Longevity Ten

– Santiago, Chile –

Hedging Longevity Risk in Life Settlements Using Biomedical Research-Backed Obligations

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Buddha of longevity...

Introduction

Background

Longevity risk

$\Downarrow$

Policyholders' future realized mortality rates

$\Downarrow$

Liabilities of life insurance market's participants

Various mortality-linked securities proposed in the *longevity market*.

- Longevity bonds, mortality forwards, longevity swaps, etc.
- Payments dependent on the longevity/mortality prospect of certain **underlying population**
  - Reduce asymmetric information
  - Work well for life insurer/pension funds
- Less effective as hedging tools in the *life settlement market*

  $\Leftarrow$ Considerable basis risk materializing between the general population and the small settled groups

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  - $\Leftarrow$ Considerable basis risk materializing between the general population and the small settled groups

A **life settlement** is a sale of an existing life insurance policy to an outside investor (life settlement company)

- Both the insurance benefit and the liability of future contingent premiums are transferred to the investor in exchange for a lump sum payment (settlement price)
- Emerged form the "viatical settlement" market in the 1980s (AIDS)
- Typically involves senior insured with below average life expectancy [usually with certain disease]
- Priced on a policy-by-policy basis

Specific longevity risk: future biomedical evolution of the **underlying disease**

- Collapse of the viatical settlement market $\Leftarrow$ new AIDS drug/therapy
- Medical breakthrough of (chronic) disease acts as an (adverse) longevity shock to the life settlement companies
- Hardly picked up in a population longevity index

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Literature & Contributions

Fernandez et al. (Nature Bio, 2012) & Fagnan et al. (AER, 2013) propose a business model to finance the research in the biotechnology and pharmaceutical industries

... To solve the current problem of under-funding in biomedical research

- Combining a large number of drug-development projects into a single portfolio – megafund
- Further securitize with different tranches – *research-backed obligations* (RBOs)
- Senior tranche ratable and accessible to institutional investors

We connect the two strands of seemingly independent literature:

- Biomedical RBOs used by LSCs as (much more) effective longevity hedging tool
- LSCs serve as instinctive buyers of the risky equity tranche
- Promote the healthy development of both markets

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A Simple Model

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No Hedging

Competitive life settlement market with risk-averse companies

Simple three-period model

- Time-0: propose to purchase a whole-life policy (face value 1), policyholder with disease A, one-period survival prob. p_0
- Time-1: potential medical research with success rate π, survival prob.

$$p_1 \nearrow p_1 + \Delta$$

- Time-2: Every individual deceases by the end

The intrinsic value of the policy:

- With shock:

$$V^s = \frac{1-p_0}{1+r} + \frac{p_0(1-p_1-\Delta)}{(1+r)^2} + \frac{p_0(p_1+\Delta)}{(1+r)^3}$$

- No shock:

$$\begin{aligned} V^n &= \frac{1-p_0}{1+r} + \frac{p_0(1-p_1)}{(1+r)^2} + \frac{p_0 \cdot p_1}{(1+r)^3} \\ &= V^s + \frac{rp_0\Delta}{(1+r)^3}. \end{aligned}$$

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A Simple Model

No Hedging (cont')

The *actually fair price*

$$P^a = \pi \times V^s + (1-\pi) \times V^n$$

- Violates the *individually rational constraint*

$\Rightarrow$ Expected utility

$$\pi \times U(V^s - P^a) + (1-\pi) \times U(V^n - P^a) < U(0)$$

With risk averse LSCs, the *equilibrium offer price*

$$P^* \triangleq \arg_x \{\pi \times U(V^s - x) + (1-\pi) \times U(V^n - x) - U(0) = 0\}$$

With continuous and monotonic $U(\cdot)$, P^* unique and

$$V^s < P^* < P^a < V^n$$

A Simple Model

Hedge with Longevity Swap

Use standard longevity swap as representative of conventional longevity securities

- Entire population equally composed of two cohorts
  - Disease A: $p_1 \Rightarrow p_1 + \Delta$ with prob. π
  - Disease B: $p_1 \Rightarrow p_1 + \tilde{\Delta}$ with prob. $\tilde{\pi}$
- LSC be the long party for the float survival probability

Longevity swap payoff:

	Chance	Realized rate	Long position payoff
Both successful	$\pi \times \tilde{\pi}$	$p_1 + \frac{1}{2}(\Delta + \tilde{\Delta})$	$\frac{1}{2}\Delta(1-\pi) + \frac{1}{2}\tilde{\Delta}(1-\tilde{\pi})$
A successful	$\pi \times (1-\tilde{\pi})$	$p_1 + \frac{1}{2}\Delta$	$\frac{1}{2}\Delta(1-\pi) - \frac{1}{2}\tilde{\Delta}\tilde{\pi}$
B successful	$\tilde{\pi} \times (1-\pi)$	$p_1 + \frac{1}{2}\tilde{\Delta}$	$\frac{1}{2}\tilde{\Delta}(1-\tilde{\pi}) - \frac{1}{2}\Delta\pi$
Both fail	$(1-\pi) \times (1-\tilde{\pi})$	p_1	$-\frac{1}{2}\Delta\pi - \frac{1}{2}\tilde{\Delta}\tilde{\pi}$

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- LSC be the long party for the float survival probability
- The company chooses optimal positions of longevity swap n^*:

$$\begin{aligned} EU^* \quad = \quad & \max_n \Big\{ \pi\tilde{\pi} U \left(V^s - P^* + n[\frac{1}{2}\Delta(1-\pi) + \frac{1}{2}\tilde{\Delta}(1-\tilde{\pi})] \right) \\ & + \pi(1-\tilde{\pi}) U \left(V^s - P^* + n[\frac{1}{2}\Delta(1-\pi) - \frac{1}{2}\tilde{\Delta}\tilde{\pi}] \right) \\ & + \tilde{\pi}(1-\pi) U \left(V^n - P^* + n[\frac{1}{2}\tilde{\Delta}(1-\tilde{\pi}) - \frac{1}{2}\Delta\pi] \right) \\ & + (1-\pi)(1-\tilde{\pi}) U \left(V^n - P^* + n[-\frac{1}{2}\Delta\pi - \frac{1}{2}\tilde{\Delta}\tilde{\pi}] \right) \Big\} \end{aligned}$$

- $\frac{1}{2}\Delta\pi(1-\pi)\left(U'(V^s - P^*) - U'(V^n - P^*)\right) > 0$ with $n = 0$

A Simple Model

Hedge with Medical RBOs

Simplest form of medical RBOs. Return rate:

- R when the research is successful $\mapsto \pi$
- $-R\pi/(1-\pi)$ when the research fails $\mapsto 1-\pi$

Company chooses optimal investment K:

$$EU^{**} = \max_K \left\{ \pi U \left(V^s - P^* + KR \right) + (1-\pi) U \left(V^n - P^* - K \frac{R\pi}{1-\pi} \right) \right\}$$

- $K^* = \frac{rp_0(1-\pi)\Delta}{(1+r)^3 R}$
- Same payoff: $V^s - P^* + \frac{rp_0(1-\pi)\Delta}{(1+r)^3} = P^a - P^*$

Proposition

The company achieves highest expected utility when using medical RBOs to hedge longevity risk, compared with no hedge, or longevity swaps.

Numerical Analyses

Numerical Analyses

Assumption and Equilibrium Price

Acquiring a whole-life policy from a 75 year-old female with general cancer, face amount $500,000

- Initially purchased at age 40 $\Rightarrow$ Premium $5,774.13
- Impact of cancer on the survival rate
  - Statistics from the National Cancer Institute $\Rightarrow$ increase annual mortality at age 75 by 0.75%
  - 150 independent cancer-related researches, 2% success rate
  - Reduction of mortality rate at 10%, 15%, and 20%, with one, two to three, or more than three successful outcomes
- Actuarially fair price $P^a = \$223,888$
- $U(x) = 1 - \exp(-ax)$, with $a = 0.002$
- Equilibrium price $P^e = \$223,339$

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Longevity Hedging

Entire population: 5% cancer patients, the rest 95% move up 0.1%, down 0.1%, or remain unchanged with same probability

12 different scenarios from the longevity swap:

Success	*Remaining population*		
	Up	Same	Down
0	1.61%	1.61%	1.61%
1	4.93%	4.93%	4.93%
2-3	15.04%	15.04%	15.04%
>3	11.76%	11.76%	11.76%

Success	*Remaining population*		
	Up	Same	Down
0	$0.8653	$-0.0574	$-0.9801
1	$0.9028	$-0.0199	$-0.9426
2-3	$0.9216	$-0.0011	$-0.9238
>3	$0.9403	$0.0176	$-0.9051

Optimal number of positions in the longevity swap $n^* = 13.18$

- Limited participation in the longevity swap
- $EU^* = 1.97 \times 10^{-4}$: marginally improved from no hedging case

Numerical Analyses

Medical RBO

Megafund constructed to support all 150 researches:

- Each one has upfront cost at $1,000,000
- Time-0 discounted return at $60,000,000 if successful
- Securitization with two tranches:
  - Debt tranche: backed by the first successful research
  - Equity tranche: backed by any remaining revenue

	Tranche	
	Debt	Equity
Volume	$55,000,000	$95,000,000
P(Return$<$ 0)	4.83%	19.61%
Expected return	$57,102,239	$122,750,148

K^*: $1,085, $EU^* = 0.7701$

Conclusion

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For a life settlement transaction, conventional longevity-linked securities:

- Alleviate longevity exposure from the underlying disease
- But also brings in excess basis risk that cannot be hedged
- Limited participation in the life market

By investing in the hypothetical medical RBOs:

- Access to the typically exclusive biomedical researches
- Reduce basis risk by a large scale – directly disease-related mortality movements

$\Rightarrow$ Better longevity hedging performance

- Complete the market:
  - LSCs have natural appetite in the risky equity tranche, compared with general investors
  - Promote both biomedical securitization market and secondary life market

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Thank you!