The Impact of Price Discrimination in Markets with Adverse Selection

André Veiga (Oxford/Imperial)

Jerusalem, May 2017
EU rules on gender-neutral pricing in insurance industry enter into force

20-12-2012

Under new rules which are entering into force, insurers in Europe will have to charge the same prices to women and men for the same insurance products without distinction on the grounds of sex.
What is the welfare effect of “community rating” (CR)?

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Why should we care?

- CR is widespread but extremely heterogeneous

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  - subsidies imply a cost of public funds (often ignored)
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- Planner’s objective function might directly include redistribution, equality, etc
  - what is the efficiency cost of CR?
In this paper

- Theoretical contribution:
  - characterize of the optimal contractibility of a public signal

- Empirical contribution:
  - develop methodology to calibrate CR policy
  - apply to UK annuities
  - use the first annuities dataset to include individual life expectancy
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Literature

- Static lemons markets: CR is bad
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  - Levin RAND 2001 assumes very informative signals
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**Literature**

- **Static lemons markets: CR is bad**
  - Levin RAND 2001 assumes very informative signals
  - Handel et al EMA 2015, Geruso 2016 consider a restricted set of policies

- **Monopolistic price discrimination without selection**

- **Empirical studies of adverse selection**

More Literature
Outline

1. Theory
2. Environment & Data
3. Contract Choice Model
4. Counterfactuals
5. Conclusion
Setup (EFC 2010)

- 1 product, symmetric firms compete **only in prices**, symmetric price $p$
- Unit mass of individuals, WTP $u \in [0, \bar{u}]$, PDF $f(u)$
- Buy if $u \geq p$
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\[
Q(p) = \int_{p}^{u} f(u) \, du, \quad \sigma = -\frac{Q'}{Q}
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\[ c(p) \]
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Industry Marginal Cost $c(p)$

Industry Average Cost $AC(p) = \mathbb{E}[c \mid u \geq p]$
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$$\pi(p) = Q(p - AC), \quad \pi'' < 0$$
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\[ W(p) = \pi + \int_p^\bar{u} (u - p) f(u) \, du \]
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- $c \neq AC \Rightarrow$ competitive equilibrium is not efficient
Selection & Distortions

- Adverse selection: $c'(u) > 0$
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  - $\Rightarrow AC' > 0$ and $AC \geq c$
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$AC'(u) = \sigma(AC - c)$ is a measure of adverse selection
Community Rating (CR)

- Public signal (e.g., gender) partitions consumers into groups: \( m \in \{A, B\} \)
  - primitives are \( p_m, Q_m, c_m, AC_m, \pi_m \), etc

Literature has focused on two extreme policies:

- Zero CR: \( p_m(\bar{p}_m) = 0 \)
- Full CR: \( p_A(\bar{p}_A) + p_B(\bar{p}_B) = 0 \)

Assume no rejections

WLOG, let \( A \) be the high-cost group:

- \( p_A(\bar{p}_A) < 0 < p_B(\bar{p}_B) \)

Levin 2001: \( \min(c_A) \), \( \max(c_B) \)

Chen & Schwartz 2013: monopoly & \( c_0^A = c_0^B = 0 \)
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I consider the continuum of policies between zero CR and full CR
  ignored by Levin, Handel et al, etc
Continuum of CR policies

- I consider the continuum of policies between zero CR and full CR
  - ignored by Levin, Handel et al, etc
- Regulator chooses $\chi \in [0, 1]$ and $p_m(\chi)$ is
  \[
  \pi_m(p_m(\chi)) = \chi \pi_m(\bar{p})
  \]
- $\chi = 0 \Rightarrow$ zero CR
- $\chi = 1 \Rightarrow$ full CR
- Industry profit is always $\chi (\pi_A(\bar{p}) + \pi_B(\bar{p})) = 0$
- CR lowers $p_A$ and raises $p_B$
- Graph: paths of prices
Welfare & Intuition

- Welfare is

\[ W(\chi) = W_A(p_A(\chi)) + W_B(p_B(\chi)) \]
Welfare & Intuition

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- CR:
  - lowers \( p_A \) ⇒ mitigates adverse selection in \( A \)
  - increases \( p_B \) ⇒ reduces consumer surplus in \( B \)
  - shifts deadweight loss from \( A \) to \( B \)
Zero CR ($\chi = 0$)

Proposition 1

Zero CR ($\chi = 0$) maximizes welfare iff

$$AC'_A (p^*_A) - AC'_B (p^*_B) \leq 0.$$ 

- High cost group ($A$) has less adverse selection
Zero CR ($\chi = 0$)

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- The condition seems empirically rare (Hendren EMA 2013)
Proposition 2

The unique interior optimal policy $\chi = \tilde{\chi}$ satisfies

$$\sigma_A (p_A - c_A) = \sigma_B (p_B - c_B).$$
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- Uniqueness requires $\frac{d}{dp_m} \left( \frac{\pi'_m}{Q_m} \right) < 0$
  - sufficient conditions: $Q_m$ log-concave and $c'_m < 1$
  - intuition: large marginal benefit of correcting large distortions
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  - intuition: large marginal benefit of correcting large distortions
- Higher $\sigma_A \Rightarrow$ higher $\tilde{\chi}$
Full CR ($\chi = 1$)

**Proposition 3**

Full CR ($\chi = 1$) maximizes welfare iff, at $\bar{p}$,

$$0 < \mathbb{E}_{\frac{1}{q}} [\sigma] (AC_A - AC_B) < AC'_A - AC'_B.$$ 

- High cost group ($A$) has more adverse selection
- Similar cost levels
  - CR is a weak instrument → must be used fully
  - similar to Levin 2001
Full CR ($\chi = 1$)

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- High cost group ($A$) has more adverse selection
- Similar cost levels
  - CR is a weak instrument $\Rightarrow$ must be used fully
  - similar to Levin 2001
- Take away:
  - informative signals should be contractible
  - some CR on poor signals can be desirable

Graph: Full CR is optimal
Extensions

M>2 Signal Realisations

- e.g.: post codes, gender + age
Extensions

- **M>2 Signal Realisations**
  - e.g.: post codes, gender + age
  - policy has dimension $M - 1$: $\chi_B, \ldots, \chi_M$
  - interior optimal CR: $\sigma_A (p_A - c_A) = \sigma_B (p_B - c_B) = \ldots = \sigma_M (p_M - c_M)$
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- **Two Products**
  - Two products $j \in \{H, L\}$ & mandatory purchase
  - as in Handel, Hendel, Whinston 2015
  - UK annuities, US health insurance, auto insurance
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Optimal CR depends on group characteristics

CR beneficial if high-cost group
- exhibits greater adverse selection
- is more price-sensitive

Calibration to US health insurance
How to calibrate CR policy empirically?

- Focus on UK annuities
- Structurally estimate the joint distribution of demand and cost
- Find optimal CR by
  - gender
  - age
How to calibrate CR policy empirically?

Focus on UK annuities

Structurally estimate the joint distribution of demand and cost

Find optimal CR by
- gender
- age

Empirical model builds on Einav Finkelstein Schrimpff EMA 2010 (EFS)
- fewer covariates
- no variation in rates
- must use old data to estimate distribution of mortality
UK annuities

- Annuities provide income while buyer is alive
  - cost depends on individual mortality
- £12bn annuitized in 2013
- Competitive: 14 providers, break-even rates
UK annuities

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- Workers contribute to DC tax-free funds ($\phi$) throughout life
  - $\phi$ must be annuitized
  - individuals also have non-annuitized wealth
- Annuities often purchased at retirement, but not necessarily

[UK annuities - Details]
Contracts

A contract has two main characteristics

- Rate \( r \in [0, 1] \):
  - yearly payment is \( \phi r \)
  - rate is an inverse measure of price
A contract has two main characteristics

- **Rate** $r \in [0, 1]$:
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- **Guarantee**: $g \in \{0, 5, 10\}$ years
A contract has two main characteristics

- **Rate** $r \in [0, 1]$:
  - yearly payment is $\phi r$
  - rate is an inverse measure of price
- **Guarantee:** $g \in \{0, 5, 10\}$ years
- **Higher** $g \Rightarrow$ **lower** $r$
- **Firms** compete only in $r$
Demand & Adverse Selection

- Individual choices are determined by
  - mortality $\alpha$
  - bequest preferences $\beta$
  - rates $[r_0, r_5, r_{10}]$
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  - if buyers of $g = 0$ (low $\beta$) have low $\alpha$ (costly) $\Rightarrow g = 0$ adversely selected
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  - if buyers of $g = 10$ (high $\beta$) have low $\alpha$ (costly) $\Rightarrow$ $g = 10$ adversely selected

- I will estimate the joint distribution of $(\alpha, \beta)$
Data

- Proprietary data from a large UK insurer
- July 2006 - June 2008
  - Interest Rates
- Contract characteristics: \((g,r)\)
- Individual-level variables:
  - date of purchase
  - gender
  - age
  - contract choice
  - fund size \(\phi\)
  - use of financial advisor
  - life expectancy (computed by firm)
  - use of financial advisor
  - etc
Sub-samples

- Retirement age
  - Men: 65
  - Women: 60
Sub-samples

- Retirement age
  - Men: 65
  - Women: 60
- I will analyze 4 sub-samples independently:
  - Men 65
  - Women 65
  - Men 60
  - Women 60
Sub-samples

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- I will analyze 4 sub-samples independently:
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  - Women 60
- Individuals might buy earlier due to
  - poor health
  - large wealth
Information

Firm’s information

Econometrician’s information

Contractible variables: gender, age, fund
Rates

- Rates depend only on: gender, age, fund size $\phi$
- $r_5$ for Men 65, as a function of $\phi$:

![Rates for g=5 Independent of FA](image)

- Rates vary across individuals (unlike in EFS)
- Rates Imputation
Life expectancy

- Life expectancy allows use of recent data
About 65% of individuals choose $g = 5$
### Summary Statistics

**Table: Summary Statistics by Group**

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<td>Garantee 10-yrs</td>
<td>0.181</td>
<td>0.184</td>
<td>0.198</td>
<td>0.224</td>
</tr>
<tr>
<td>Garantee 5-yrs</td>
<td>0.703</td>
<td>0.614</td>
<td>0.680</td>
<td>0.623</td>
</tr>
<tr>
<td>Internal</td>
<td>0.824</td>
<td>0.460</td>
<td>0.714</td>
<td>0.485</td>
</tr>
<tr>
<td>Life Expectancy</td>
<td>23.58</td>
<td>26.14</td>
<td>28.64</td>
<td>31.14</td>
</tr>
<tr>
<td>Fund (1000s)</td>
<td>14.31</td>
<td>19.73</td>
<td>17.04</td>
<td>19.87</td>
</tr>
<tr>
<td>Financial Advisor</td>
<td>0.382</td>
<td>0.712</td>
<td>0.451</td>
<td>0.641</td>
</tr>
<tr>
<td>Postcode High</td>
<td>0.295</td>
<td>0.498</td>
<td>0.371</td>
<td>0.423</td>
</tr>
<tr>
<td>Postcode Med</td>
<td>0.359</td>
<td>0.296</td>
<td>0.362</td>
<td>0.344</td>
</tr>
<tr>
<td>Observations</td>
<td>3679</td>
<td>830</td>
<td>1733</td>
<td>4857</td>
</tr>
</tbody>
</table>

- Sample is representative of UK annuity buyers (Banks and Emmerson [1999])
Outline

1. Theory
2. Environment & Data
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4. Counterfactuals
5. Conclusion
Utility conditional on choice of $g$

- Goal: estimate joint distribution of $(\alpha, \beta)$
Utility conditional on choice of $g$

- Goal: estimate joint distribution of $(\alpha, \beta)$

- Time $t \in \{1, \ldots, T\}$, with $T = 65$
- At $t = 1$, individual $i$ chooses a contract
- Conditional on $g$, individual solves

$$V_{gi} = \max_{c_t, w_t} \left[ \sum_{t=1}^{T} \delta^t S_{ti} u_i (c_t) + \sum_{t=1}^{T+1} \delta^t H_{ti} v_i (w_t + G_t^g) \right]$$

subject to: $w_{t+1} = R (w_t + y_t - c_t)$.
Utility conditional on choice of $g$

- Goal: estimate joint distribution of $(\alpha, \beta)$

- Time $t \in \{1, \ldots, T\}$, with $T = 65$
- At $t = 1$, individual $i$ chooses a contract
- Conditional on $g$, individual solves

\[
V_{gi} = \max_{c_t, w_t} \sum_{t=1}^{T} \delta^t S_{ti} u_i (c_t) + \sum_{t=1}^{T+1} \delta^t H_{ti} v_i (w_t + G_t^g) \\
\begin{array}{l}
\text{alive} \\
\text{dies}
\end{array}
\]

subject to: $w_{t+1} = R(w_t + y_t - c_t)$.

- $i$ chooses $g$ if $V_{gi} = \max [V_{0i}, V_{5i}, V_{10i}]$
Parameterization: mortality

- Gompertz survival \( S_{ti} = \exp \left[ \frac{\alpha_i}{\lambda} \left( 1 - e^{\lambda t} \right) \right] \)
- \( \alpha_i \) captures mortality (observable, not contractible)
- \( \lambda \) determines slope of \( S_{ti} \) (calibrated)

![Survival Functions, \( \lambda=0.11 \)](image_url)
Parameterization: utility

- Utility from consumption and bequests is CRRA:

\[
\begin{align*}
  u(c) &= \frac{c^{1-\gamma}}{1-\gamma} \\
  v(w, \beta) &= \beta \frac{w^{1-\gamma}}{1-\gamma}
\end{align*}
\]

- \( \beta \geq 0 \) is bequest preference (heterogeneous, unobserved)
Parameterization: utility

- Utility from consumption and bequests is CRRA:

\[ u(c) = \frac{c^{1-\gamma}}{1-\gamma} \quad v(w, \beta) = \beta \frac{w^{1-\gamma}}{1-\gamma} \]

- \( \beta \geq 0 \) is bequest preference (heterogeneous, unobserved)

- Assume same curvature \( \gamma \)
  - contract choice independent of (unobserved) initial wealth
  - variation in rates exogenous to contract choice
Simulated Choices for Men 65

Annuity choices

\[ r_0 = 0.071, r_5 = 0.0705, r_{10} = 0.069 \]

\[ \text{gar} = 0 \]
\[ \text{gar} = 5 \]
\[ \text{gar} = 10 \]
Calibrated parameters

- Interest rate $R = 1.0313$
  - average yield of 10-year zero-coupon inflation-index bond
- Discount factor $\delta = 1/R$
- Inflation 2.13%

- Non-annuitized wealth $w_1 = 4\phi$ (Banks and Emmerson [1999])
- Curvature $\gamma = 2$ (Friend and Blume [1975], Laibson et al. [1998], Hurd [1989])
- Gompertz shape $\lambda = 0.11$ (Levy and Levin [2014], Einav et al. [2010])
- Robustness checks on $\gamma$ and $\lambda$

- Remaining heterogeneity: $\beta$
Unobserved heterogeneity in $\beta$

- Assume $\beta$ lognormal:

$$\log(\beta) \sim \mathcal{N}(\bar{\beta}, \sigma_{\beta}^2)$$

$$\bar{\beta} = \beta_0 + \beta_\phi \log(\phi) + \beta_\alpha \log(\alpha) + \beta_{FA} FA + \beta_{INT} INT + \ldots$$

$$\ldots + \beta_{PcodeH} PcodeH + \beta_{PcodeM} PcodeM$$

- Likelihood - Details
- Identification Intuition
### Estimates

- Fully independent estimation in each sub-sample

<table>
<thead>
<tr>
<th></th>
<th>Men-65</th>
<th>Women-65</th>
<th>Men-60</th>
<th>Women-60</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log(\sigma_{\beta}) )</td>
<td>-1.111</td>
<td>-0.569</td>
<td>-0.655</td>
<td>-0.857</td>
</tr>
<tr>
<td>( \beta_0 )</td>
<td>-10.996</td>
<td>-6.882</td>
<td>-17.271</td>
<td>-6.190</td>
</tr>
<tr>
<td>( \beta_{\phi} )</td>
<td>0.702</td>
<td>0.021</td>
<td>0.706</td>
<td>0.181</td>
</tr>
<tr>
<td>( \beta_{\alpha} )</td>
<td>-2.046</td>
<td>-2.229</td>
<td>-3.171</td>
<td>-1.777</td>
</tr>
<tr>
<td>( \beta_{FA} )</td>
<td>0.019</td>
<td>0.135</td>
<td>0.023</td>
<td>0.107</td>
</tr>
<tr>
<td>( \beta_{INT} )</td>
<td>0.031</td>
<td>0.591</td>
<td>0.011</td>
<td>0.063</td>
</tr>
<tr>
<td>( \beta_{PcodeM} )</td>
<td>0.063</td>
<td>0.020</td>
<td>-0.067</td>
<td>0.045</td>
</tr>
<tr>
<td>( \beta_{PcodeH} )</td>
<td>0.020</td>
<td>-0.003</td>
<td>-0.050</td>
<td>0.041</td>
</tr>
</tbody>
</table>

- Significant heterogeneity in \( \beta \)
Estimates

- Fully independent estimation in each sub-sample

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<th>Men-60</th>
<th>Women-60</th>
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<tbody>
<tr>
<td>$\log(\sigma_\beta)$</td>
<td>-1.111 (0.006)</td>
<td>-0.569 (0.011)</td>
<td>-0.655 (0.007)</td>
<td>-0.857 (0.019)</td>
</tr>
<tr>
<td>$\beta_0$</td>
<td>-10.996 (0.130)</td>
<td>-6.882 (0.316)</td>
<td>-17.271 (0.210)</td>
<td>-6.190 (0.123)</td>
</tr>
<tr>
<td>$\beta_\phi$</td>
<td>0.702 (0.005)</td>
<td>0.021 (0.015)</td>
<td>0.706 (0.007)</td>
<td>0.181 (0.018)</td>
</tr>
<tr>
<td>$\beta_\alpha$</td>
<td>-2.046 (0.052)</td>
<td>-2.229 (0.126)</td>
<td>-3.171 (0.028)</td>
<td>-1.777 (0.035)</td>
</tr>
<tr>
<td>$\beta_{FA}$</td>
<td>0.019 (0.008)</td>
<td>0.135 (0.037)</td>
<td>0.023 (0.012)</td>
<td>0.107 (0.016)</td>
</tr>
<tr>
<td>$\beta_{INT}$</td>
<td>0.031 (0.011)</td>
<td>0.591 (0.038)</td>
<td>0.011 (0.013)</td>
<td>0.063 (0.014)</td>
</tr>
<tr>
<td>$\beta_{P_{codeM}}$</td>
<td>0.063 (0.012)</td>
<td>0.020 (0.018)</td>
<td>-0.067 (0.014)</td>
<td>0.045 (0.016)</td>
</tr>
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<td>-0.050 (0.013)</td>
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</tr>
</tbody>
</table>

- Significant heterogeneity in $\beta$
- $(\alpha, \beta)$ negatively correlated $\Rightarrow$ adverse selection into $g = 10$
- Histogram of Estimated Distribution - Men 65
- Summary Statistics of Estimated Distributions
Outline

1. Theory
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4. Counterfactuals
5. Conclusion
Roadmap

1. Compute rates at full PD and full CR
   1.1 Find break-even rates in group $A$ (zero CR)
   1.2 Find break-even rates in group $B$ (zero CR)
   1.3 Find break-even rates when $A$ and $B$ are together (full CR)
Roadmap

1. Compute rates at full PD and full CR
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- Short-run effect of unexpected policy:
  - purchase age, $\phi$, insurer targeting are held constant
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- Welfare is willingness to pay for preferred annuity contract
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- Short-run effect of unexpected policy:
  - purchase age, $\phi$, insurer targeting are held constant

- Welfare is willingness to pay for preferred annuity contract

- Who gains from CR? Women and 60-YOs
Gender-neutral pricing (65-year-olds)

- Optimal CR increases welfare by about £5/person/year
- Why? Women gain but have smaller deadweight loss ⇒ small gain of CR
Gender-neutral pricing (60-year-olds)

- Optimal CR increases welfare by £22/person/year
- Why? Men 60 inelastic (large $\nabla [\beta]$) $\Rightarrow$ small cost of CR
Gender-neutral pricing (60-year-olds)

- Optimal CR increases welfare by £22/person/year
- Why? Men 60 inelastic (large $\nabla [\beta]$) $\Rightarrow$ small cost of CR
- There is significant redistribution
More

- Age-neutral pricing
- Robustness checks in $\gamma$ and $\lambda$
- PD by fund size
Outline

1. Theory
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Conclusion

- CR is beneficial when high-cost groups
  - exhibit greater adverse selection
  - are price-sensitive

- Calibrated optimal CR for UK annuities
  - new dataset features individual life expectancy
Thank you!
Calibration to US Health Insurance

- Each contract has
  - price $p$
  - coverage $x \in [0, 1]$ (actuarial rate)
- Two contracts $j \in \{H, L\}$
  - $x_L = 0.6$ and $x_H = 0.9$
Calibration to US Health Insurance

- Each contract has
  - price $p$
  - coverage $x \in [0, 1]$ (actuarial rate)
- Two contracts $j \in \{H, L\}$
  - $x_L = 0.6$ and $x_H = 0.9$
- CARA utility & Gaussian wealth shocks
- Willingness to pay is $u_j = x_j \mu + \frac{1}{2} \left( 1 - (1 - x_j)^2 \right) \nu$
  - expected cost $\mu$
  - insurance value $\nu$ (captures risk aversion)
Calibration to US Health Insurance

- Each contract has
  - price \( p \)
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- Two contracts \( j \in \{H, L\} \)
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- CARA utility & Gaussian wealth shocks
- Willingness to pay is \( u_j = x_j \mu + \frac{1}{2} \left( 1 - (1 - x_j)^2 \right) \nu \)
  - expected cost \( \mu \)
  - insurance value \( \nu \) (captures risk aversion)
- Consumer buys \( H \) if \( u_H - u_L > p_H - p_L \)
- \( (\mu, \nu) \) jointly lognormal following estimates from Handel et al. [2015] (HHW)
  - correlation \( \rho \) captures the intensity of adverse selection into \( x_H \)
Calibration to US Health Insurance

- Group $B$ is the population average in HHW
- High-cost group ($A$) has less adverse selection ($\rho_A < \rho_B$)

$$E[\mu_A]=9463.5 \ , \rho_A=0.33007 \ , E[\mu_B]=6229.2 \ , \rho_B=0.57317$$
Calibration to US Health Insurance

- High-cost group ($A$) has greater adverse selection ($\rho_A > \rho_B$)

$$E[\mu_A] = 9474.7, \rho_A = 0.78281, E[\mu_B] = 6229.2, \rho_B = 0.57317$$
Two Products - Setup

- Two products $j \in \{H, L\}$
- Mandatory purchase
- Consumers buy $H$ if $u > p_H - p_L = \Delta p$
- Demands $Q_H$ and $Q_L = 1 - Q_H$
- Marginal costs: $c_H(u) > c_L(u)$
- Average costs
  
  $$AC_H = E[c_H | u \geq \Delta p]$$
  $$AC_L = E[c_L | u < \Delta p]$$

- $\Delta AC = AC_H - AC_L$
- Profit on contract $j$ is $\pi_j = Q_j (p_j - AC_j)$
- Free entry into each contract
- Equilibrium:

  $$\pi_H (p_H^*, p_L^*) = \pi_L (p_H^*, p_L^*) = 0 \Rightarrow \Delta p^* = \Delta AC (\Delta p^*)$$
Two products - Price Discrimination

- Two groups \( m \in \{A, B\} \)
- Full PD requires \( p_{HA}^*, p_{LA}^*, p_{HB}^*, p_{LB}^* \) such that
  \[
  \pi_{HA} = \pi_{LA} = \pi_{HB} = \pi_{LB} = 0
  \]
- Full CR requires \( \bar{p}_H, \bar{p}_L \) such that
  \[
  \pi_{HA} + \pi_{HB} = 0
  \]
  \[
  \pi_{LA} + \pi_{LB} = 0
  \]
- Consider \( \chi \in [0, 1] \) and
  \[
  \begin{bmatrix}
  \pi_{Hm}(p_{Hm}(\chi), p_{Lm}(\chi)) \\
  \pi_{Lm}(p_{Hm}(\chi), p_{Lm}(\chi))
  \end{bmatrix}
  = \chi
  \begin{bmatrix}
  \pi_{Hm}^- \\
  \pi_{Lm}^-
  \end{bmatrix}.
  \]
Two Products - Full PD

**Full PD (2 products)**

With 2 products, full CR is optimal if

$$\Delta AC_A' (\Delta p_A^*) - \Delta AC_B' (\Delta p_B^*) < 0$$

and $Q_{HB}^* > Q_{HA}^*$.

- Extra condition: $Q_{HB} > Q_{HA}$
  - CR would increase price in $B$
  - consumers in $B$ have large surplus $\Rightarrow$ CR bad
With 2 products, full PD is optimal if, at $\bar{p}$,

$$0 < (A_{CH_A} - A_{CH_B}) \frac{\sigma_{HB}}{Q_{HB}} + \frac{1}{Q_{HA}} + (A_{CL_A} - A_{CL_B}) \frac{\sigma_{LB}}{Q_{LB}} + \frac{1}{Q_{LA}} + \frac{1}{Q_{LB}} < \Delta A_{C_A} - \Delta A_{C_B}.$$ 

and $Q_{HB}^- < Q_{HA}^-$. 

Return
Full CR is optimal: graph
Calibration (1 product)

- CARA-Gaussian insurance market with coverage $x$
- Willingness to pay is $u = x\mu + \frac{1}{2} \left( 1 - (1 - x)^2 \right) \nu$
  - risk $\mu$, risk aversion $\nu$ jointly lognormal following estimates from Handel et al. [2015]
  - correlation $\rho$ captures the intensity of adverse selection
- High-cost group has more adverse selection:

\[
E[\mu_A] = 9474.7, \rho_A = 0.78281, E[\mu_B] = 6229.2, \rho_B = 0.57317
\]

\[
\Delta DLW_{PD} = -9.6252\%, \text{Min}_{\Delta DLW} = 10.0564\%
\]
Calibration (1 product)

- High-cost group has less adverse selection:
  - PD is better than CR, but some CR is optimal

\[ E[\mu_A] = 9463.5, \rho_A = 0.33007 \]
\[ E[\mu_B] = 6229.2, \rho_B = 0.57317 \]

\[ \Delta \text{DWL}_{PD} = 4.1984\%, \text{Min } \Delta \text{DWL} = -2.7973\% \]
Timeline of Interest Rates

Sample period occurs before Quantitative Easing policy
Mortality and Life Expectancy
I only observe rates for chosen contracts
  - must impute rates
Rate in contract $g$ for an individual $i$ with fund $\phi_i$ in month $\tau$ is

$$r_{gi\tau} = r_g^\phi(\phi_i) + FE_\tau + \varepsilon_{gi\tau}$$

- $FE_\tau$ are month fixed-effects
- Estimate $r_g^\phi(\cdot)$ non-parametrically

Use only imputed (not observed) rates and average $FE_\tau$
- Use $\phi \in [\£5K, \£40K]$ (90% of data)
Sample restrictions

- No “enhanced” annuities (28% of market)
  - for very unhealthy individuals
- No “joint life” annuities (33% of market)
- No “increasing” annuities (5% of market)
  - nominal payment increases over time
Estimate $\Theta = \left( \sigma^2_\beta, \beta_0, \beta_\alpha, \beta_\phi, \beta_{FA}, \beta_{INT}, \beta_{PcodeH}, \beta_{PcodeM} \right)$

- $\beta_i$ is drawn from PDF $f_\beta (\beta \mid \theta_i, \Theta)$.
- The probability of $i$ choosing $g$ is
  \[
P_{gi} = \int_\beta I \{ V_{gi} = \max [V_{0i}, V_{5i}, V_{10i}] \} f_\beta (\beta \mid \theta_i, \Theta) \, d\beta.
  \]

- Likelihood is piecewise flat, so use Logit smoothing:
  \[
P_{gi} = \int_\beta \frac{\exp (\zeta V_{gi})}{\sum_j \exp (\zeta V_{ji})} f_\beta (\beta \mid \theta_i, \Theta) \, d\beta, \quad \zeta = 10^6
  \]

- Integrated by Gaussian Quadrature
- Checked multiple starting values
Age-neutral pricing (Men)

- Men 60 very inelastic ⇒ small gain
Age-neutral pricing (Women)

- Women 60 have larger DWL

![Graph showing partial CR for Women-65 and Women-60 with the best E[WE]=100.11]
Robustness Checks

Welfare effect of full CR (%):

<table>
<thead>
<tr>
<th></th>
<th>M65+W65</th>
<th>M60+W60</th>
<th>M65+M60</th>
<th>W65+W60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-0.16</td>
<td>+0.08</td>
<td>-0.5</td>
<td>+0.11</td>
</tr>
<tr>
<td>$\gamma = 2.3$</td>
<td>-0.2</td>
<td>+0.08</td>
<td>-0.29</td>
<td>+0.03</td>
</tr>
<tr>
<td>$\gamma = 1.7$</td>
<td>-0.02</td>
<td>+0.12</td>
<td>-0.10</td>
<td>+0.19</td>
</tr>
<tr>
<td>$\lambda = 0.12$</td>
<td>-0.15</td>
<td>+0.07</td>
<td>-0.43</td>
<td>+0.10</td>
</tr>
<tr>
<td>$\lambda = 0.10$</td>
<td>-0.13</td>
<td>+0.08</td>
<td>-0.42</td>
<td>+0.09</td>
</tr>
</tbody>
</table>

- Very robust to $\lambda$
- More sensitive to $\gamma$
Multiple Signal Realizations

- Suppose signal is \( m \in \{A, B, C, \ldots, M\} \)
- Full PD: \( \pi_m(p_m^*) = 0 \)
- Full CR: \( \sum \pi_m(\bar{p}) = 0 \)
- Let \( \mathcal{A} \) be the subset of high-cost groups, so that \( m \in \mathcal{A} \Rightarrow \pi_m(\bar{p}) < 0 \).
  - \( \mathcal{B} \) is the subset of low-cost groups
- Again, define \( \chi \in [0, 1] \) and \( \pi_m(p_m(\chi)) = \chi \pi_m(\bar{p}) \)
- Full PD is optimal if
  \[
  \min_{m \in \mathcal{B}} \{ AC'_m(p_m^*) \} > \max_{m \in \mathcal{A}} \{ AC'_m(p_m^*) \} .
  \]
- Full CR is optimal if all \( \tilde{A} \tilde{C}_m \) are sufficiently similar and
  \[
  \max_{m \in \mathcal{B}} \{ AC'_m(p_m^*) \} < \min_{m \in \mathcal{A}} \{ AC'_m(p_m^*) \} .
  \]
UK annuities - Details

In the period of the data:

- Around 10% of individuals had DC pensions
- No secondary market for annuities (taxed at around 70%)
- Individuals can withdraw 25% of \( \phi \) tax-free (virtually all do)
- Annuity must be purchased between ages of 55 and 75
- State pensions
  - basic pension is not means-tested
  - typically a small share of income for those with DC pensions
- Taxes
  - annuity payments are taxed as earned income
  - payments are made after tax has been deducted
  - payments made to dependent’s estate are subject to inheritance tax

In 2013:

- About 5M annuitants, increasing by 300K/year
- 20% DC pensions
Competition

- Offered rates are similar and close to break-even rates
  - also found by Einav et al. [2010]
Policy implied a small overall loss for 65 year olds
CR by gender for intervals of $\phi$, 60-YO

Policy led to a significant gain by 60 year olds
Estimated distribution of \((\alpha, \beta)\), Men 65

\[
\rho_{\alpha,\beta} = 0.59726, E[\alpha] = 0.0051652, V[\alpha] = 5.2864 \times 10^{-7}, E[\beta] = 613.39, V[\beta] = 138418
\]
More Literature

- Age-based CR eliminates “reclassification risk”
  - Koch IJIO 2014, Handel et al EMA 2015

- Ambiguous value of better private information
  - in screening markets: Kessler 1998

- Competitive insurance markets with screening: CR is bad

- Bergemann et al 2015
  - Some information structure can achieve any feasible division of surplus
  - monopoly without selection
## Summary Statistics

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<tr>
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<th>Men 60</th>
<th>Women 60</th>
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<tbody>
<tr>
<td>$\mathbb{E}[\alpha] \times 10^{-3}$</td>
<td>5.16</td>
<td>3.77</td>
<td>2.79</td>
<td>2.09</td>
</tr>
<tr>
<td>$\nabla [\alpha] \times 10^{-7}$</td>
<td>5.28</td>
<td>2.07</td>
<td>1.69</td>
<td>0.715</td>
</tr>
<tr>
<td>$\mathbb{E}[\beta]$</td>
<td>618</td>
<td>434</td>
<td>2573</td>
<td>627</td>
</tr>
<tr>
<td>$\nabla [\beta] \times 10^{3}$</td>
<td>148</td>
<td>64</td>
<td>291</td>
<td>68</td>
</tr>
<tr>
<td>$\rho$</td>
<td>-0.58</td>
<td>-0.38</td>
<td>-0.59</td>
<td>-0.53</td>
</tr>
<tr>
<td>DWL (%)</td>
<td>0.47</td>
<td>0.22</td>
<td>0.48</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Identification Intuition

- Similar market shares in all contracts $\Rightarrow$ large $\sigma_\beta$
- Large market share in $g = 5$ and $g = 10$ $\Rightarrow$ large $\bar{\beta}(\theta)$

- Assumption on $\gamma$ $\Rightarrow$ variation in rates is exogenous
  - Improves on EFS (identification through functional form only)
Full PD is optimal: graph

\[ AC_A = c_A \]

\[ AC_B \]

\[ c_B \]

\[ p_B^{**} \quad p_B^* \quad \overline{p} \quad p_A^* = p_A^{**} \]
Price Paths

\[ \pi_A + \pi_B = 0 \]

\[ \pi_A \]

\[ \pi_B \]

\[ \overline{\pi} \]

\[ -\overline{\pi} \]

Profit

\[ p_A \]

\[ p_A^* \]

\[ p_B \]

\[ p_B^* \]

Price

\( \chi \)

0

1

Return
Uniqueness of optimal CR

- Assume $\forall m : \frac{d}{dp_m} \left( \frac{\pi'_m}{Q_m} \right) < 0$
- sufficient conditions: $Q_m$ log-concave and $c'_m < 1$. 


