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

Topic Coverage

Background

- The surge in healthcare costs $\rightarrow$ 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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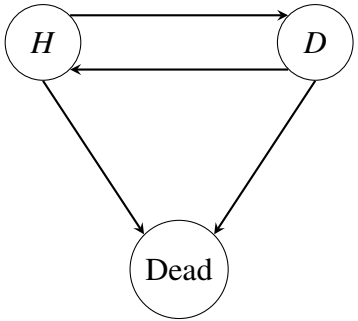
Health state transitions



- Health state classification based on number of difficulties in performing ADLs
  - bathing, toileting, dressing, indoor transferring, continence, feeding
- Disabled state: difficulty in $>= 2$ 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 ψ 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 $\boldsymbol{\theta}$

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

- Integrate over $\boldsymbol{\theta}$ using the Monte Carlo simulation

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

- Kalman filtering to recover the frailty process

Data

	China	U.S.
Data	Chinese Longitudinal Healthy Longevity Survey (CLHLS)	U.S. Health and Retirement Study (HRS)
Inw. freq.	Every 2 –3 years	Every 2 years
Year	1998, 2000, 2002, 2005, 2008-09, 2011-12, 2014	1998 – 2014
Age	≥ 65	≥ 50 (select ≥ 65)

- CLHLS
  - 22 provinces, $\sim$ 85% of the population in mainland China (Zeng, 2004)
  - representative of national population in terms of the province distribution

Estimation results (static model)

	Coeff.	$H \to D$	$D \to H$	$H \to$ Dead	$D \to$ Dead
China / U.S.	Age	$+$ve ***	$-$ve ***	$+$ve ***	$+$ve ***
	Female	$+$ve ***	$+$ve	$-$ve ***	$-$ve ***

- 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)

	Coeff.	$H \to D$	$D \to H$	$H \to$ Dead	$D \to$ Dead
China	Time	$-$ve ***	$-$ve ***	$-$ve **	$-$ve ***
U.S.		$-$ve	$-$ve ***	$-$ve **	$+$ve

- 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 $\to$ improves disabled mortality

Estimation results (frailty model)

	Coeff.	$H \to D$	$D \to H$	$H \to$ Dead	$D \to$ Dead
China	Frailty	$+$ve ***	$+$ve ***	$-$ve ***	$-$ve ***
U.S.		$+$ve **	$-$ve ***	$+$ve ***	$-$ve ***

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

Model comparison

Model	Likelihood ratio test p-value	AIC
China		
Static		163,030
Trend	< 0.01	162,778
Frailty	< 0.01	162,337
U.S.		
Static		123,817
Trend	< 0.01	123,761
Frailty	< 0.01	123,613

- 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

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Numerical simulations

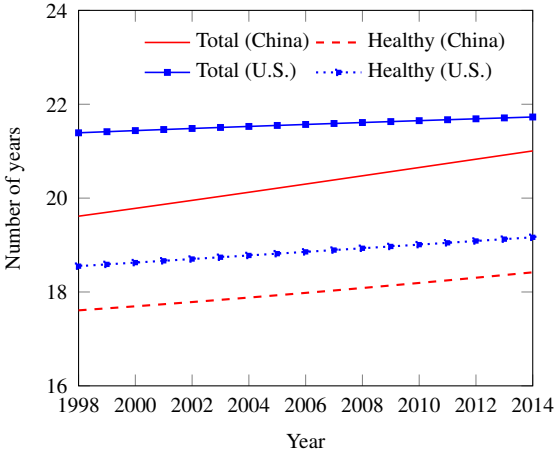
Subjects: females who are healthy at 65

- 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* $\rightarrow$ implications on pricing and risk management of retirement income products

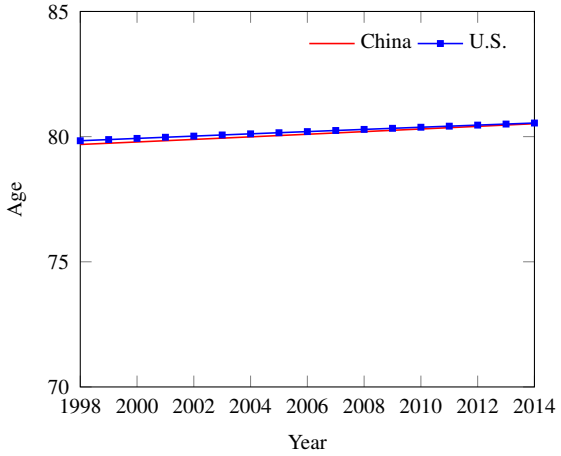
- Life expectancy affects how long the payment will last
- Entry age affects when the payment will start

Life expectancy (trend model)



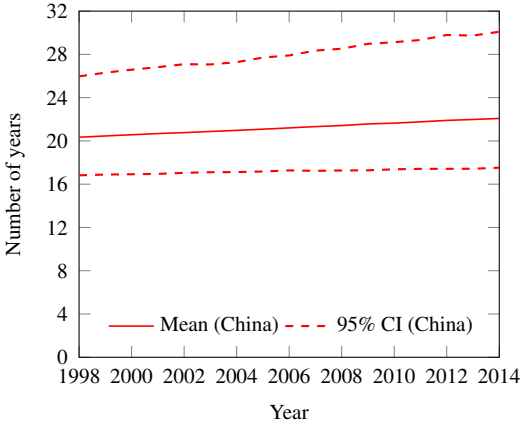
- Improvement in life expectancy
  - China $>$ U.S.
- China: Δ Total $>$ Δ Healthy
  $\rightarrow$ more time spent in disability
- U.S.: Δ Total $<$ Δ Healthy
  $\rightarrow$ more time spent in the healthy state

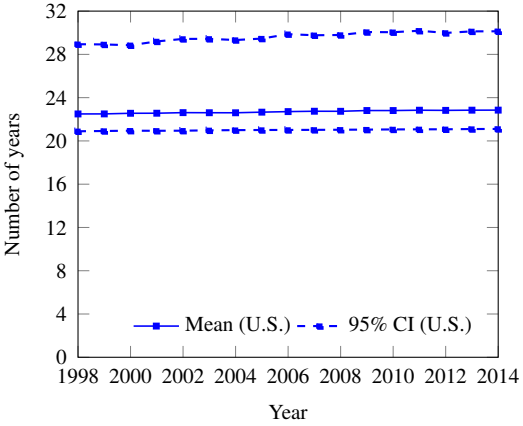
First entry into disability (trend model)



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

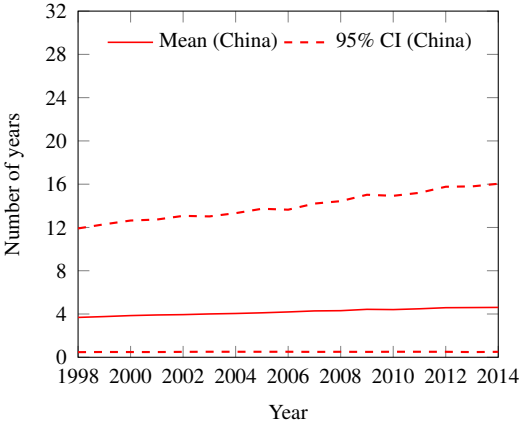
Life expectancy (frailty model)

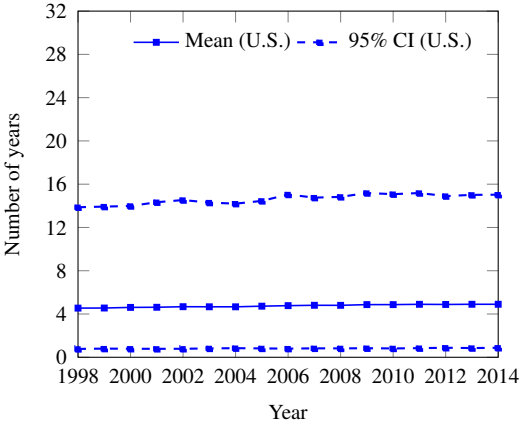




- China: wider confidence interval, and it increases over time
  ↪ survival-contingent payouts: more challenging to price and manage risks

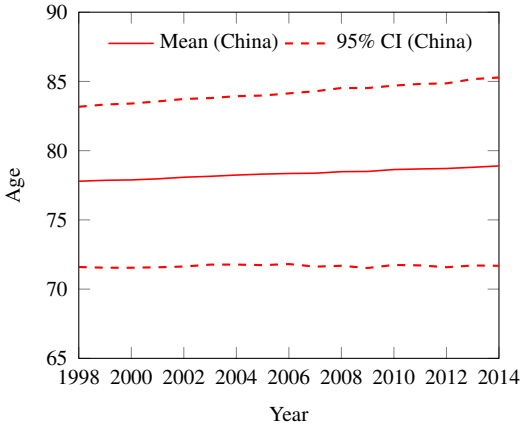
Time spent in disability (frailty model)

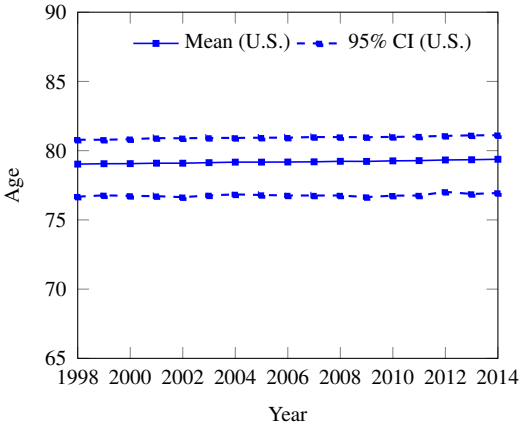




- China: wider confidence interval, and it increases over time
  ↪ more pressure on risk management of long-term care benefits

First entry into disability (frailty model)





- China: much wider variability in the onset of disability
  $\hookrightarrow$ complicates the cash flow (i.e. long-term care benefits) discounting

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Conclusions

- Study trends and uncertainty in long-term care risks and mortality using China and U.S. data
- 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

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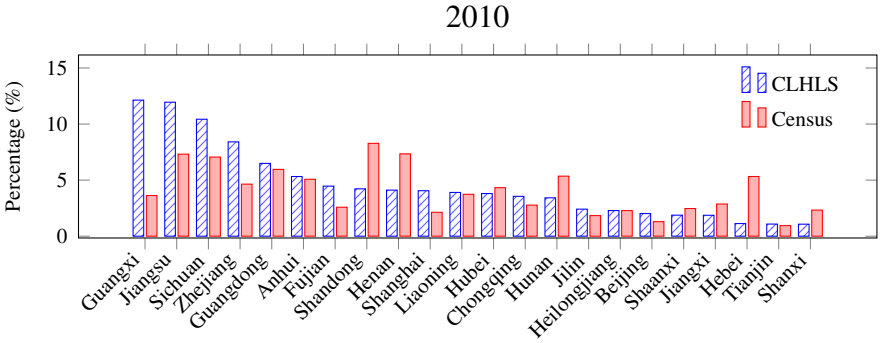
Appendix

CLHLS province distribution (2010)



CLHLS province distribution (2011-12)