^m_{\theta_1}$ is implemented.</td>
</tr>
<tr>
<td>▶ buyer forms posterior $F_m$.</td>
<td>▶ payoffs $\pi$ and $u$ are realized.</td>
</tr>
</tbody>
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optimal dynamic mechanism

- insurer’s profit is given by:

\[
\Pi = \int_\rho^\overline{\rho} \pi(\rho)f(\rho)d\rho
\]

- the optimization problem:

\[
\max_{r,c} \Pi \quad \text{s.t.} \quad IC_\rho, IC_{\theta_1}, IR, \text{ & regulatory constraint.}
\]
odm: constraints

- incentive constraints:
  - $IC_{\rho}: \pi(\rho, \rho) \geq \pi(\rho, \hat{\rho})$, and
  - $IC_{\theta_1}: u(\theta_1, \theta_1; m) \geq u(\theta_1, \hat{\theta}_1; m)$.
  - under truthtelling: $\pi(\rho)$ and $u_{\theta_1}(m)$.

- message and contract space:
  - $\mathcal{M} = \text{Supp}(r)$,
  - $\mathcal{C} = \{c^m \mid m \in \mathcal{M}\}$.

- regulatory revelation constraint:
model setup with 2-dimensional asymmetric info
  ▶ agent has partial **hard information** advantage $\theta_1$
  ▶ principal has **statistical information** advantage $\rho$

3 cases: principal’s informational advantage
  ▶ no, $\rho$ is common knowledge $\Rightarrow$ Rothschild-Stiglitz
  ▶ yes and agents are gullible ("gutgläubig")
  ▶ yes and agents are rational

regulation:
  ▶ nationalize statistical information analysis
  ▶ force to reveal statistical info

welfare
special case 1: $\rho$ is comm know

what if $F = \delta_{\rho}$?

- we are back in the rothschild-stiglitz world.
- both insurer and insuree integrate over $\theta_2$ using $\rho$.
- but insuree has more information: knows $\theta_1$.

proposition

$\exists \rho^* \text{ s.t. } \pi^{rs}(\rho^*) = \max_{\rho} \pi^{rs}(\rho), \text{ and}$

full (partial) insurance for high (low) risk type, (no overinsurance),

1. $\rho > \rho^* \Rightarrow 1 = x_H^{rs} > x_L^{rs}$,
2. $\rho < \rho^* \Rightarrow x_H^{rs} < x_L^{rs} = 1$.

- not consistent with data $\Rightarrow$ “advantageous selection”
special case 1: $\rho$ is commonly know

(a) optimal profit

(b) optimal coverage

figure: rothschild-stiglitz profits and coverage for different correlations
roadmap

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special case 2: gutgläubig

- no inference by agent from contract offer
- agent is gullible and believes principle’s announced $\rho$
- no regulatory constraints
- mechanism is given by $\{m(\rho), c^\rho\}_{\rho \in [\underline{\rho}, \bar{\rho}]}$.

**lemma**

*the seller reports extreme correlations to the buyer:*

$$m \in \{\underline{\rho}, \bar{\rho}\} \quad \text{and} \quad F_m = \delta_{\underline{\rho}} \text{ or } \delta_{\bar{\rho}}.$$
special case 2: gutgläubig

proposition

if the buyer is a gutgläubig, \( \exists \tilde{\rho} \in (\underline{\rho}, \bar{\rho}) \) such that:

1. extreme binary and misleading messages: 
   \[ m(\rho) = \bar{\rho} \text{ for } \rho < \tilde{\rho} \text{ and } m(\rho) = \underline{\rho} \text{ for } \rho > \tilde{\rho}, \]

2. higher profits: 
   \[ \pi(\rho) > \pi^{rs}(\rho) \ \forall \ \rho, \]

3. generically separating: 
   \[ x_H \neq x_L \ \forall \ \rho \neq \tilde{\rho}, \]

4. generically inexact coverage: 
   \[ x_i \neq 1 \ \forall \ \rho \ \text{a.s.}, \] 
   (one type under-, one type overinsured)

5. RS-comparison: less (more) coverage for high (low) risk type,
   \[ x_H < x_H^{rs} \text{ and } x_L > x_L^{rs} \text{ for } \rho > \tilde{\rho}, \]
   \[ x_H > x_H^{rs} \text{ and } x_L < x_L^{rs} \text{ for } \rho < \tilde{\rho}. \]
special case 2: gutgläubig

(a) optimal profit

(b) optimal coverages
roadmap

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  ► force to reveal statistical info

► welfare
rational agents

- main tradeoff:
  - between belief gap and price discrimination,
  - offering many contracts helps better discriminate among different $\rho$,
  - but also enables rational agent to infer $\rho$,
  - resolved (mostly) in favor of maintaining the belief gap.
- limited number of contracts (one or two).
\[ |\mathcal{M}| = |C| = 2 \]

**figure:** profits in equilibrium with two pooling regions.
\[ |\mathcal{M}| = |\mathcal{C}| = 2 \]

**figure:** coverage for different correlations

(a) optimal coverage for $H$

(b) optimal coverage for $L$
roadmap

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- regulation to reveal $\rho$:
  - nationalize statistical information analysis
  - force to reveal statistical info

- welfare
regulating information revelation

- Information analysis is “nationalized” and $\rho$ freely revealed $\Rightarrow$ common knowledge $\rho$ Rothschild-Stiglitz case.

- Insurer is incentivized to reveal $\rho$.
  - Needs incentive to collect data and estimate $\rho$
  - Additional IC-constraint
regulating information revelation

proposition

1. profits are uniformly lower:
   \[ \pi(\rho) < \pi^{rs}(\rho) \forall \rho. \]

2. generically inexact insurance: \( x_i \neq 1 \) for \( i = H, L \).

3. there is pooling and separation at the optimum:
   3.1 \( \rho > \rho^* \Rightarrow x^\rho(\theta_H) \geq x^\rho(\theta_L) \),
   3.2 \( \rho < \rho^* \Rightarrow x^\rho(\theta_H) \leq x^\rho(\theta_L) \),
   3.3 one of these holds with equality.
regulating information revelation

**figure**: optimal profits with full info revelation.
regulating information revelation

(a) optimal coverage for $H$

(b) optimal coverage for $L$

**figure:** coverage for different correlations
insuree welfare

\( (a) \) total surplus

\( (b) \) consumer surplus

**figure:** welfare is mostly higher for full information revelation
what did we learn so far?

- without regulatory constraints, insurer resolves tradeoff between belief gap and price discrimination in favor of the former.
  - why do we see such little price discrimination in the market?
  - role for consumer activism.
- regulatory information requirement increases the class of contracts, and shrinks the firm’s profit.
  - should we store data in a public platform, usable for a fee?
- overinsurance and partial insurance at the optimum.
  - “cross-subsidizing” across different populations.