



SOCIETY OF ACTUARIES

**SOA Annual Symposium Shanghai**

**November 5-6, 2012**

**Shanghai, China**

**Session 2b: Mortality Improvement and Longevity  
Risk: Implication for Insurance Company in China**

Xiaojun Wang



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**SOA周年会议(上海)**  
**5-6 November, 2012**  
**Shanghai, China**

## **Mortality Improvement and Longevity Risk: Implication for Insurance Company in China**

Xiaojun Wang  
**Renmin University of China**

## **Agenda**

- Background
- Mortality improvement in China
- Modeling mortality and longevity
- Implication of longevity risk for China
- Longevity risk management

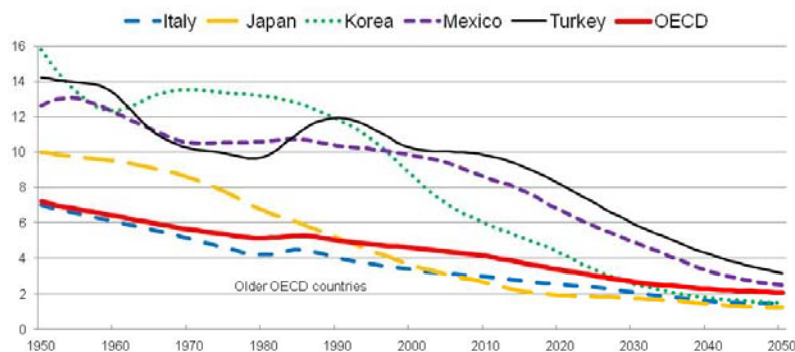
## Background

- Global ageing and longevity trend
- Lot of analysis and research relating to mortality improvement and longevity risk for developed countries
- China face more serious ageing and longevity problem in the future
- But, poor and limited research on mortality
- How to measure and manage mortality risk for social security, pension, annuities in China?

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## Global Ageing Trend

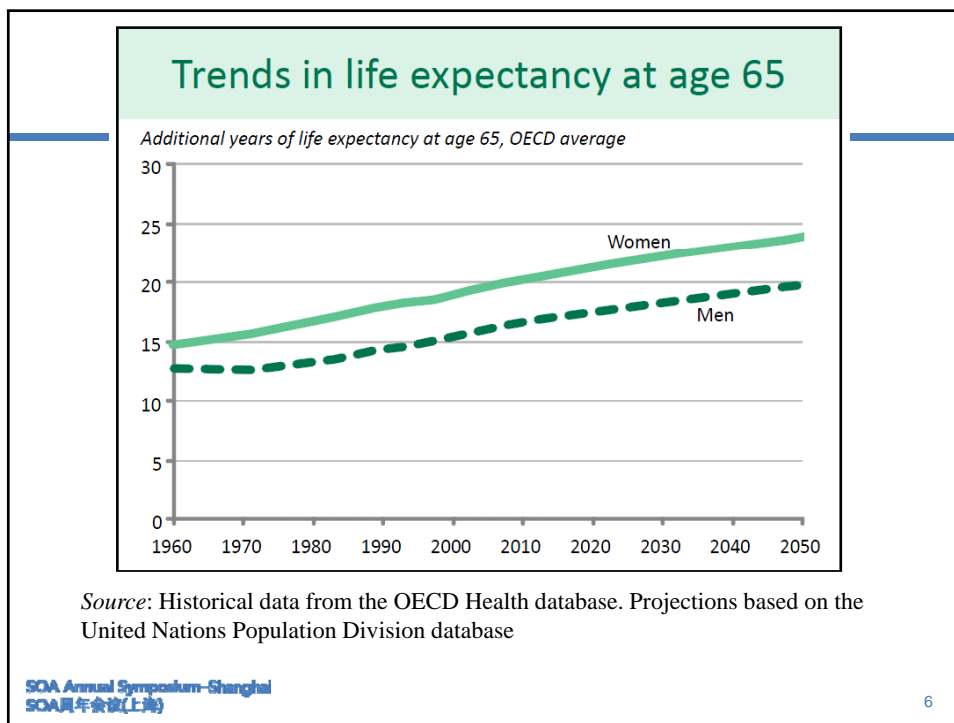
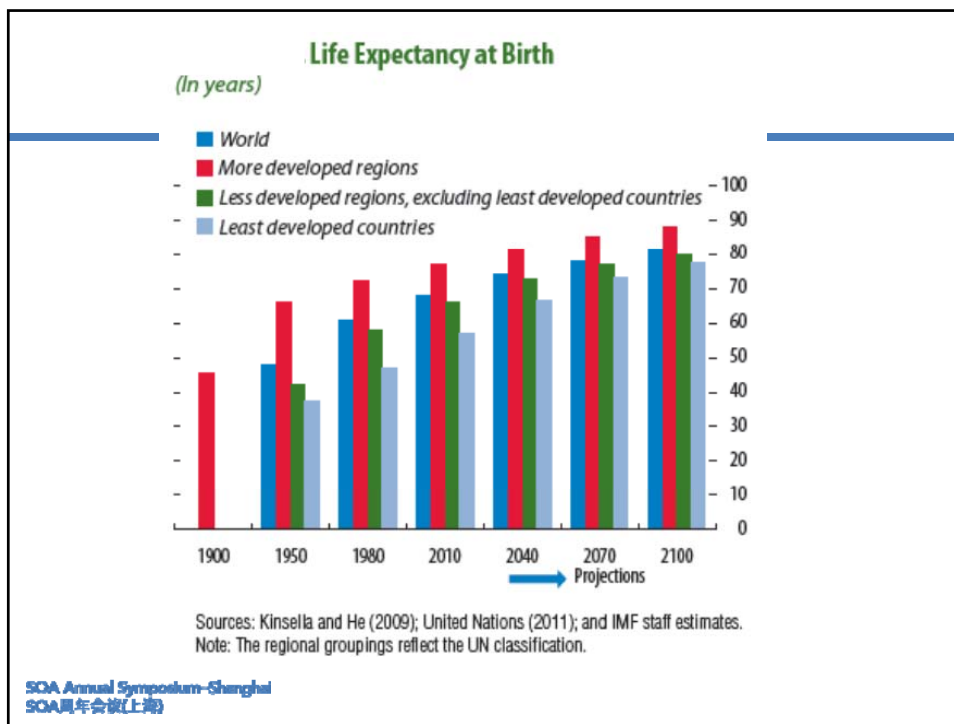
Old age support rate in selected countries, 1950-2050  
(Number of people of working age (20-64) per person of pension age (65+))



Source: OECD (2011), *Pensions at a Glance*, OECD Publishing, Paris  
([www.oecd.org/els/social/pensions/PAG](http://www.oecd.org/els/social/pensions/PAG)); United Nations, World Population Prospects - 2008 Revision.

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## Literature

- Google scholar
  - Mortality improvement
    - 1970,000 results
    - 736,000 results since 2002
    - **18,700 results since 2012**
  - Longevity risk
    - 260,000 results
    - 81,700 results since 2002
    - **17,100 results since 2012**
  - Conference and seminar
    - International Longevity Risk and Capital Markets Solutions Conference, 2012 8<sup>th</sup>.(from 2005)
    - ...

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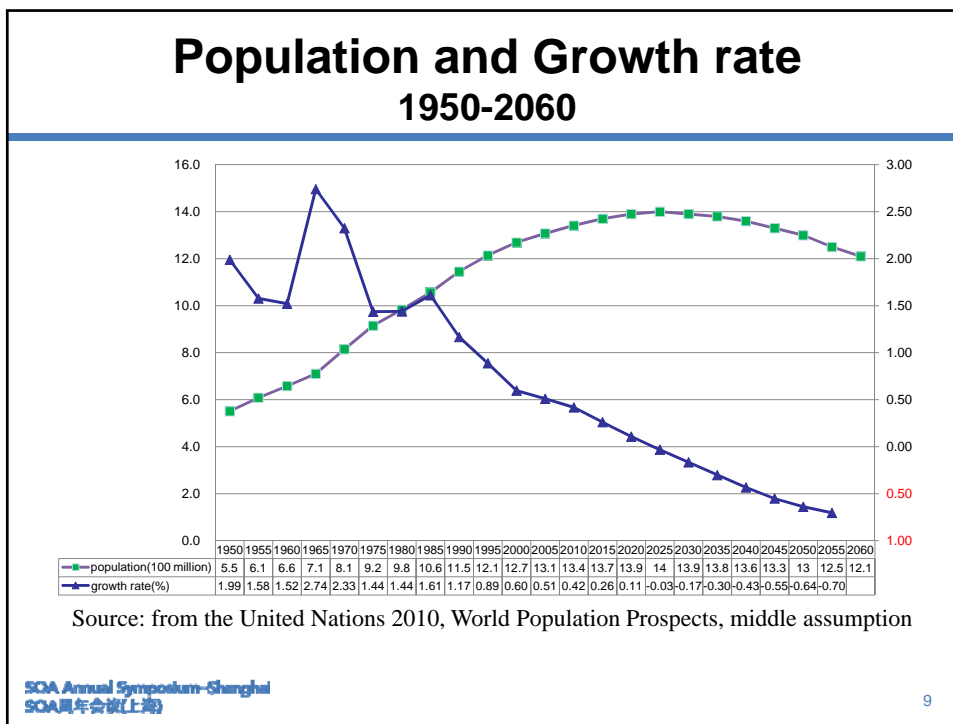
## Population Ageing in China

### Data from 2010 Population Census

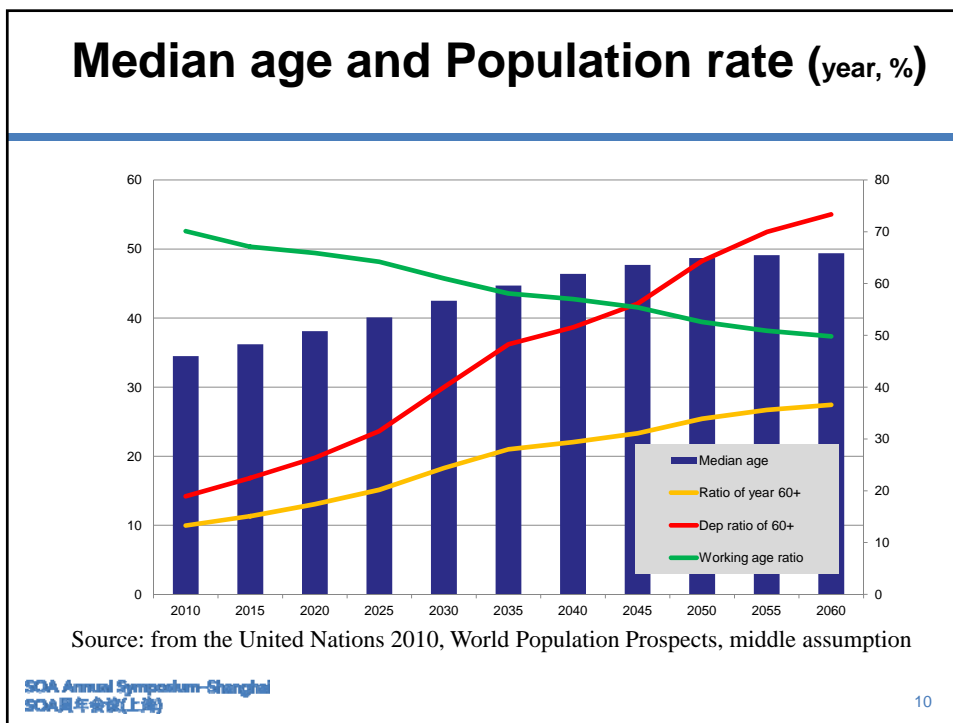
- TFR: China 1.18; Beijing, Shanghai,0.7; Guangxi, Guizhou, 1.7; Xinjiang, 1.5.
- Life expectancy: 72.5
- Population: 1.33 billion
- Aged 60 and over: 178 million (**13.3%**)
- Aged 65 and over: 119 million (**8.87%**)
- Old age Support rate
  - 7.5 for (20-64)/ (65+)
  - 5.2(16-59)/60+

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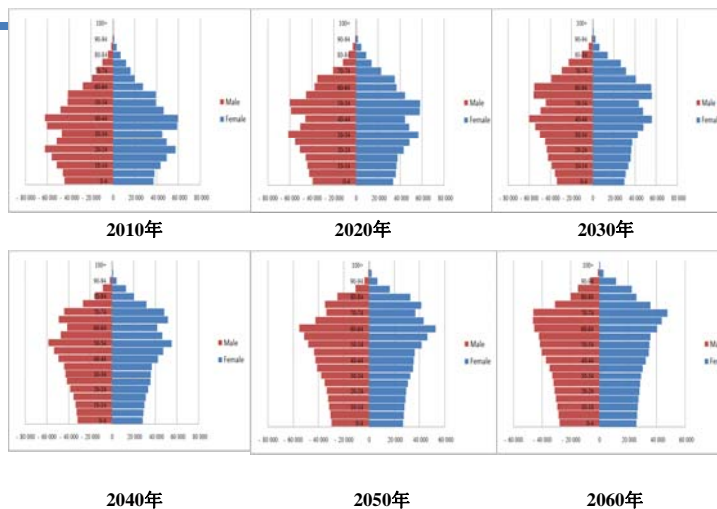


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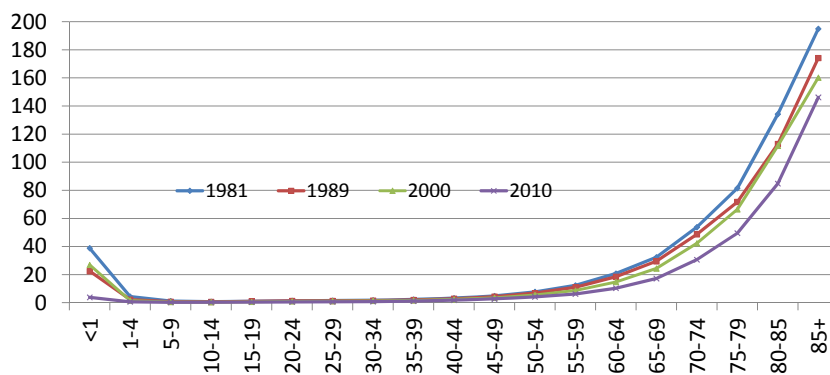
## Age Pyramid



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## Age-specific mortality rate(‰)



Source: Xiaojun Wang, Haijie Mi(2012)

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## Mortality improvement

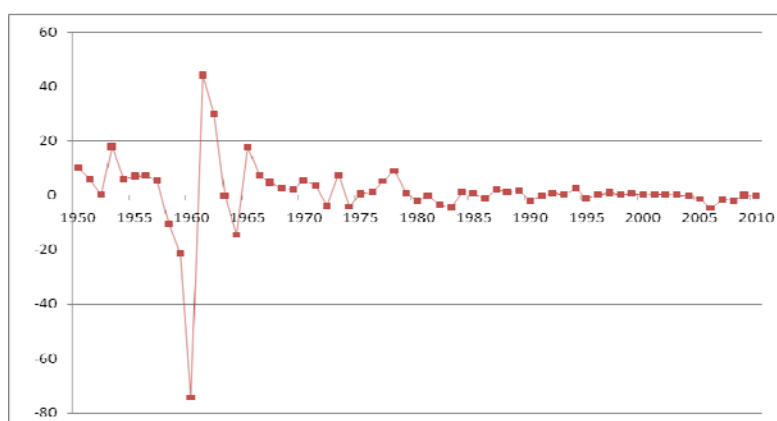
- Data( 23 years)
  - Census: 1981/1989/2000/2010
  - 1% sample: 1986/1995/2005
  - 1‰ sample: from 1990 per year

- Formula: 
$$r_x^{t \sim t+k} = 1 - \left( \frac{q_x^{t+k}}{q_x^t} \right)^{\frac{1}{k}}$$

$$q_x^{t+k} = q_x^t \cdot (1 - r_x^{t \sim t+k})^k$$

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## Historical Mortality improvement rate (%)

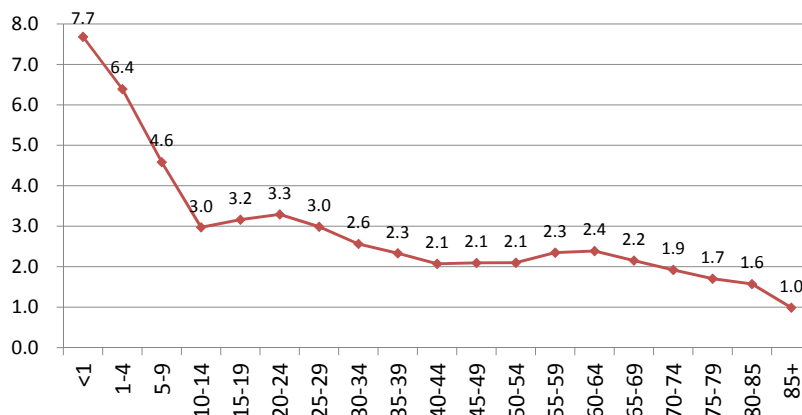


Source: Xiaojun Wang, Haijie Mi(2012)

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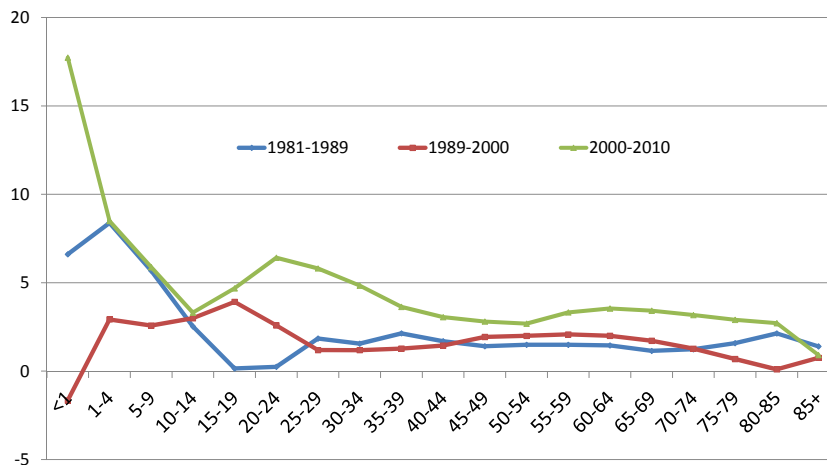
## Annualized mortality improvement rate by age, 1981-2010(%)



Source: Xiaojun Wang, Haijie Mi(2012)

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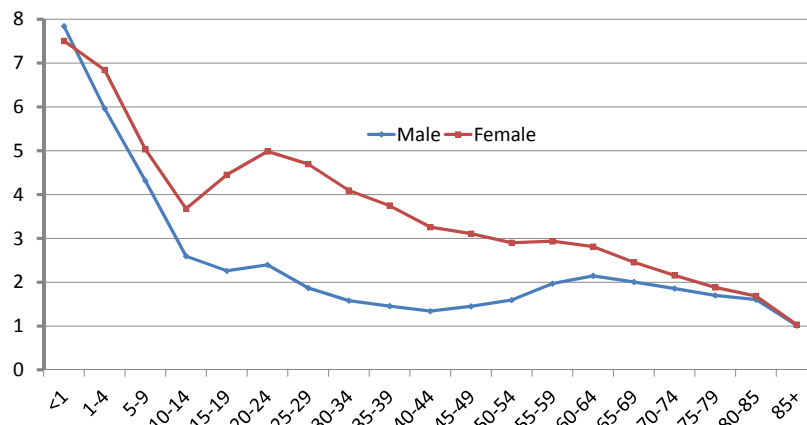
## Annualized mortality improvement rate during three periods(%)



Source: Xiaojun Wang, Haijie Mi(2012)

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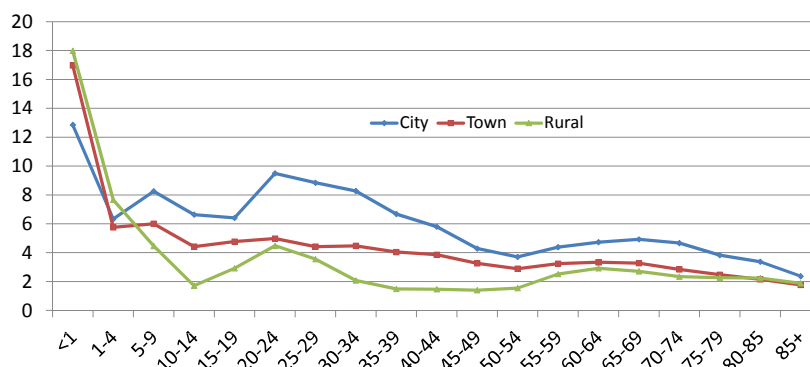
## Annualized mortality improvement rate by gender, 1981-2010(%)



Source: Xiaojun Wang, Haijie Mi(2012)

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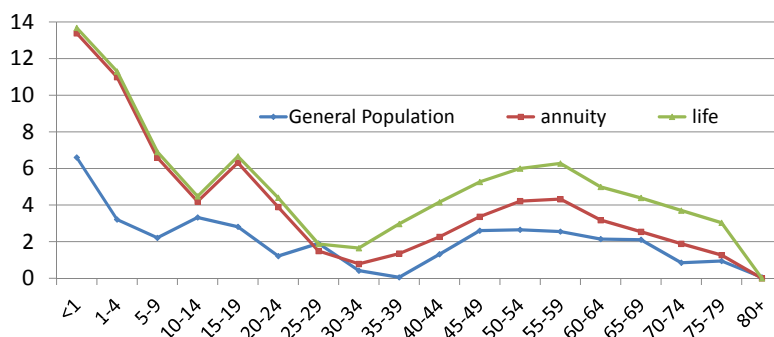
## Mortality improvement for regions 1989-2010(%)



Source: Xiaojun Wang, Haijie Mi(2012)

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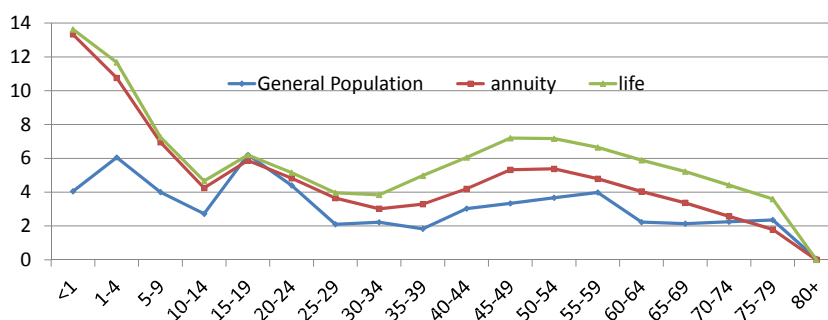
## Mortality improvement between insured and general population, male, 1990-2003(%)



Source: Xiaojun Wang, Haijie Mi(2012)

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## Mortality improvement between insured and general population, female, 1990-2003(%)



Source: Xiaojun Wang, Haijie Mi(2012)

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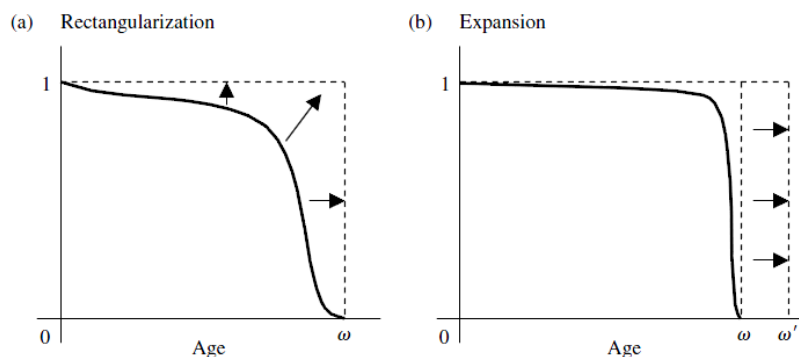
## Mortality improvement by Country, 2000-2007(%)

age \ country	0	1-19	20-34	35-64	65-84	85+
US	0.76	1.29	-0.68	-0.14	2.37	2.68
Canada	0.17	1.39	1.29	0.35	2.21	2.06
UK	1.53	1.14	1.79	1.51	2.86	2.17
Australia	2.84	4.86	4.97	1.02	2.37	1.82
Japan	3.36	4.54	1.17	1.34	1.01	0.96
Russia	6.76	3.85	1.70	1.84	0.61	1.63
Bulgaria	4.98	2.01	0.74	0.20	-0.28	1.37
China	17.79	5.18	0.98	5.12	4.24	5.96

Source: Xiaojun Wang, Haijie Mi(2012)

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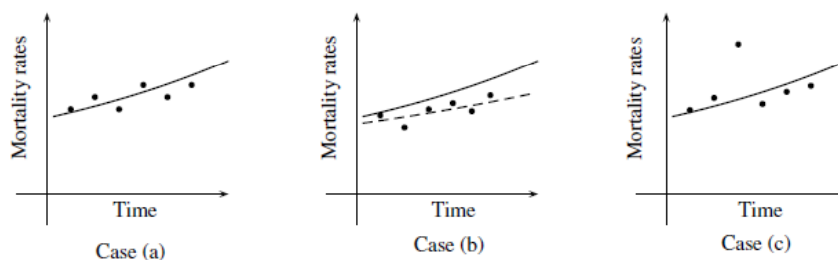
## Mortality trends in survival function



Source: Pitacco, Denuit, Haberman, and Olivieri: *Modelling Longevity Dynamics for Pensions and Annuity Business*, Oxford University Press, 2009

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## Mortality risk



Case (a): insurance risk

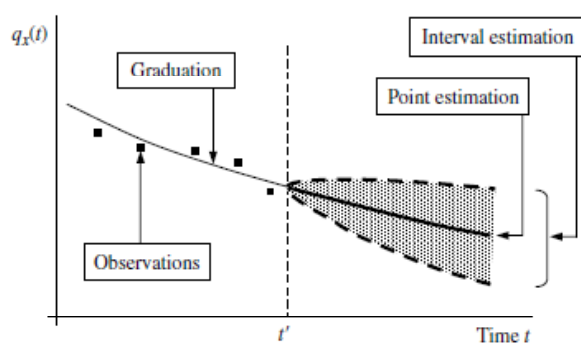
Case (b): longevity risk (model and parameter risk)

Case (c): catastrophe risk

Source: Pitacco, Denuit, Haberman, and Olivieri: *Modelling Longevity Dynamics for Pensions and Annuity Business*, Oxford University Press, 2009

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## Mortality forecasts



Mortality forecasts: point estimation vs interval estimation.

Source: Pitacco, Denuit, Haberman, and Olivieri: *Modelling Longevity Dynamics for Pensions and Annuity Business*, Oxford University Press, 2009

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## Stochastic mortality models

- Lee-carter model (LC)
  - Lee and Carter(1992)
- Age–period–cohort model(APC)
  - Renshaw and Haberman(2006)
- Cairns–Blake–Dowd model(CBD)
  - Cairns-Blake-Dowd(2006)
- ...

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## Other Techniques for projecting mortality

- Gompertz
- Makeham
- GLM (Generalized linear models)
- Heligman-Pollard
- Poisson log-bilinear
- P-Spline
- Renshaw-Haberman
- Weibull

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## LC model and application in China

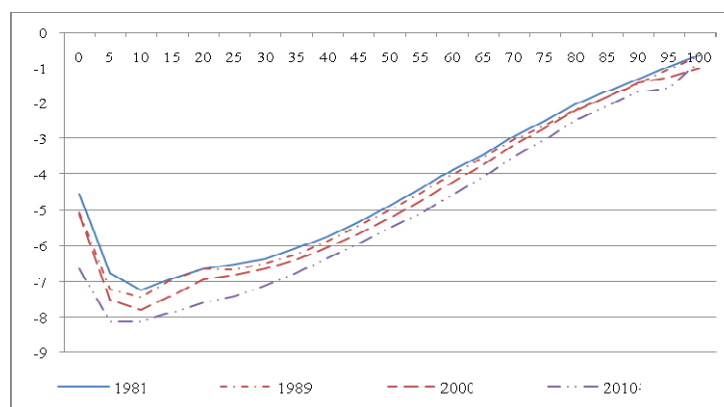
$$\ln m_x(t) = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t}$$

- $\alpha_x, \beta_x$  are age factors and  $\kappa_t$  is time factor
- One estimated method was proposed in Bell(1997)

$$\ln \hat{m}_x(t) = \ln \hat{m}_x(t_n) + \hat{\beta}_x (\hat{\kappa}_t - \hat{\kappa}_{t_n}), t > t_n.$$

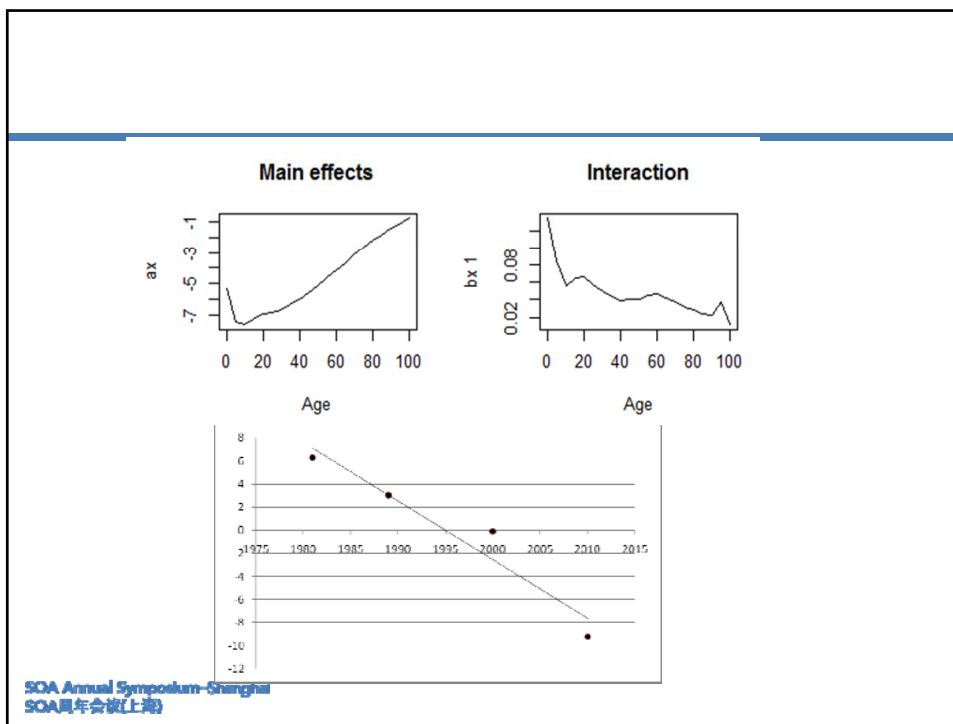
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## Log-mortality for 1981/1989/2000/2010

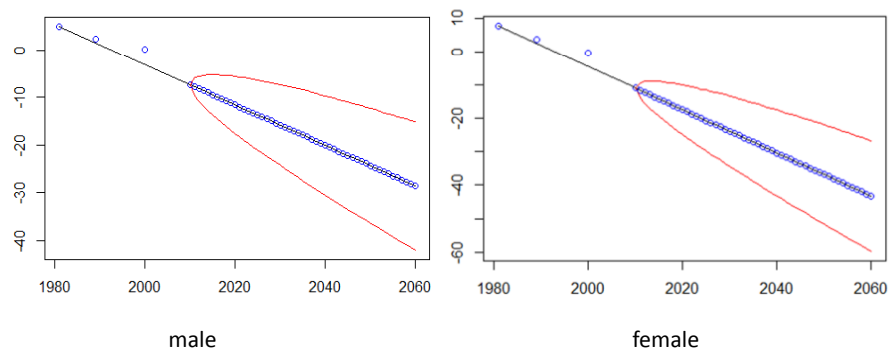


Source: Xiaojun Wang, Wendong Ren(2012)

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## The predictive value and 95% confidence level of $\kappa_t$



Source: Xiaojun Wang, Wendong Ren(2012)



## Mortality forecast for 2015-2030(‰)

Age group	2015	2020	2025	2030
0-5	0.90	0.63	0.44	0.31
5-9	0.24	0.19	0.15	0.12
10-14	0.26	0.22	0.19	0.16
15-19	0.33	0.27	0.23	0.19
20-24	0.42	0.35	0.30	0.25
25-29	0.52	0.45	0.38	0.33
30-34	0.71	0.62	0.55	0.48
35-39	1.03	0.92	0.82	0.73
40-44	1.58	1.42	1.28	1.16
45-49	2.35	2.11	1.90	1.70
50-54	3.76	3.38	3.04	2.73
55-59	5.48	4.86	4.31	3.82
60-64	9.12	8.07	7.13	6.31
65-69	15.40	13.77	12.32	11.03
70-74	27.78	25.18	22.83	20.69
75-79	45.51	41.83	38.44	35.33
80-84	78.72	73.07	67.83	62.96
85-89	119.43	111.94	104.91	98.33
90-94	179.85	169.54	159.82	150.66
95-99	196.09	177.11	159.97	144.49
100+	441.13	428.31	415.85	403.76

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## Implication of longevity risk for annuity

- Pricing
- Reserve
- Required capital
- ...

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## Mortality improvement by age (%)

Age	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
1981-2010	6.3	4.33	2.99	3.32	3.24	2.82	2.42	2.21	2.01	2.09	2.09
2011-2030	6.92	4.37	2.96	3.4	3.48	3.04	2.6	2.29	2.07	2.11	2.11

Age	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100+
1981-2010	2.33	2.36	2.12	1.86	1.59	1.39	1.23	1.09	2.00	0.88
2011-2030	2.38	2.42	2.20	1.94	1.67	1.48	1.29	1.17	2.02	0.59

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## Comparing the regulated and estimated annuity factor for social basic pension

Age	Regulated	2010		2020		2030	
		Estimated	Increase %	Estimated	Increase %	Estimated	Increase %
<i>i</i> = 3%							
55	170	216	26.78	224	31.95	232	36.76
60	139	190	36.94	200	43.61	208	49.90
65	101	164	62.03	173	71.30	182	80.28
age	Regulated	2010		2020		2030	
<i>i</i> = 4%							
		Estimated	Increase %	Estimated	Increase %	Estimated	Increase %
55	170	193	13.56	200	17.53	206	21.15
60	139	173	24.59	181	29.92	187	34.89
65	101	151	49.71	159	57.44	166	64.82

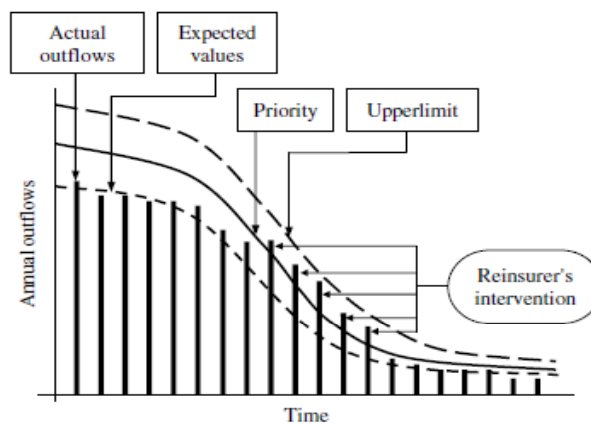
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## Longevity risk management

- Risk Mitigation
  - Loss Control
    - Loss Prevention(Frequency Control)
    - Loss Reduction(Severity Control)
    - Product Design(Participation)
  - Loss Financing
    - Natural Hedging
    - Reinsurance
    - Capital market Solutions

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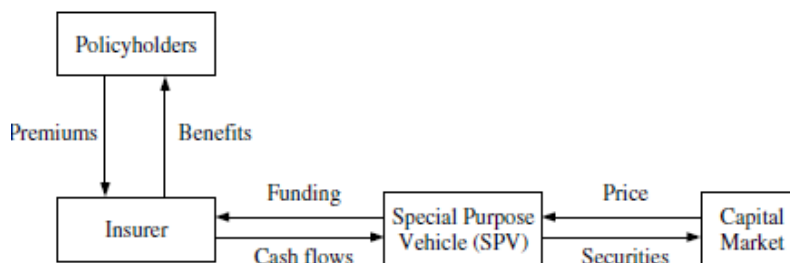
## *A Stop-Loss reinsurance arrangement on annual outflows*



Source: Pitacco, Denuit, Haberman, and Olivieri: *Modelling Longevity Dynamics for Pensions and Annuity Business*, Oxford University Press, 2009

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## The securitization process in life insurance: a simplified structure



Source: Pitacco, Denuit, Haberman, and Olivieri: *Modelling Longevity Dynamics for Pensions and Annuity Business*, Oxford University Press, 2009

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The End

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