Health Status and Functional Disability with Systematic Trends: A Comparison between China and the U.S.

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Topic Coverage

1. Introduction
2. Health state transition model
3. Life expectancy and first entry into disability
4. Conclusions
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Introduction

Background

- The surge in healthcare costs → public programs at risk of funding shortfalls
- The solutions from the private market are inevitable, but ...
- A lack of private long-term care products due to various reasons
- To inform the product innovations, it is crucial to better understand
  - the risks of functional disability based on activities of daily livings (ADLs)
  - trends and uncertainty in long-term care risks and mortality of healthy and disabled lives
Literature on estimating health transitions

- Fong et al. (2015) propose a GLM approach to estimate health transition intensities
- Li et al. (2017) extend Fong et al. (2015) to quantify time trend and uncertainty in health transitions
  - Sherris and Wei (2018) include medical history in health states
- Hanewald et al. (2019) estimate health transitions of Chinese elderly
  - include a deterministic time trend
Motivation

- Prior research mostly focuses on the U.S. experience
- China: the largest economy following the U.S., most populous country in the world
  - population in China, although still young, is ageing rapidly
  - China has large regional differences e.g. in economic growth, population urbanisation, social security system
- A cross-country comparison will provide a rich understanding
  - the trends and risks of functional disability and longevity
Research overview

- Apply the framework in Li et al. (2017) to China’s data
- Estimate the time trend and uncertainty in disability, recovery, and mortality
- Compare with the U.S. experience
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Health state transition model

Health state transitions

- Health state classification based on number of difficulties in performing ADLs
  - bathing, toileting, dressing, indoor transferring, continence, feeding
- Disabled state: difficulty in $\geq 2$ ADLs
Model specification

Transition intensity for individual $k$ of transition type $s$ at time $t_j$

- Static model
  \[
  \ln\{\lambda_{k,s}(t_j)\} = \beta_s + \gamma_{s}^{\text{age}} x_k(t_j) + \gamma_{s}^{\text{female}} F_k
  \]

- Trend model
  \[
  \ln\{\lambda_{k,s}(t_j)\} = \beta_s + \gamma_{s}^{\text{age}} x_k(t_j) + \gamma_{s}^{\text{female}} F_k + \gamma_{s}^{\text{trend}} t_j, \quad t_j \text{ is time trend}
  \]

- Frailty model \( \psi \) affects all transitions \( \rightarrow \) generate systematic risk
  \[
  \ln\{\lambda_{k,s}(t_j)\} = \beta_s + \gamma_{s}^{\text{age}} x_k(t_j) + \gamma_{s}^{\text{female}} F_k + \gamma_{s}^{\text{trend}} t_j + \alpha_s \psi(t_j), \quad \psi \text{ is frailty}
  \]
  \[
  \psi(t_j) = \psi(t_{j-1}) + \varepsilon(t_j), \quad \varepsilon(t_j) \overset{iid}{\sim} \mathcal{N}(0, 1), \quad \psi(t_1) = 0
  \]
Estimation method

- Maximum likelihood estimation for $\theta$

$$L(\theta|\mathcal{F}_J, \Psi), \quad \Psi = \{\psi(t_j) : j = 1, \cdots, J\}$$

- Integrate over $\theta$ using the Monte Carlo simulation

$$L(\theta|\mathcal{F}_J) = \int L(\theta|\mathcal{F}_J, \Psi) \approx \frac{1}{N} \sum_{n=1}^{N} L(\theta|\mathcal{F}_J, \Psi^{(n)})$$

- Kalman filtering to recover the frailty process
## Data

<table>
<thead>
<tr>
<th></th>
<th>China</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data</strong></td>
<td>Chinese Longitudinal Healthy Longevity Survey (CLHLS)</td>
<td>U.S. Health and Retirement Study (HRS)</td>
</tr>
<tr>
<td><strong>Inw. freq.</strong></td>
<td>Every 2 –3 years</td>
<td>Every 2 years</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>≥ 65</td>
<td>≥ 50 (select ≥ 65)</td>
</tr>
</tbody>
</table>

- **CLHLS**
  - 22 provinces, ~ 85% of the population in mainland China (Zeng, 2004)
  - representative of national population in terms of the province distribution
## Estimation results (static model)

<table>
<thead>
<tr>
<th>Coeff.</th>
<th>$H \rightarrow D$</th>
<th>$D \rightarrow H$</th>
<th>$H \rightarrow \text{Dead}$</th>
<th>$D \rightarrow \text{Dead}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>China / U.S.</td>
<td>Age</td>
<td>$+ve$ ***</td>
<td>$-ve$ ***</td>
<td>$+ve$ ***</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>$+ve$ ***</td>
<td>$+ve$</td>
<td>$-ve$ ***</td>
</tr>
</tbody>
</table>

- Age and gender have similar impact on health transitions in both countries
  - age $\uparrow$: disability $\uparrow$  recovery $\downarrow$  mortality $\uparrow$
  - female: more likely to become disabled, tend to live longer
Estimation results (trend model)

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>$H \rightarrow D$</th>
<th>$D \rightarrow H$</th>
<th>$H \rightarrow \text{Dead}$</th>
<th>$D \rightarrow \text{Dead}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Time</td>
<td>−ve ***</td>
<td>−ve ***</td>
<td>−ve **</td>
<td>−ve ***</td>
</tr>
<tr>
<td>U.S.</td>
<td>Time</td>
<td>−ve</td>
<td>−ve ***</td>
<td>−ve **</td>
<td>+ve</td>
</tr>
</tbody>
</table>

- Time trend is significant in most transitions
- China experienced significant improvement in disabled mortality
  - possible explanation: development of old-age social security system has profound impact on healthcare $\rightarrow$ improves disabled mortality
Estimation results (frailty model)

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>$H \rightarrow D$</th>
<th>$D \rightarrow H$</th>
<th>$H \rightarrow \text{Dead}$</th>
<th>$D \rightarrow \text{Dead}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Frailty</td>
<td>$+ve$ ***</td>
<td>$+ve$ ***</td>
<td>$-ve$ ***</td>
<td>$-ve$ ***</td>
</tr>
<tr>
<td>U.S.</td>
<td>Frailty</td>
<td>$+ve$ **</td>
<td>$-ve$ ***</td>
<td>$+ve$ ***</td>
<td>$-ve$ ***</td>
</tr>
</tbody>
</table>

- Health transitions are subject to significant systematic uncertainty in both countries
## Model comparison

<table>
<thead>
<tr>
<th>Model</th>
<th>Likelihood ratio test</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td>&lt; 0.01</td>
<td>163,030</td>
</tr>
<tr>
<td>Trend</td>
<td>&lt; 0.01</td>
<td>162,778</td>
</tr>
<tr>
<td>Frailty</td>
<td>&lt; 0.01</td>
<td>162,337</td>
</tr>
<tr>
<td>U.S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td>&lt; 0.01</td>
<td>123,817</td>
</tr>
<tr>
<td>Trend</td>
<td>&lt; 0.01</td>
<td>123,761</td>
</tr>
<tr>
<td>Frailty</td>
<td>&lt; 0.01</td>
<td>123,613</td>
</tr>
</tbody>
</table>

- Inclusion of the time trend and the frailty factor improves the fit.
- Use the trend and frailty models to compare life expectancy and age of becoming disabled.

Use the trend and frailty models to compare life expectancy and age of becoming disabled.
Life expectancy and first entry into disability

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Numerical simulations

Subjects: females who are healthy at 65
- Females are more likely to require long-term care
- Typically assume people retire at age 65
- Disabled individuals unlikely to obtain long-term care insurance due to underwriting

Investigate life expectancy and age of first entering into the disabled state conditional on occurrence → implications on pricing and risk management of retirement income products
- Life expectancy affects how long the payment will last
- Entry age affects when the payment will start
Life expectancy and first entry into disability

Life expectancy (trend model)

- Improvement in life expectancy
  - China > U.S.
- China: $\Delta$ Total $> \Delta$ Healthy
  $\rightarrow$ more time spent in disability
- U.S.: $\Delta$ Total $< \Delta$ Healthy
  $\rightarrow$ more time spent in the healthy state
Life expectancy and first entry into disability

First entry into disability (trend model)

- Slight delay in the first entry into disability *conditional on occurrence*
  - China ≈ U.S.

Mengyi Xu (CEPAR, UNSW)
China: wider confidence interval, and it increases over time

→ survival-contingent payouts: more challenging to price and manage risks
China: wider confidence interval, and it increases over time

→ more pressure on risk management of long-term care benefits
China: much wider variability in the onset of disability complicates the cash flow (i.e. long-term care benefits) discounting
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Conclusions

- Both countries experienced life expectancy improvement.
  - China: larger improvement in disabled mortality $\rightarrow$ more time spent in disability.
  - U.S.: larger improvement in healthy mortality $\rightarrow$ more time spent in the healthy state.
- Health transitions are subject to more significant systematic uncertainty in China.
  - Life expectancy, first entry age into disability: wider confidence intervals, and they have increased over time.
  - More challenging to price and manage risks for retirement income products in China.


Appendix
CLHLS province distribution (2010)

2010

Percentage (%)

0 5 10 15

Guangxi Jiangsu Sichuan Zhejiang Guangdong Anhui Fujian Shandong Henan Shanghai Liaoning Hebei Chongqing Hunan Jilin Heilongjiang Beijing Shaanxi Jiangxi Hebei Tianjin Shanxi

CLHLS Census

CLHLS province distribution (2011-12)

Percentage (%)

CLHLS
Census

Shandong
Guangxi
Jiangsu
Hunan
Henan
Guangdong
Hubei
Hainan
Jiangxi
Shanghai
Hunan
Guangdong
Zhejiang
Jilin
Heilongjiang
Shaanxi
Hainan
Jilin
Heilongjiang
Hebei
Tianjin

0 5 10 15

Percentage (%)

2011-12