Optimal portfolio choice with longevity and health insurance: A developing country context

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1. Introduction

2. The life-cycle model

3. Preliminary results

4. Conclusion
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4. Conclusion
1 – Background

Rapid population ageing & growing awareness of health risks due to COVID-19
Developing countries: basic public insurance → catastrophic medical expenditure

- Government - public insurance system not adequate, how to expand?
- Individuals - retirement risks (longevity, medical, aged care), how to manage them?

Challenging task!

- Future survival probabilities, health cost risks (incl. aged care), economic environment
- Societal changes: family values, growing female labour force participation, etc.

Q: What’s the optimal portfolio for retirees in a less-well developed retirement system?
1 – Annuity puzzle

Theory - Annuities are part of an optimal portfolio
Practice - Voluntary annuitisation rates are low

Many explanations (e.g., Benartzi et al., 2011) - three key reasons

- **Precautionary savings** due to uncertain health-related expenditures (e.g., Koijen et al., 2016; Pang and Warshawsky, 2010; Peijnenburg et al., 2017)
- **Stochastic mortality and correlated health costs** (Laitner et al., 2018; Reichling and Smetters, 2015)
- **Adverse selection** (e.g., Braun et al., 2019; Brown and Finkelstein, 2009; Finkelstein and Poterba, 2004)

Remarks

- Not wise to plan retirement only with retirement **INCOME** products - health risks matter!
- Limited research considering longevity and **health insurance** simultaneously
1 – Our paper

A life-cycle model with annuity, critical illness insurance (CII), and long-term care insurance (LTCI) in a less-well developed retirement system (urban China)

- Multiple health states and random health costs
- Choice of health investment determines post-illness mortality
- Different weights on the marginal utility of consumption in poorer health states
- Sensitivity of health transitions, pricing, preferences, and subsidy
1 – Main contributions

1. The first paper to include **critical illness insurance** in a life-cycle model where existing studies only consider a life annuity and long-term care insurance (Koijen et al., 2016; Pang and Warshawsky, 2010; Peijnenburg et al., 2017; S. Wu et al., 2016).

2. Consider health investment and health-state dependent utility of consumption simultaneously (Peijnenburg et al., 2017; Yogo, 2016)
2 – Outline

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2 – The individual decision

An individual decides his optimal portfolio at retirement.

- Period – from retirement (male, age 60) to death (age 105).
- Portfolio - annuities, CII, LTCI, and savings
- Utility of consumption depends on health state $H_t$, weighted by $\eta H_t$

$$ u(c_t|H_t) = \eta H_t c_t^{1-\gamma} / (1 - \gamma) $$

- One-off portfolio choice

Individual has three health investment choices for medical expenditures, and the post-illness mortality rates depend on these choices.
Individual has typical wealth and public insurance (pension + medical insurance)
Insurance products (standalone):

- Life annuity product: industry mortality curve
- Critical illness insurance: industry incidence and mortality curves
- Long-term care insurance: estimated from the China Health and Retirement Longitudinal Study (CHARLS)

Real discount rate: 1.5%
Real Interest rate: 2%
2 – Decision process and transitions

At retirement: choose insurance portfolio and pay premiums, one-off choice
Other periods:

- Current wealth and pension \( M_t + P_t \)
- Annuity
- Check health state \( H_t \)
- Cash on hand \( A_t \)
- Check if subsidy \( S \) needed

\[ \begin{align*}
& \text{Next period wealth and pension} \\
& = M_{t+1} + P_{t+1} \\
& - \text{Consumption } c_t \\
& - \text{Accrual of interest } R \\
& - \text{CostLTC}_t + \text{LTC}_t \text{ (if first time)} \\
& + \text{CI}_t \\
& - \text{CostCl}_t \\
\end{align*} \]

Figure 1: Decision and transition for each period \( t \)
2 – Calibrated parameters 1/2

Preferences (base case)

- Risk aversion $\rho = 3$ (İmrohoroglu and Zhao, 2018)
- Time preferences $\beta = 0.999$ (İmrohoroglu and Zhao, 2018)
- Bequest strength $b = 50$ (Friedman and Warshawsky, 1990)
- $\eta_{H_t=\text{Cl}} = 1.2$, $\eta_{H_t=\text{LTC}} = 0.7$ (X. Wang and C. Wang, 2020)

Critical illness medical costs (estimated based on Fang et al., 2018 and D. Wu et al., 2018)

$$\text{CostCl} \sim \text{Lognormal}(11.86, 0.92^2), \quad (2)$$

Long-term care cost (estimated based on CHARLS):

$$\text{CostLTC(Age)} \sim \text{Lognormal}(6.13 + 0.02 \times \text{Age}, 1.46^2), \quad (3)$$
Table 1: Calibration methods for health transition probability matrix

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>Critically ill</th>
<th>Long-term care</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy</td>
<td>1-rest</td>
<td>Industry incidence curve</td>
<td>CHARLS estimates</td>
<td>Adjusted from industry mortality curve for pension business</td>
</tr>
<tr>
<td>Critically ill</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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Life expectancy at age 60: 21.2 years (national: 18.4, industry pension curve: 25)
2 – Bellman function

\[ V_t(M_t, H_t) = \max_{c_t, \omega_a, \omega_c, \omega_l} E_t \left\{ u(c_t | H_t) + \beta \left[ \sum_{j=1}^{3} \pi_t(H_t, j)V_{t+1}(M_{t+1}, H_{t+1} = j) + \pi_t(H_t, 4)v(M_{t+1}) \right] \right\}, \]

s.t.

\[
A_t = M_t + P_t + \text{Annuity}_t + \text{CII}_t + \text{LTCI}_t - \text{CostCl}_t - \text{CostLTC}_t - c_t, \\
M_{t+1} = RA_t, \\
A_t \geq 0, \\
c_t \geq S, \\
\omega_a, \omega_c, \omega_l \geq 0, \\
\omega_a + \omega_c + \omega_l \leq M.
\]

Solved numerically by backward induction with the endogenous grid-points method (Carroll, 2006)
3 – Outline

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3 – Optimal allocation

- High demand for CII (with adequate health investment and fewer budget constraints);
- High demand for annuity (if pension is low)
- Small demand for LTCI
- A lower health investment (*Half* or *Quarter*) is better, CII demand drops
- Substantial welfare gain, especially for those with less wealth or pension

<table>
<thead>
<tr>
<th>Allocation of wealth</th>
<th>Choice of health investment</th>
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<tbody>
<tr>
<td><strong>Wealth = 1 million, Pension = 3,000</strong></td>
<td>Adequate</td>
</tr>
<tr>
<td>Annuity</td>
<td>10%</td>
</tr>
<tr>
<td>CII</td>
<td>30%</td>
</tr>
<tr>
<td>LTCI</td>
<td>5%</td>
</tr>
<tr>
<td>Savings</td>
<td>55%</td>
</tr>
<tr>
<td>Utility</td>
<td>-0.36</td>
</tr>
<tr>
<td>Wealth gain</td>
<td>12%</td>
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| **Wealth = 1 million, Pension = 1,000** | Adequate | Half | Quarter |
| Annuity | 40% | 65% | 40% |
| CII | 25% | 5% | 0% |
| LTCI | 5% | 5% | 10% |
| Savings | 30% | 25% | 50% |
| Utility | -0.83 | -0.64 | -0.68 |
| Wealth gain | 32% | 100% | 100% |

| **Wealth = 150,000, Pension = 3,000** | Adequate | Half | Quarter |
| Annuity | 0% | 0% | 0% |
| CII | 80% | 73% | 27% |
| LTCI | 13% | 27% | 33% |
| Savings | 7% | 0% | 40% |
| Utility | -2.68 | -1.39 | -1.03 |
| Wealth gain | 39% | 78% | 100% |

| **Wealth = 150,000, Pension = 1,000** | Adequate | Half | Quarter |
| Annuity | 93% | 100% | 47% |
| CII | 0% | 0% | 33% |
| LTCI | 7% | 0% | 20% |
| Savings | 0% | 0% | 0% |
| Utility | -11.16 | -9.89 | -9.97 |
| Wealth gain | 65% | 97% | 100% |
3 – Health-state dependent utility

- Modify the results - still largely determined by the economic background
- Higher demand for health insurance when the weight $\eta H_t$ is higher, trade-off with longevity insurance
- Annuity demand: 0 → 10% or 20% (high wealth & pension)

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## 3 – Sensitivity Analysis: health transition

### Assumptions of transitions between critically ill (CI) and needing long-term care (LTC)

| Scenario 1 (Benchmark) | Transition from CI state to LTC state = Transition from Healthy to LTC state  
Transition from LTC state to CI state = Transition from Healthy to CI state |
|------------------------|------------------------------------------------------------------------------------------------|
| Scenario 2             | CI to LTC = Healthy to LTC × 2  
LTC to CI = Healthy to CI × 1 |
| Scenario 3             | CI to LTC = Healthy to LTC × 1  
LTC to CI = Healthy to CI × 2 |
| Scenario 4             | CI to LTC = Healthy to LTC × 2  
LTC to CI = Healthy to CI × 2 |
| Scenario 5             | CI to LTC = Healthy to LTC × 5  
LTC to CI = Healthy to CI × 1 |
| Scenario 6             | CI to LTC = Healthy to LTC × 1  
LTC to CI = Healthy to CI × 3 |
| Scenario 7             | CI to LTC = Healthy to LTC × 5  
LTC to CI = Healthy to CI × 3 |

- Benchmark results confirmed
- Annuity demand decreases when transitions to CI and LTC rise
- Largest change: Annuity (60% - 100%, low wealth & pension), CII (25% - 35%, high wealth & pension), LTCI (0 - 40%, low wealth & pension)
3 – Sensitivity Analysis: pricing

Previous: industry pricing, each insurance priced separately wrt their own health transitions for pricing
Now: priced with the same joint health transition matrix

1. Health matrix, pricing and evaluation, unmatched
2. Health matrix, pricing and evaluation, matched
3. The previous seven health transition assumptions tested

Results

• Benchmark results confirmed
• Annuity demand increases substantially from 10% to 35% (high wealth & pension)
3 – Sensitivity Analysis: preferences

Vary preference parameters

• Risk aversion: $\rho = 2, 3, 4, 5$
• Time preference: $\beta = 0.96, 0.985, 0.999$
• Strength of bequest motif: $\beta = 0, 5, 10, 50, 100$

Results (high wealth & pension group)

• Stable demand for CII and LTCI
• More risk averse $\rightarrow$ more annuity (0-10%)
• More patient $\rightarrow$ more annuity (0-10%)
• Higher bequest strength $\rightarrow$ less annuity (30%-0)
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4 – Conclusion

The first paper to include critical illness insurance in a life-cycle model where existing studies only consider a life annuity and long-term care insurance (Koijen et al., 2016; Pang and Warshawsky, 2010; Peijnenburg et al., 2017; S. Wu et al., 2016). The individual has a health-state dependent utility function and chooses among three levels of health investment, facing random health transitions and random health-related costs. Key findings:

- Demand for CII is high, but still depends on the choice of health investment
- High demand for annuity if pension is low & small demand for LTCI
- Allowing for health-state dependent utility and health investment simultaneously results in different trade-offs among the three insurance products, depending on a retiree’s economic background.

Suggestions for insurance companies and governments in developing countries

- Targeting - different products for the relevant population segments
- Price - bundled products priced by a joint health transition matrix
- Priority - given a small proportion of wealth, the next insurance to purchase/expand generating the largest welfare
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Contact: cheng.wan@student.unsw.edu.au


