Health Status and Functional Disability with Systematic Trends:

A Comparison of China and the USA

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Motivation

Increasing demand of LTC

Reason of arising LTC burden

- Accelerating ageing process
- Declining fertility
- Ineffectiveness of self-insure
- Improving survival rate of the oldest elderly

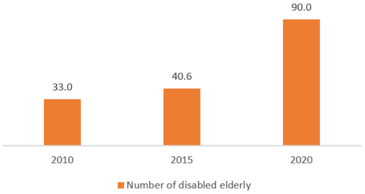


Figure 1: No. of disabled elderly(Million)

Early stage of studies on health status transition rates of China

Studies among other populations provide suggestive insights

- Significant trend improvement in incidence of disability
- Necessity of taking uncertainty into account

Our contribution

- Follow Li, Shao, and Sherris (2017) to estimate the health status transition rates of disabled elderly incorporating trend and uncertainty impact for China.
- Provide interesting perspectives by comparing with the USA analysis with the same model.

Data source: The 4th National Disabled Elderly Situation Study in Urban and Rural Areas, China National Working Commission On Ageing, 2016.09

Questions we will answer

Factor impacts

- Whether the compression of disability, improvement of recovery, improvement of healthy mortality and disabled mortality exist?
- What's the role the uncertainty plays in the health status transitions?
- How big is the gap of the disability rate among female and male, urban and rural residence?
- Factor impact comparison with the USA.

Influence on the life path of individuals

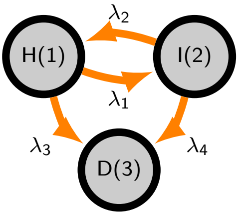
- How does the gap between disabled mortality and healthy mortality goes as time pass?
- How does the probability of being disabled change in the life path of a certain healthy individual
- How does the ratio of years spent in disabled to total life expectancy change?
- Are people living longer active lives as well as longer lives?
- The similarity and difference of the influence compared with the USA.

Outline

Outline

Three-state continuous time Markov model

Three-state disability model with recovery



- Two transition states
  Healthy(H)
  Incident of disability(I)
- One absorbing state
  Dead(D)

(Could easily be extended by splitting the disabled state to more states)

Continuous time Markov process

- The conditional distribution of future states depend on the current state
- Transition rates are allowed to update any time during the survey spell when the transition happens.

Outline

Specification of the intensity function

Adopt the Cox proportional hazards specification(Cox 1992)
The conditional transition intensity for individual k of transition type s at time t:

$$\lambda_{sk} = \exp[\beta_s + \gamma_s^{'} \omega_k(t) + \aleph_x \cdot \psi(t)] \cdot H_{sk}(t) \quad (1)$$

$\omega_k(t)$, vector of the observed covariates for each individual k (Age, gender and residence,time).
$\psi(t)$, the unobserved latent factor (Frailty).
$H_{sk}(t)$, the baseline hazard function to allow for duration dependence (Set to 1).

Static model(Reference level)

$$\ln \lambda_{skx} = \beta_s + \gamma_s^{age} \cdot x + \gamma_s^{female} \cdot F + \gamma_s^{urban} \cdot U \quad (2)$$

Time trend model

$$\ln \lambda_{skx}(t) = \beta_s + \gamma_s^{age} \cdot x + \gamma_s^{female} \cdot F + \gamma_s^{urban} \cdot U + \phi_s \cdot t \quad (3)$$

Frailty model

$$\ln \lambda_{skx}(t) = \beta_s + \gamma_s^{age} \cdot x + \gamma_s^{female} \cdot F + \gamma_s^{urban} \cdot U + \phi_s \cdot t + \alpha_s \cdot \psi(t) \quad (4)$$

[1] [2] [3]

[1] s-Health status, 1-3; k- the kth individual; x- age.
[2] x-age, 1-3; F,U-indicator variables, female,urban; t-time;ψ-the latent factor
[3] Note that ψ is the same for all transition types

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1 2 3

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Parameter Estimation: Maximum Likelihood

Notation

$Y_{sk}(t)$-whether a transition happens at time t, if so, $Y_{sk}(t) = 1$;
$R_{sk}(t)$-whether exposed to transition risk between $t-1$ to t, if so, $R_{sk}(t) = 1$.

The ML function

- Static and Time trend model

$$L(\theta|\mathcal{F}_T)_{timeTrend} = \prod_{t=1}^{T}\prod_{k=1}^{K}\prod_{s=1}^{S} exp\{Y_{sk}(t)\cdot \ln[\lambda_{skx}(t)] - R_{sk}(t)\int_{t-1}^{t}\lambda_{skx}(u)du\} \tag{5}$$

- Frailty model

  Conditional ML function

$$L(\theta|\mathcal{F}_T,\Psi)_{frailty} = \prod_{t=1}^{T}\prod_{k=1}^{K}\prod_{s=1}^{S} exp\{Y_{sk}(t)\cdot \ln[\lambda_{skx}(t)] - R_{sk}(t)\int_{t-1}^{t}\lambda_{skx}(u)du\} \tag{6}$$

  Unconditional ML function

$$L(\theta|\mathcal{F}_T)_{frailty} = \int L(\theta|\mathcal{F}_T,\Psi)dP(\Psi) = \frac{1}{N}\sum_{m=1}^{N} L(\theta|\mathcal{F}_T,\Psi^m) \tag{7}$$

Monte Carlo simulation is used to generate the latent factor to get the simulated estimator of the ML function.

Definition and data

Definition of disability: Functional disability

Evaluate the inability to perform basic self-care activities without assistance

- Commonly used trigger of LTCI.
- Evaluated by Activities of Daily Living(ADL), including bathing, dressing, toileting, transferring, continence, feeding.
- Categorised as disabled when having difficulties in 2 or more of the 6 ADLs.

Data: Chinese Longitudinal Healthy Longevity Survey, 1998-2011

- Interviewees: the elderly aged 65 and above in 22 provinces.
- Samples: 42155 individuals.
- Year the surveys were conducted: 1998, 2000, 2002, 2005, 2008, 2011

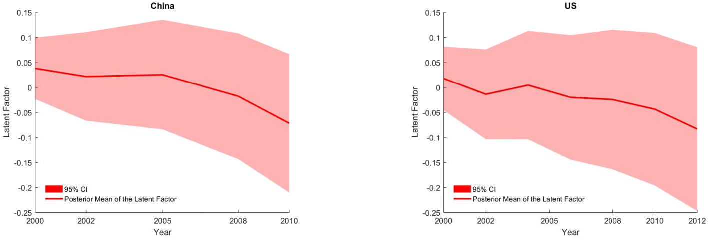
Outline

Recovery of the latent factor

Recovery: Kalman Filter

- Follow Li, Shao, and Sherris (2017) to use the state space model to link the observation indicator $Y_{s,k,t}$ to the $\ln \lambda_{s,k,t}$.
- Using Gaussian distribution to estimate Y's non-Gaussian distribution.

Posterior mean of latent frailty factor



(a) China (b) US

Figure 2: Posterior mean of latent frailty factor

Outline

Parameter estimates for China

Table 1: Parameter estimates for the frailty model

	Transition Type	H-I	I-H	H-D	I-D
	s=	1	2	3	4
Frailty	β_s	-8.8398***	-0.7123*	-9.5553***	-6.6308***
	(σ_β)	*0.1655*	*0.3712*	*0.0879*	*0.1765*
	γ_s^{age}	0.0670***	-0.0171***	0.0863***	0.0606***
	$(\sigma_{\gamma^{age}})$	*0.0017*	*0.0039*	*0.0009*	*0.0018*
	γ_s^{female}	0.1833***	0.0571	-0.2866***	-0.2083***
	$(\sigma_{\gamma^{female}})$	*0.0331*	*0.0699*	*0.0164*	*0.0273*
	γ_s^{urban}	0.3333***	-0.2204***	-0.0600***	-0.0576**
	$(\sigma_{\gamma^{urban}})$	*0.0312*	*0.0629*	*0.0165*	*0.0239*
	ϕ_s	-0.0855***	-0.0868***	0.0060**	-0.0136***
	(σ_{α_s})	*0.0050*	*0.0096*	*0.0029*	*0.0039*
	$(\alpha_s$	-0.1070***	0.0000	0.0104**	0.0098
	(σ_{α_s})	*0.0099*	*0.0190*	*0.0050*	*0.0072*
	Log Likelihood	**-75461**			
Static	**Log Likelihood**	**-75669**			
Time trend	**Log Likelihood**	**-75525**			

The significant level are marked as $*p < 0.1$; ** $p < 0.05$; ***$p < 0.01$.
Similarly hereinafter. The parameter estimated is for annual rates.
1000 paths of ϕ is generated for the frailty model.

Parameter estimates for Comparison

Table 2: Parameter estimates of model without residence variable

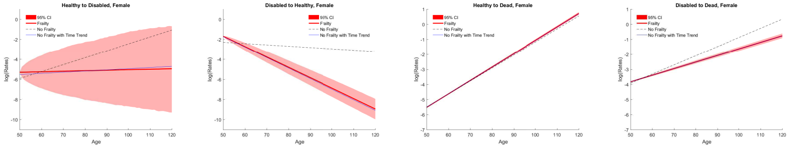
	Transition Type	H-I	I-H	H-D	I-D
	s=	1	2	3	4
	β_s	-8.6576***	0.1502	-10.5629***	-6.9249***
	(σ_β)	*0.1108*	*0.1299*	*0.1173*	*0.1502*
	γ_s^{age}	0.0682***	-0.0318***	0.1015***	0.0648***
	$(\sigma_{\gamma^{age}})$	*0.0014*	*0.0017*	*0.0014*	*0.0018*
	γ_s^{female}	0.2898***	0.0491	-0.4566***	-0.3778***
USA	$(\sigma_{\gamma^{female}})$	*0.0284*	*0.0400*	*0.0271*	*0.0357*
	ϕ_s	-0.0039	0.0058	-0.0388***	0.0023
	(σ_{α_s})	*0.0042*	*0.0056*	*0.0040*	*0.0053*
	$(\alpha_s$	0.0121	0.0287***	-0.0207**	0.0134
	(σ_{α_s})	*0.0084*	*0.0115*	*0.0084*	*0.0107*
	Log Likelihood	**-63642**			

Outline

Simulated Transition Rates

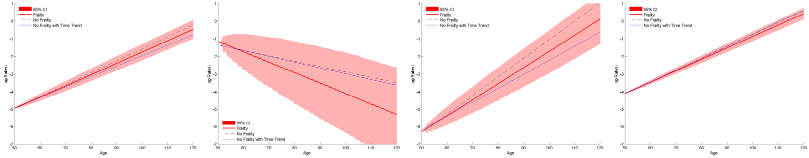
The frailty produces greater uncertainty in the morbidity rate in China whereas it has a greater impact on the recovery and healthy mortality rates in the USA.

China



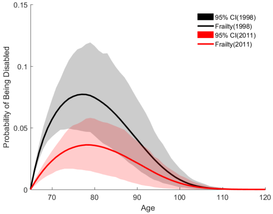
Incidence | Recovery Rate | Healthy Mortality | Disabled Mortality

The USA

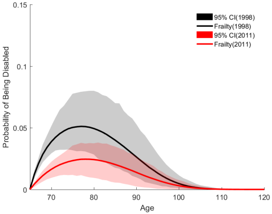


Age onset of disability

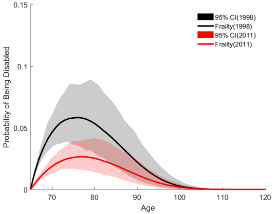
- The age most likely onset of disability is delayed by 1 year in 2011 compared with 1998 .
- The peak of the disability occurs at an older age for females.
- Less uncertainty for the cohort in the later period.



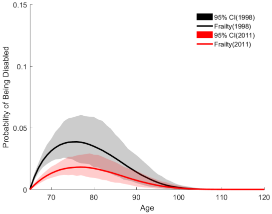
(a) Urban Females



(b) Rural Females



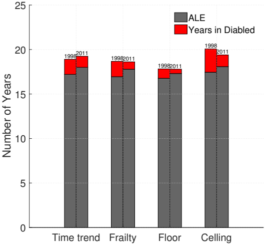
(c) Urban Males



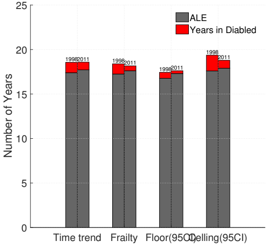
(d) Rural Males

Trend of life expectancy

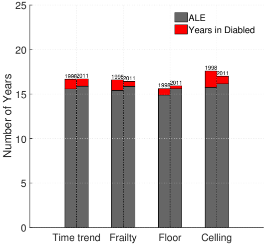
- Living longer active lives as well as longer lives.
- Sharp decline of years spent in disabled.



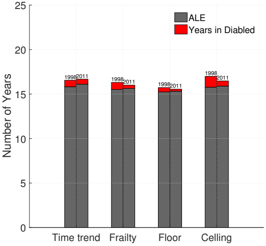
(a) Urban Female



(b) Rural Female



(c) Urban Male



(d) Rural Male

Active life expectancy of the total life expectancy

- Ratio of active life expectancy in China faces higher uncertainty than in the USA.
- Trend improvement of the ALE/TLE in China is larger than in the USA.

Table 3: ALE/TLE in China

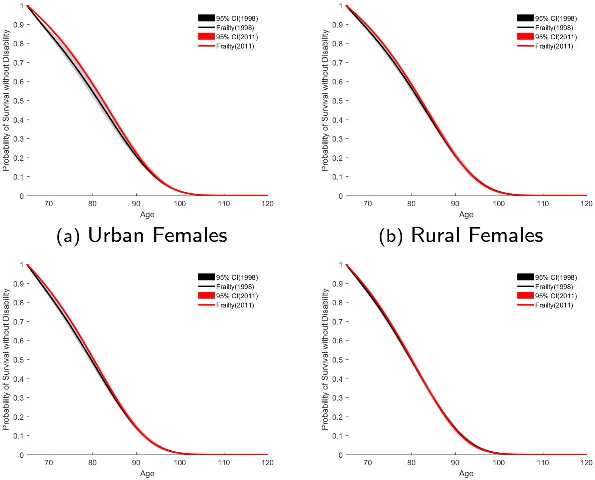
	Age	Static	Time Trend	Frailty	low(95CI)	up(95CI)
Males	50	0.96	0.98	0.96	0.91	0.96
	65	0.94	0.96	0.95	0.87	0.96
	75	0.93	0.95	0.93	0.88	0.95
Females	50	0.95	0.97	0.95	0.87	0.96
	65	0.93	0.95	0.93	0.83	0.95
	75	0.91	0.93	0.91	0.82	0.94

Table 4: ALE/TLE in the USA

	Age	Static	Time Trend	Frailty	low(95CI)	up(95CI)
Males	50	0.938	0.936	0.941	0.917	0.967
	65	0.911	0.909	0.915	0.896	0.938
	75	0.889	0.891	0.892	0.874	0.913
Females	50	0.901	0.897	0.908	0.866	0.951
	65	0.859	0.859	0.867	0.834	0.907
	75	0.822	0.825	0.828	0.796	0.861

ALE: Active life expectancy; TLE: Total life expectancy.

Active survival curves



(a) Urban Females (b) Rural Females (c) Urban Males (d) Rural Males

Figure 5: Simulated disability-free survival curve for an individual aged 65

Summary: Characteristics in China

- Factor impact
  - Residence gap exists in all transition rates.
  - Compression of disability and disabled mortality happens in China.
  - Deterioration of recovery rates shows rather than improvement
  - The role the uncertainty plays (enhance or reduce) on incidence and healthy mortality relates to specific periods.
- Influence on the life path of individuals
  - Less uncertainty in the probability of being disabled for the cohort in the later period.
  - Delay of the most likely age onset of disability.
  - Live healthier as well as live longer (Rectangularization of healthy survival curves).
  - Shrinking years spent in disabled.
  - Narrowing gap between disabled and healthy mortality.

Summary: Comparison between China and the USA

Something in common for both countries

- A downward trend for the frailty factor.
- Existence of compression(trend improvement) of incidence of disability.
- Similar role of age and gender for both countries(No gender difference in recovery rates).
- Later occurrence of the peak of the age onset for females.

Something different between China and the USA

- Trend improvement of mortality happens in both countries, but for different groups. It is for the healthy in the USA, while for the disabled in China.
- Significant latent factor impact shows on incidence and healthy mortality in China , compared to on recovery and healthy mortality rates in the US.
- The latent factor produces greater uncertainty in the incidence in China whereas it has a greater impact on the recovery and healthy mortality in the US.
- Ratio of active life expectancy faces higher uncertainty in Chinathan in the USA.
- Disability is expected to occur at older ages in the future due to different reasons. In China it is because of a significant reduction in disability rates. In the US there is expected to be more old-age healthy survivors due to the systematic improvement on mortality rates.

Any suggestion is appreciated . . .

Thank You!

Work done so far on China and our contribution

Studies on factor impact in China

- Static
  - Age ,Gender and residence impact
    Zhang (2015) and Pan, Sun, and Xue (2015)
- Dynamic Prevalence of disability over several decades Zheng et al. (2011)
  Time trend Hanewald, Li, and Shao (2017)

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Trend improvement in incidence of disability

First introduced by Fries et al. (1984)

- United States (Manton 1988; Reynolds, Crimmins, and Saito 1998; De Leon et al. 1999; Freedman, Martin, and Schoeni 2002; Crimmins and Beltrán-Sánchez 2011; Li, Shao, and Sherris 2017)
- Spain (Sagardui-Villamor et al. 2005)
- UK (Jagger and Clarke 1991; Rickayzen and Walsh 2002)

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Necessity of taking uncertainty into account

- Theoretically, complexity of the interplay between innate function decline and environmental factors produces uncertainty in the estimation of health status transitions.
- Practically, Li, Shao, and Sherris (2017) prove the existence of uncertainty in transition rates.

Conclusion

Uncertainty in transition rate rise uncertainty in survival probabilities, life expectancy, and consequently future cost, and provoke the necessity to be taken into account to better capture the risk and allow for stress scenario analysis.

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Studies on factor impact on incidence of disability

- Gender bias
  Crimmins, Saito, and Reynolds (1997), Jette and Branch (1981), Strauss et al. (2000), Robinson (1996), and Rickayzen and Walsh (2002)
- Age effect
  Guillaume BIESSY (2015): Incidence rate increase exponentially with respect to the age
- Social, psychosocial environment and historical events
  Fried and Guralnik (1997), Manton, Stallard, and Corder (1997), Reynolds, Crimmins, and Saito (1998), De Leon et al. (1999), and Freedman et al. (2006)
- Trend improvement(Existence of compression) of disability
  First introduced by Fries et al. (1984)
  - United States (Manton 1988; Reynolds, Crimmins, and Saito 1998; De Leon et al. 1999; Freedman, Martin, and Schoeni 2002; Crimmins and Beltrán-Sánchez 2011; Li, Shao, and Sherris 2017)
  - Spain (Sagardui-Villamor et al. 2005)
  - UK (Jagger and Clarke 1991; Rickayzen and Walsh 2002)
- Uncertainty
  Li, Shao, and Sherris (2017)

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