The Impact of Price Discrimination in Markets with Adverse Selection

André Veiga (Oxford/Imperial)

Jerusalem, May 2017

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EU rules on gender-neutral pricing in insurance industry enter into force

20-12-2012

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- What is the welfare effect of "community rating" (CR)?

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- CR is widespread but extremely heterogeneous

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US health insurance	CR		CR	CR

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- Planner's objective function might directly include redistribution, equality, etc
  - what is the efficiency cost of CR?

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  - 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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  - Handel et al EMA 2015, Geruso 2016 consider a restricted set of policies
- Monopolistic price discrimination without selection
  - Schmalensee AER 1981, Aguirre et al AER 2010, Bergemann et al AER 2015, Chen & Schwartz RAND 2013
- Empirical studies of adverse selection
  - Einav et al EMA 2010, Einav et al QJE 2010, Finkelstein & Poterba JPE 2004, Ericson Starc RESTAT 2015

More Literature

Outline

Setup (EFC 2010)

- 1 product, symmetric firms compete **only in prices**, symmetric price p
- Unit mass of individuals, WTP $u \in [0, \overline{u}]$, PDF $f(u)$
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- $c \neq AC \Rightarrow$ competitive equilibrium is not efficient

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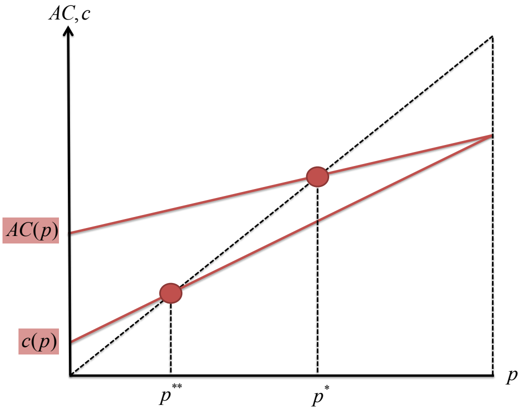

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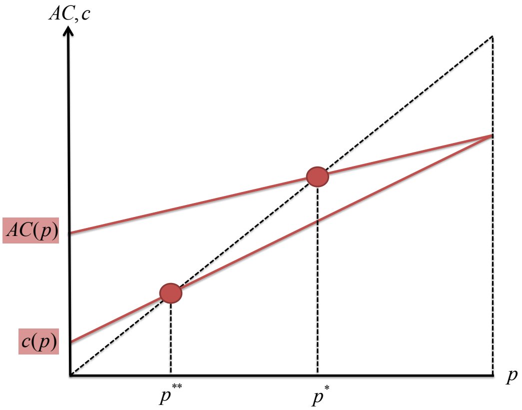

- $AC' = \sigma (AC - c)$ is a measure of adverse selection

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- Levin 2001: $\min\left(c_A\right) \geq \max\left(c_B\right)$
- Chen & Schwartz 2013: monopoly & $c'_A = c'_B = 0$

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- 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

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- CR:
  - lowers $p_A \Rightarrow$ mitigates adverse selection in A
  - increases $p_B \Rightarrow$ 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

$$AC_A'\left(p_A^\star\right) - AC_B'\left(p_B^\star\right) \leq 0.$$

- High cost group (A) has less adverse selection

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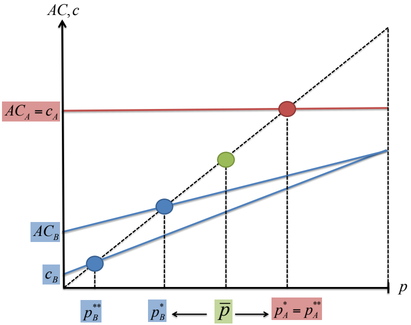

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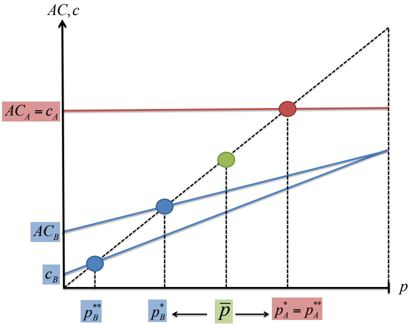

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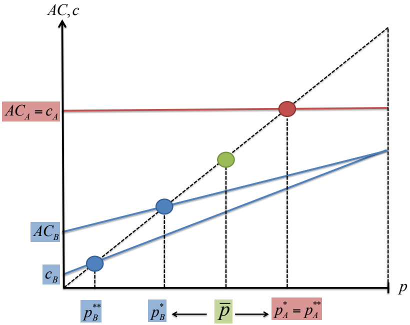

- Perfectly informative signal: $AC'_A = AC'_B = 0$
- The condition seems empirically rare (Hendren EMA 2013)

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- Higher $\sigma_A \Rightarrow$ higher $\tilde{\chi}$

Full CR ($\chi = 1$)

Proposition 3

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

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

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- Similar cost levels
  - CR is a weak instrument $\Rightarrow$ must be used fully
  - similar to Levin 2001

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- Take away:
  - informative signals should be contractible
  - some CR on poor signals can be desirable

Graph: Full CR is optimal

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  - Two products $j \in \{H, L\}$ & mandatory purchase
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  - UK annuities, US health insurance, auto insurance

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Summary

- 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

Outline

- How to calibrate CR policy empirically?

- Focus on UK annuities
- Structurally estimate the joint distribution of demand and cost
- Find optimal CR by
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- Empirical model builds on Einav Finkelstein Schrimpf EMA 2010 (EFS)
  - fewer covariates
  - no variation in rates
  - must use old data to estimate distribution of mortality

UK annuities

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

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- Guarantee: $g \in \{0, 5, 10\}$ years
- Higher $g \Rightarrow$ lower r
- Firms compete only in r

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  - mortality α
  - bequest preferences β
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- I will estimate the joint distribution of (α, β)

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 ϕ
  - use of financial advisor
  - life expectancy (computed by firm)
  - use of financial advisor
  - etc

Sub-samples

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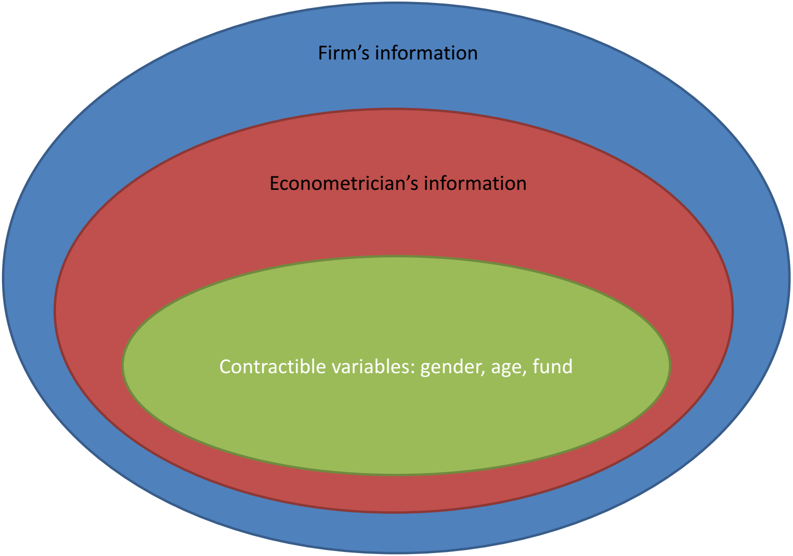
- Individuals might buy earlier due to
  - poor health
  - large wealth

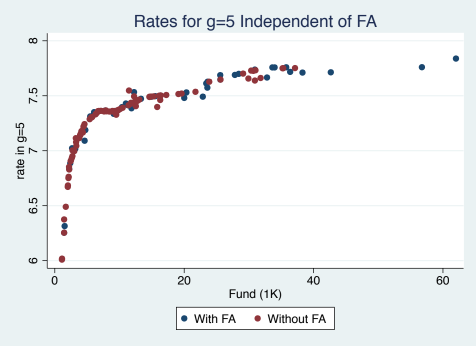
Sample Restrictions

Information



Rates

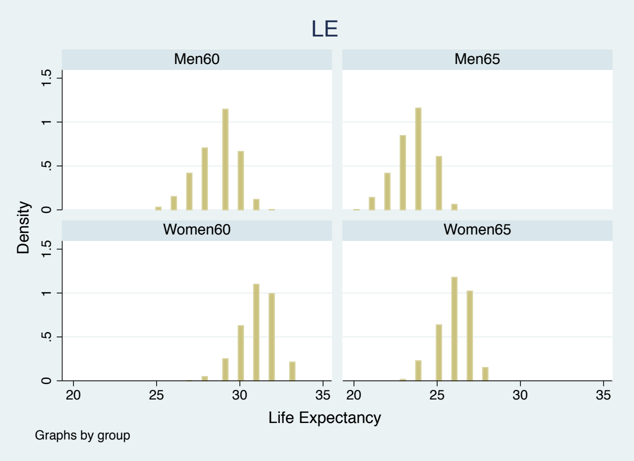
- Rates depend only on: gender, age, fund size ϕ
- r_5 for Men 65, as a function of ϕ:



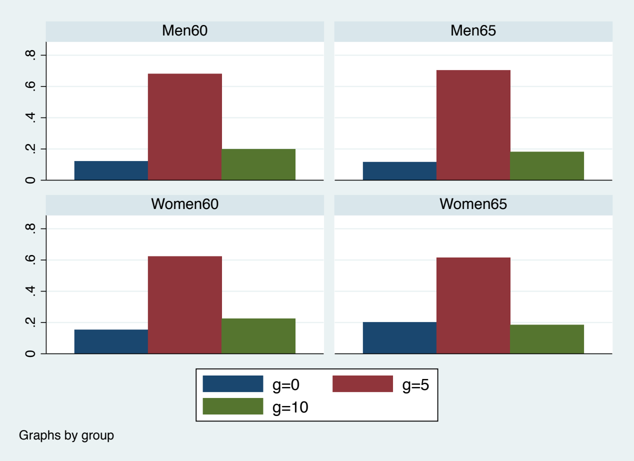
- Rates vary across individuals (unlike in EFS)
- Rates Imputation

Life expectancy

- Life expectancy allows use of recent data



Choices



- About 65% of individuals choose $g = 5$

Summary Statistics

Table: Summary Statistics by Group

	Men 65	Women 65	Men 60	Women 60
Garantee 10-yrs	0.181	0.184	0.198	0.224
Garantee 5-yrs	0.703	0.614	0.680	0.623
Internal	0.824	0.460	0.714	0.485
Life Expectancy	23.58	26.14	28.64	31.14
Fund (1000s)	14.31	19.73	17.04	19.87
Financial Advisor	0.382	0.712	0.451	0.641
Postcode High	0.295	0.498	0.371	0.423
Postcode Med	0.359	0.296	0.362	0.344
Observations	3679	830	1733	4857

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

Outline

Utility conditional on choice of g

- Goal: estimate joint distribution of (α, β)

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- Time $t \in \{1, ..., T\}$, with $T = 65$
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$$V_{gi} = \underbrace{\max_{c_t, w_t} \sum_{t=1}^{T} \delta^t S_{ti} u_i(c_t)}_{alive} + \underbrace{\sum_{t=1}^{T+1} \delta^t H_{ti} v_i\left(w_t + G_t^g\right)}_{dies}$$

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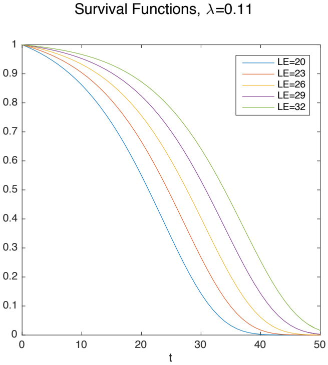
- i chooses g if $V_{gi} = \max[V_{0i}, V_{5i}, V_{10i}]$

Parameterization: mortality

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



Parameterization: utility

- Utility from consumption and bequests is CRRA:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma} \qquad\qquad v(w,\beta) = \beta\frac{w^{1-\gamma}}{1-\gamma}$$

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

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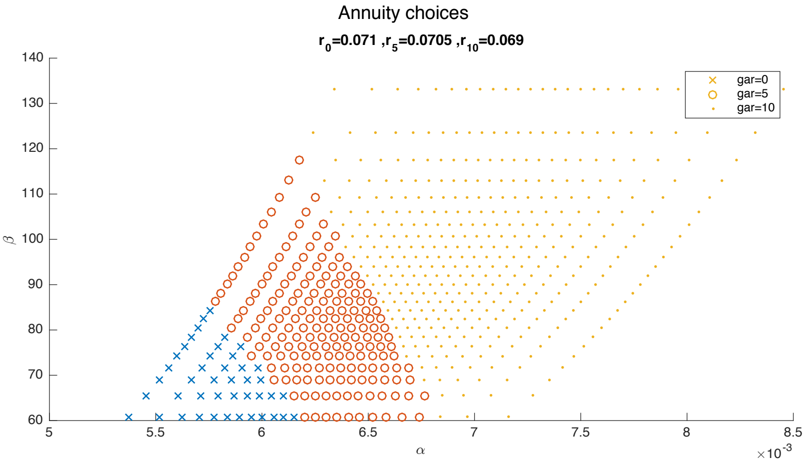
- Assume same curvature γ
  - contract choice independent of (unobserved) initial wealth
  - variation in rates exogenous to contract choice

Simulated Choices for Men 65



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 γ and λ

- Remaining heterogeneity: β

Unobserved heterogeneity in β

- Assume β lognormal:

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

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

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

- Likelihood - Details
- Identification Intuition

Estimates

- Fully independent estimation in each sub-sample

	Men-65		Women-65		Men-60		Women-60	
$log(\sigma_\beta)$	-1.111	(0.006)	-0.569	(0.011)	-0.655	(0.007)	-0.857	(0.019)
β_0	-10.996	(0.130)	-6.882	(0.316)	-17.271	(0.210)	-6.190	(0.123)
β_ϕ	0.702	(0.005)	0.021	(0.015)	0.706	(0.007)	0.181	(0.018)
β_α	-2.046	(0.052)	-2.229	(0.126)	-3.171	(0.028)	-1.777	(0.035)
β_{FA}	0.019	(0.008)	0.135	(0.037)	0.023	(0.012)	0.107	(0.016)
β_{INT}	0.031	(0.011)	0.591	(0.038)	0.011	(0.013)	0.063	(0.014)
β_{PcodeM}	0.063	(0.012)	0.020	(0.018)	-0.067	(0.014)	0.045	(0.016)
β_{PcodeH}	0.020	(0.012)	-0.003	(0.027)	-0.050	(0.013)	0.041	(0.015)

- Significant heterogeneity in β

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

Outline

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)

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- Short-run effect of unexpected policy:
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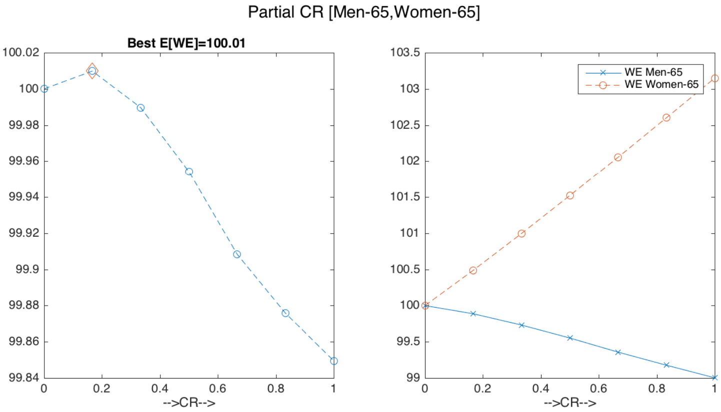
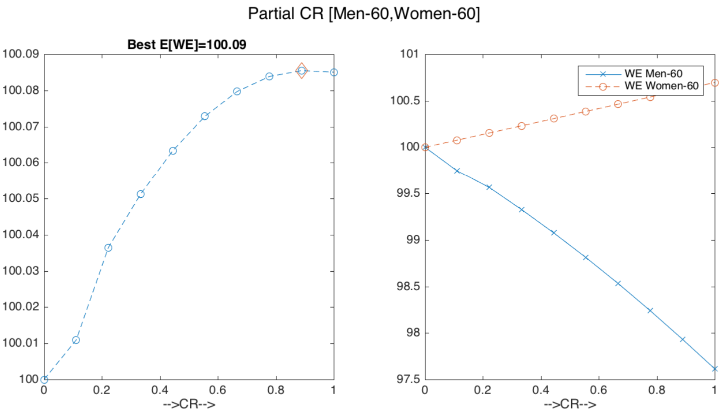
- Welfare is willingness to pay for preferred annuity contract
- Who gains from CR? Women and 60-YOs

Gender-neutral pricing (65-year-olds)



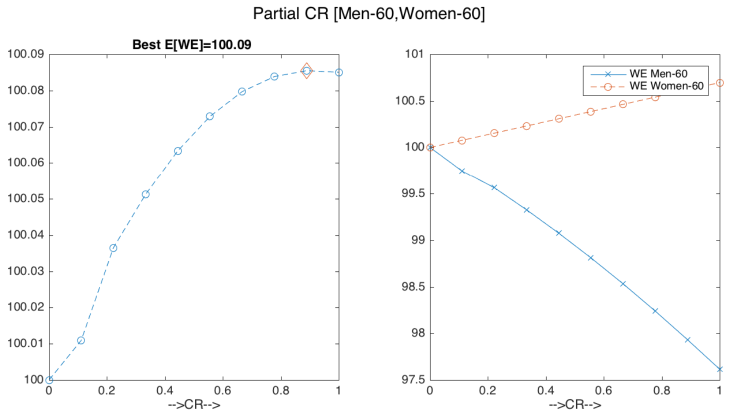
- Optimal CR increases welfare by about £5/person/year
- Why? Women gain but have smaller deadweight loss ⇒ small gain of CR

Gender-neutral pricing (60-year-olds)



- Optimal CR increases welfare by £22/person/year
- Why? Men 60 inelastic (large $\mathbb{V}[\beta]$) $\Rightarrow$ small cost of CR

Gender-neutral pricing (60-year-olds)



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

More

- Age-neutral pricing
- Robustness checks in γ and λ
- PD by fund size

Outline

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 $x_H = 0.9$

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- Two contracts $j \in \{H, L\}$
  - $x_L = 0.6$ and $x_H = 0.9$
- CARA utility & Gaussian wealth schocks
- Willingness to pay is $u_j = x_j \mu + \frac{1}{2}\left(1 - (1 - x_j)^2\right) v$
  - expected cost μ
  - insurance value v (captures risk aversion)

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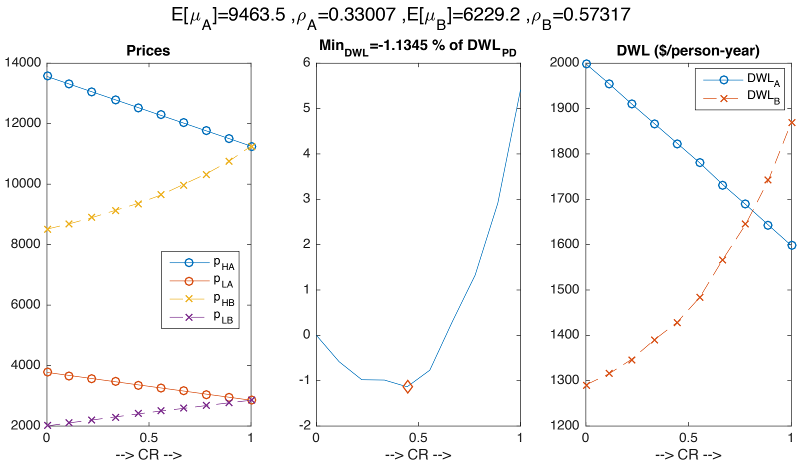
  - expected cost μ
  - insurance value v (captures risk aversion)
- Consumer buys H if $u_H - u_L > p_H - p_L$
- (μ, v) jointly lognormal following estimates from Handel et al. [2015] (HHW)
  - correlation ρ captures the intensity of adverse selection into x_H

Calibration to US Health Insurance

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



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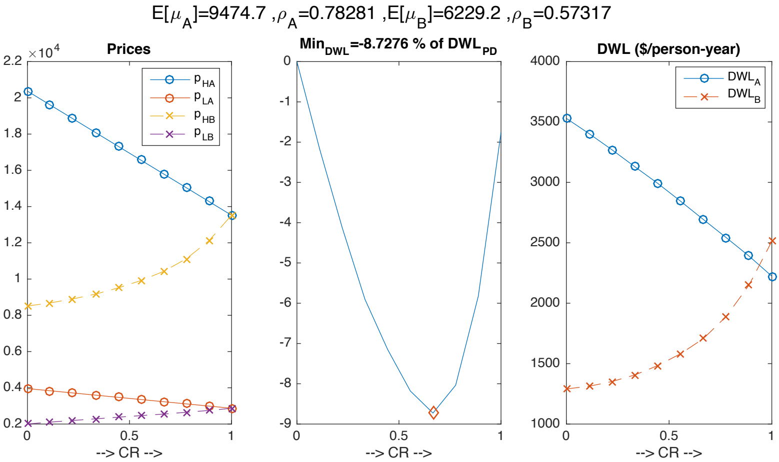


Return

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

$$AC_H = \mathbb{E}[c_H \mid u \geq \Delta p] \qquad AC_L = \mathbb{E}[c_L \mid u < \Delta p]$$

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

$$\pi_H(p_H^\star, p_L^\star) = \pi_L(p_H^\star, p_L^\star) = 0 \Rightarrow \Delta p^\star = \Delta AC(\Delta p^\star)$$

Two products - Price Discrimination

- Two groups $m \in \{A, B\}$
- Full PD requires $p^\star_{HA}, p^\star_{LA}, p^\star_{HB}, p^\star_{LB}$ 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
$$\begin{bmatrix} \pi_{Hm}\left(p_{Hm}\left(\chi\right), p_{Lm}\left(\chi\right)\right) \\ \pi_{Lm}\left(p_{Hm}\left(\chi\right), p_{Lm}\left(\chi\right)\right) \end{bmatrix} = \chi \begin{bmatrix} \pi_{\bar{H}m} \\ \pi_{\bar{L}m} \end{bmatrix}.$$

Two Products - Full PD

Full PD (2 products)

With 2 products, full CR is optimal if

$$\Delta AC'_A\left(\Delta p^\star_A\right) - \Delta AC'_B\left(\Delta p^\star_B\right) < 0$$

and $Q^\star_{HB} > Q^\star_{HA}$.

- Extra condition: $Q_{HB} > Q_{HA}$
  - CR would increase price in B
  - consumers in B have large surplus $\Rightarrow$ CR bad

Two Products - Full CR

Full CR (2 products)

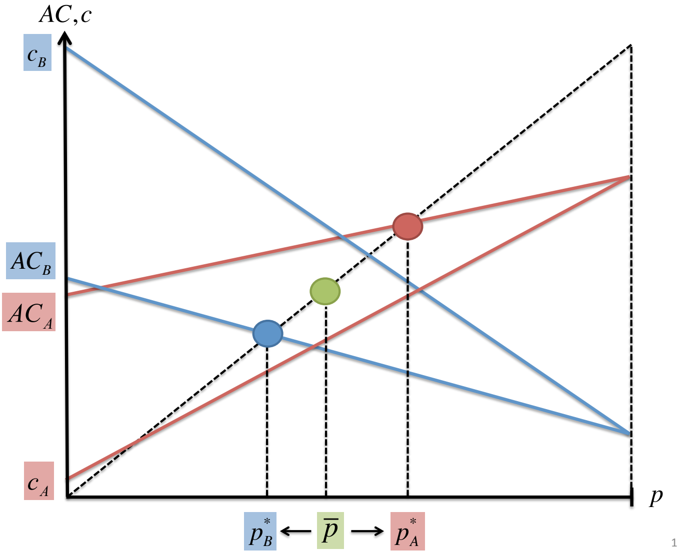
With 2 products, full PD is optimal if, at $\bar{\Delta p}$,

$$0 < (AC_{HA} - AC_{HB})\frac{\sigma_{HB}\frac{1}{Q_{HB}} + \sigma_{HA}\frac{1}{Q_{HA}}}{\frac{1}{Q_{HB}} + \frac{1}{Q_{HA}}} + (AC_{LA} - AC_{LB})\frac{\sigma_{LB}\frac{1}{Q_{LB}} + \sigma_{LA}\frac{1}{Q_{A}}}{\frac{1}{Q_{LA}} + \frac{1}{Q_{LB}}} < \Delta AC'_A - \Delta AC'_B.$$

and $\bar{Q}_{HB} < \bar{Q}_{HA}$.

Return

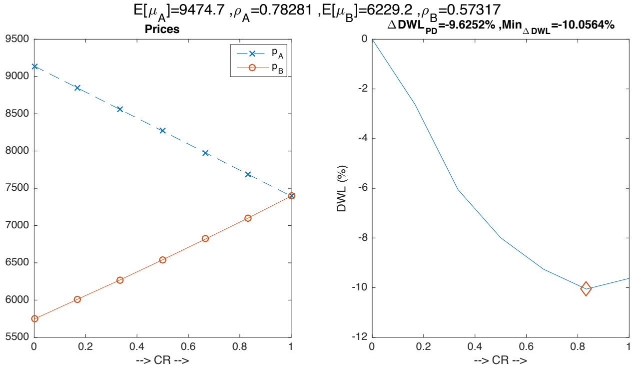
Full CR is optimal: graph



Return

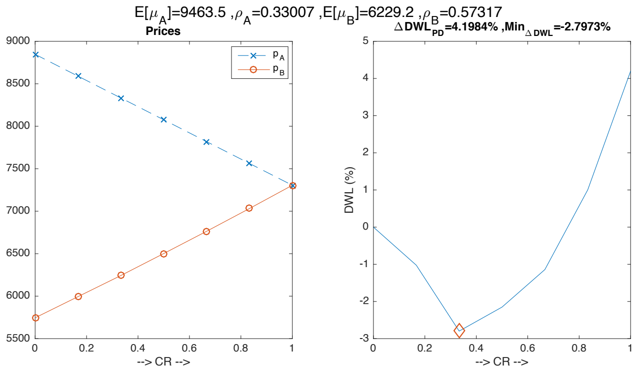
Calibration (1 product)

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



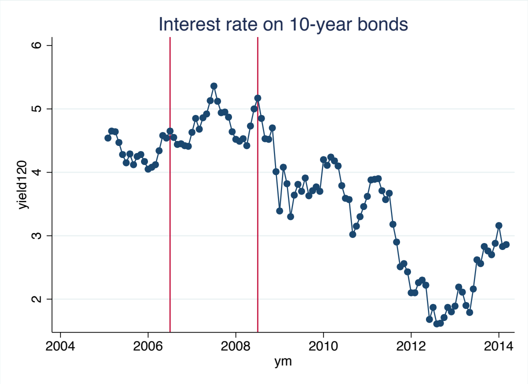
Calibration (1 product)

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



Return

Timeline of Interest Rates



- Sample period occurs before Quantitative Easing policy

Return

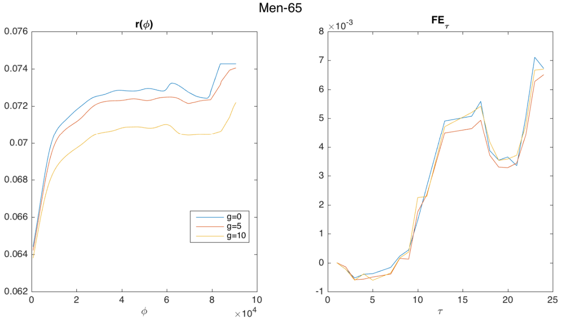
Mortality and Life Expectancy

Return

- I only observe rates for chosen contracts
  - must impute rates
- Rate in contract g for an individual i with fund ϕ_i in month τ is

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

- FE_τ are month fixed-effects
- Estimate $r_g^{\phi}(\cdot)$ non-parametrically



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

Return

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

Return

ML Details

- Estimate $\Theta = \left(\sigma_\beta^2, \beta_0, \beta_\alpha, \beta_\phi, \beta_{FA}, \beta_{INT}, \beta_{PcodeH}, \beta_{PcodeM}\right)$
- β_i is drawn from PDF $f_\beta\left(\beta \mid \theta_i, \Theta\right)$.
- The probability of i choosing g is

$$P_{gi} = \int_\beta I\left\{V_{gi} = \max\left[V_{0i}, V_{5i}, V_{10i}\right]\right\} f_\beta\left(\beta \mid \theta_i, \Theta\right) d\beta.$$

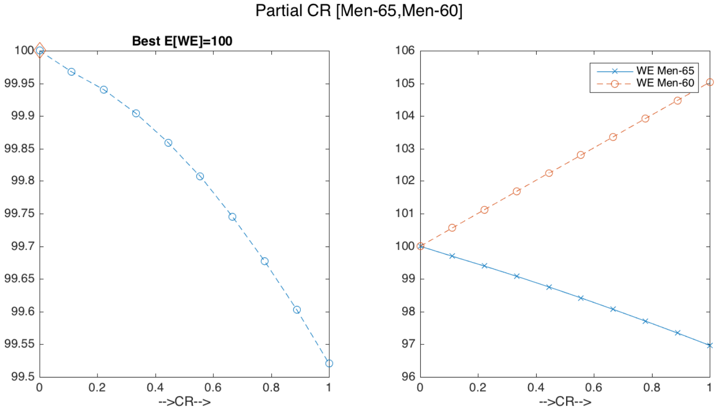
- Likelihood is piecewise flat, so use Logit smoothing:

$$P_{gi} = \int_\beta \frac{\exp\left(\varsigma V_{gi}\right)}{\sum_j \exp\left(\varsigma V_{ji}\right)} f_\beta\left(\beta \mid \theta_i, \Theta\right) d\beta, \qquad \varsigma = 10^6$$

- Integrated by Gaussian Quadrature
- Checked multiple starting values

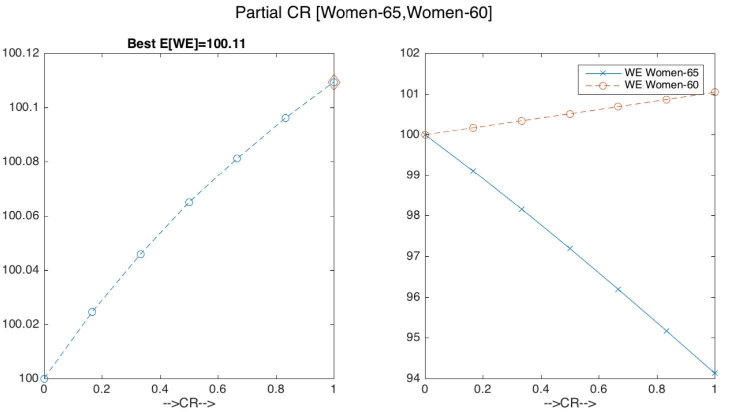
Return

Age-neutral pricing (Men)



- Men 60 very inelastic ⇒ small gain

Age-neutral pricing (Women)



- Women 60 have larger DWL

Return

Robustness Checks

Welfare effect of full CR (%):

	M65+W65	M60+W60	M65+M60	W65+W60
Baseline	-0.16	+0.08	-0.5	+0.11
$\gamma = 2.3$	-0.2	+0.08	-0.29	+0.03
$\gamma = 1.7$	-0.02	+0.12	-0.10	+0.19
$\lambda = 0.12$	-0.15	+0.07	-0.43	+0.10
$\lambda = 0.10$	-0.13	+0.08	-0.42	+0.09

- Very robust to λ
- More sensitive to γ

Return

Multiple Signal Realizations

- Suppose signal is $m \in \{A, B, C, ..., M\}$
- Full PD: $\pi_m(p_m^\star) = 0$
- Full CR: $\sum \pi_m(\bar{p}) = 0$
- Let $\mathscr{A}$ be the subset of high-cost groups, so that $m \in \mathscr{A} \Rightarrow \pi_m(\bar{p}) < 0$.
  - $\mathscr{B}$ 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

$$\min_{m \in \mathscr{B}} \left\{ AC'_m(p_m^\star) \right\} > \max_{m \in \mathscr{A}} \left\{ AC'_m(p_m^\star) \right\}.$$

- Full CR is optimal if all $A\bar{C}_m$ are sufficiently similar and

$$\max_{m \in \mathscr{B}} \left\{ AC'_m(p_m^\star) \right\} < \min_{m \in \mathscr{A}} \left\{ AC'_m(p_m^\star) \right\}$$

Return

UK annuities - Details

In the period of the data:

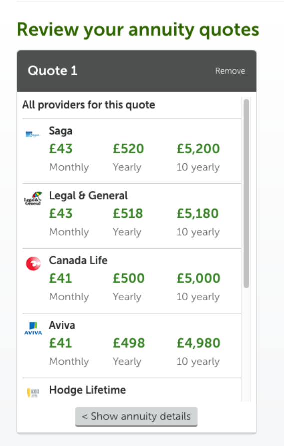
- Around 10% of individuals had DC pensions
- No secondary market for annuities (taxed at around 70%)
- Individuals can withdraw 25% of ϕ tax-free (virtually all do)
- Annuity must be purchased between ages of 55 and 75
- State pensions
  - basic pension is not means-tested
  - typically a small share 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

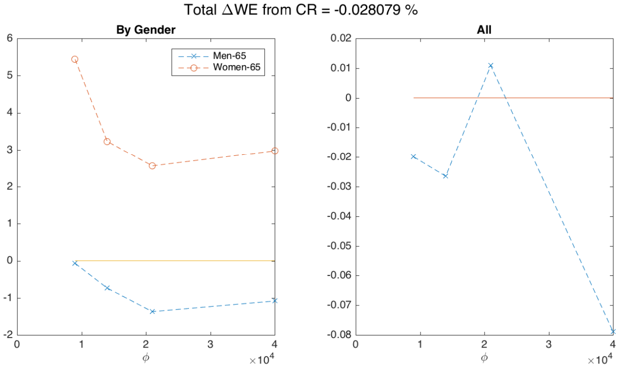
Competition

- Offered rates are similar and close to break-even rates
  - also found by Einav et al. [2010]



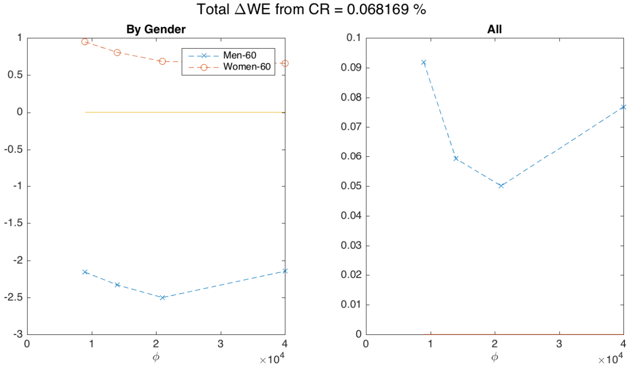
Return

CR by gender for intervals of ϕ, 65-YO



- Policy implied a small overall loss for 65 year olds

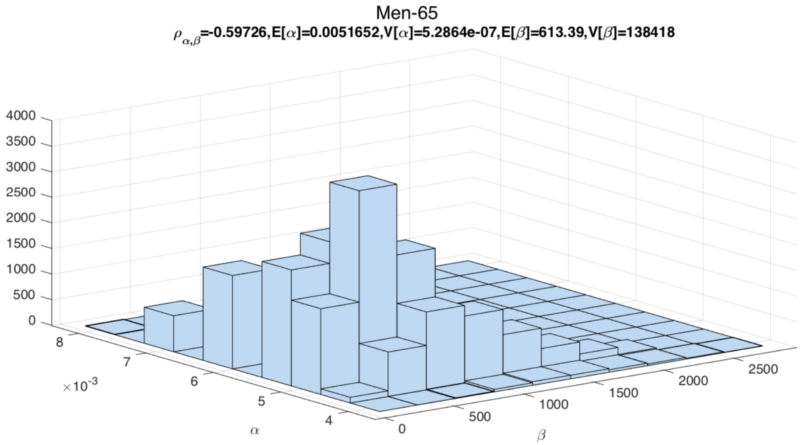
CR by gender for intervals of ϕ, 60-YO



- Policy led to a significant gain by 60 year olds

Return

Estimated distribution of (α, β), Men 65



Return

More Literature

- Age-based CR eliminates "reclassification risk"
  - Koch IJIO 2014, Handel et al EMA 2015
- Ambiguous value of better private information
  - in lemon's markets: Kessler IER 2001, Levin RAND 2001
  - in screening markets: Kessler 1998
- Competitive insurance markets with screening: CR is bad
  - Hoy QJE 1982, Crocker & Snow JPE 1986, Rea SEJ 1987
- Bergemann et al 2015
  - Some information structure can achieve any feasible division of surplus
  - monopoly without selection

Return

Summary Statistics

	Men 65	Women 65	Men 60	Women 60
$\mathbb{E}[\alpha] \times 10^{-3}$	5.16	3.77	2.79	2.09
$\mathbb{V}[\alpha] \times 10^{-7}$	5.28	2.07	1.69	0.715
$\mathbb{E}[\beta]$	618	434	2573	627
$\mathbb{V}[\beta] \times 10^{3}$	148	64	291	68
ρ	-0.58	-0.38	-0.59	-0.53
DWL (%)	0.47	0.22	0.48	0.28

Return

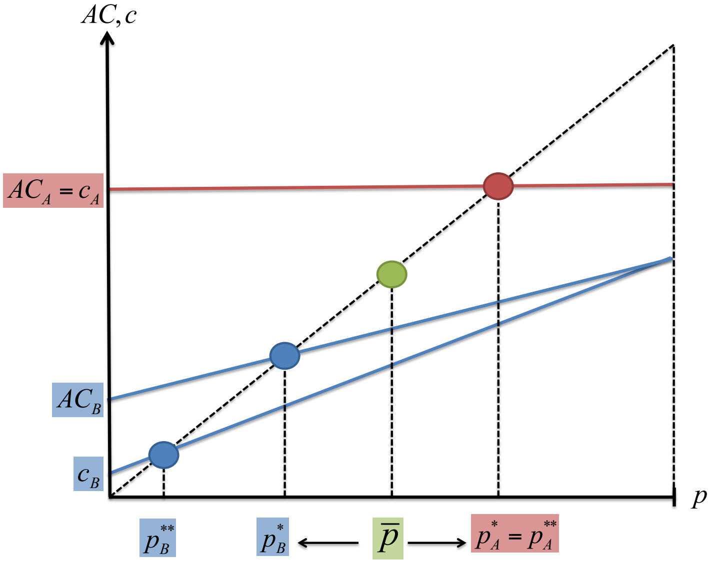
Identification Intuition

- Similar market shares in all contracts $\Rightarrow$ large σ_β
- 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)

Return

Full PD is optimal: graph



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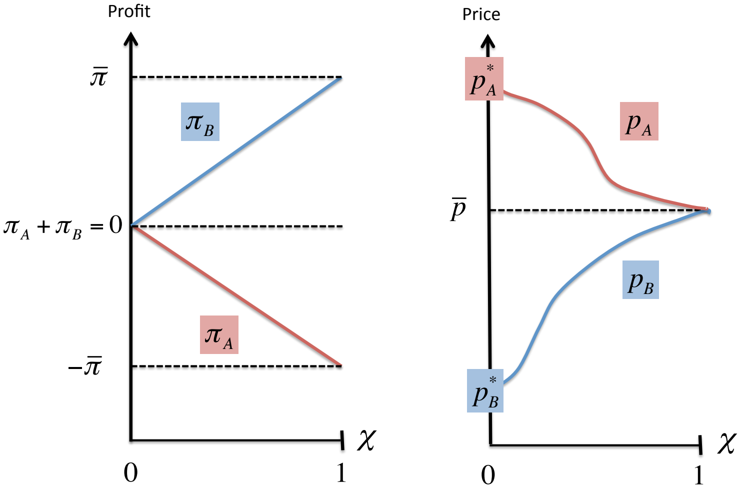
Price Paths



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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 $c'_m < 1$.

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