2014 EAAC
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How to model your mortality/longevity risks?

Focus on Taiwan mortality data

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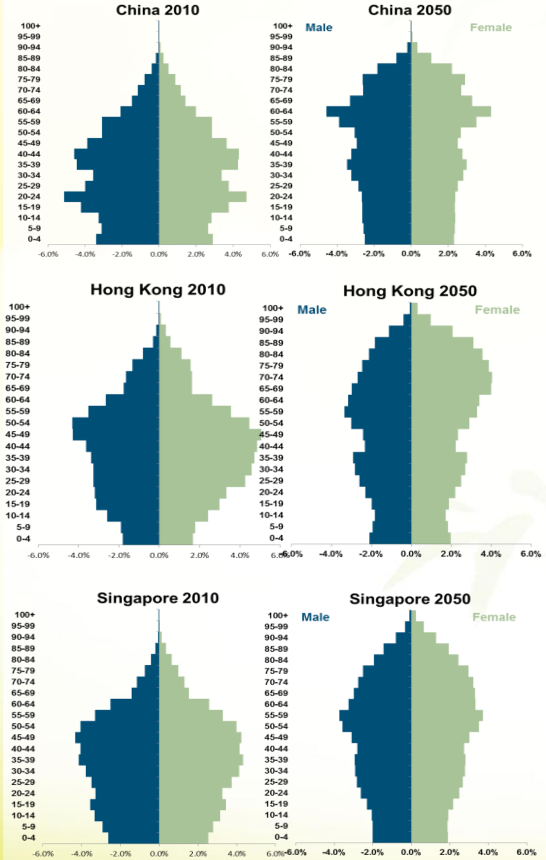
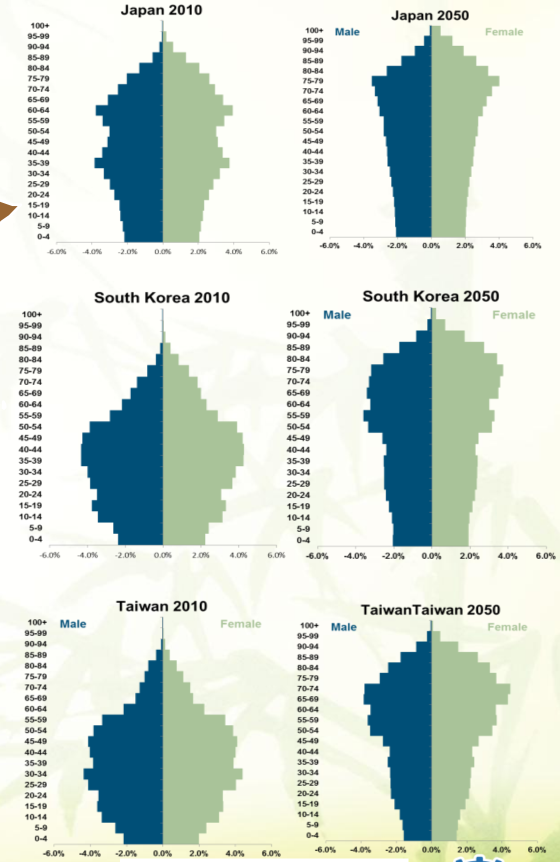
Contents

Introduction

Aging population (1/3)

- The projected population pyramids are shifting upward with thinner waist in 2050 compared to 2010.

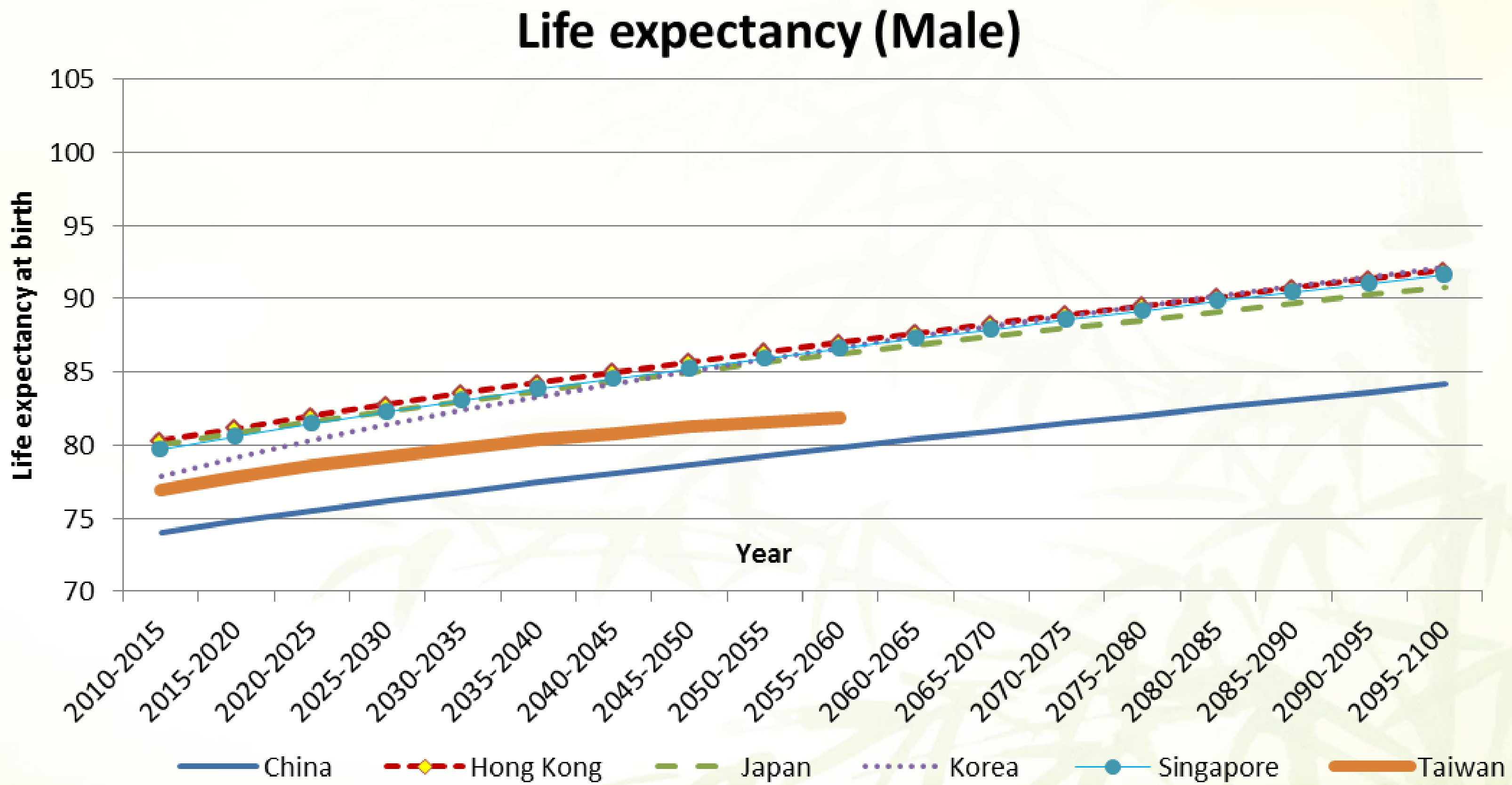




Source: United Nations, Population Division

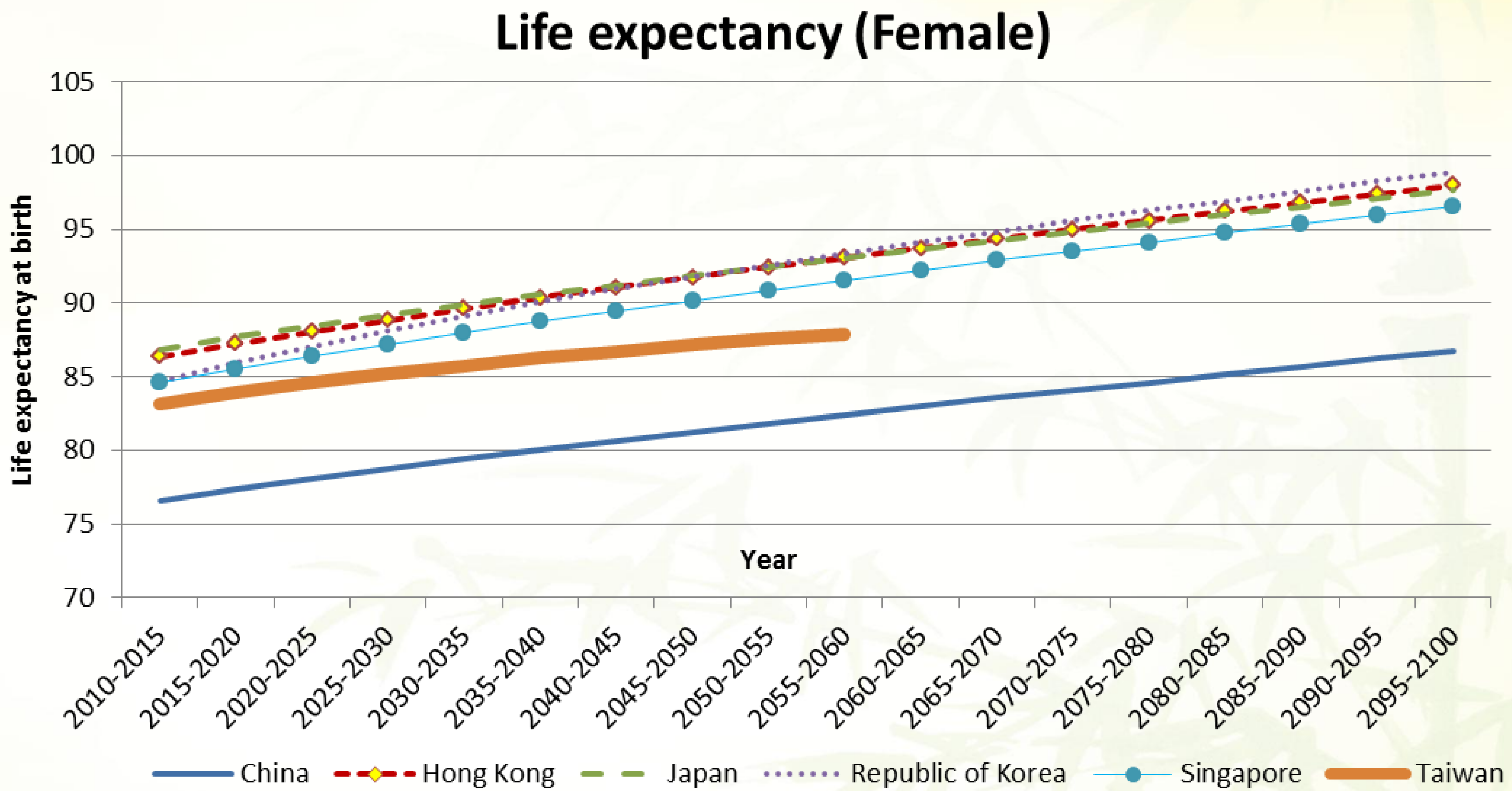
Introduction
Aging population (2/3)

- That follows the general public is facing a longer life than previous generations.



Source: United Nations, Population Division
Department of Statistics, MOI, Taiwan

Introduction
Aging population (3/3)



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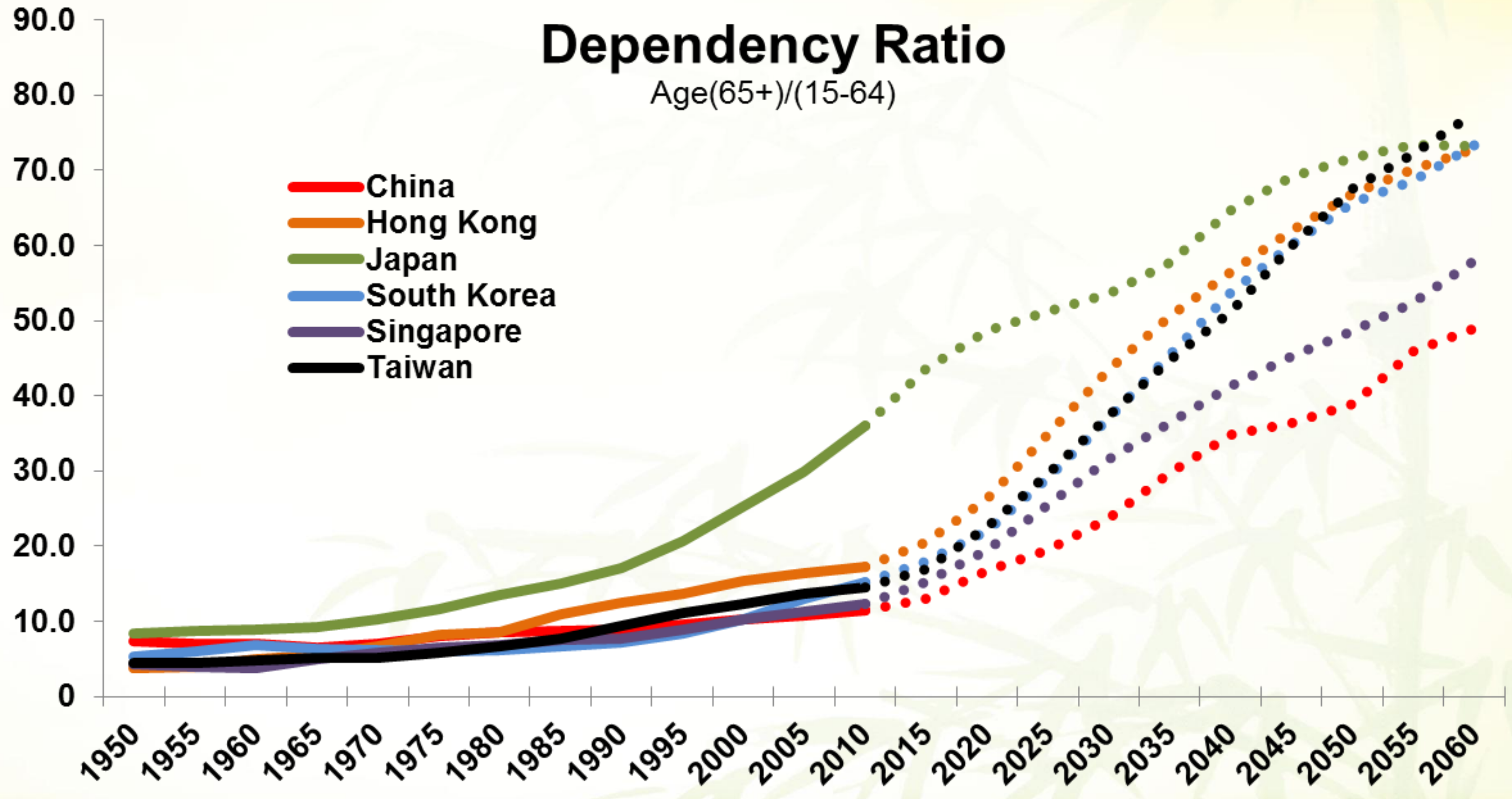
Introduction

Old age dependency ratio is increasing



Source: United Nations, Population Division

Introduction

Projecting future longevity: questions and debates

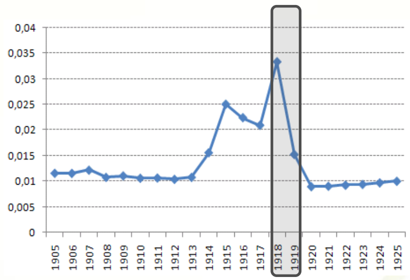
- No consensus among demographers, academics and actuaries regarding future mortality
  - Impact of medical advances? Any biological limit to life expectancy?
  - Acceleration or deceleration of mortality improvements?
  - What happened in the past can happen in the future

- Debating regarding the mortality data
  - Assured data vs national population data

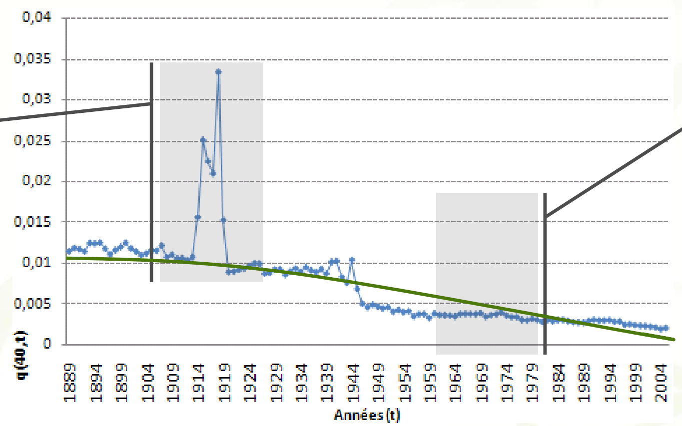
- Debate regarding the projection models to use
  - Extrapolative models (those developed in this presentation)
  - Cause-specific models

Introduction
Mortality risks

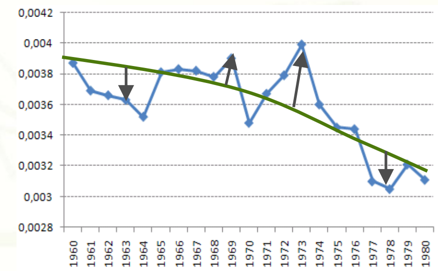
- Different mortality risks:
  - catastrophic risk -> pandemics, terrorism, …
  - mortality risk except CAT, split into :
    - a trend risk : the extension of life expectancy (longevity risk)
    - oscillations around a trend
  - Small size / non homogeneous structure of an insurance portfolio



Catastrophic risk
=
High mortality partly due to the Spanish Influenza



Drift



Fluctuations around a trend

Mortality rate of 40-year-old French men (civilian population)

Sources : the Human Mortality Database – www.mortality.org

Introduction
Definition

- Notations and indicators :
  - Mortality rate at the age of *x* and at year *t*: q(x,t)

    -> probability of dying during year *t* for a person aged of *x* at the beginning of the year
  - Number of deaths at the age of *x* and at year *t*: D(x,t)
  - Instantaneous rate of mortality whose age is *x* and during year *t*: μ(x,t)

    -> probability (assumed constant during the year) of dying instantaneously for a person *x year old*

- The mortality tables:

Mortality rate for a given generation

Age / Year	2002	2003	2004	2005	2006	2007	2008
60	0.01233	0.01251	0.01177	0.01186	0.010948	0.010748	0.010551
61	0.01341	0.01328	0.01318	0.01258	0.012152	0.011943	0.011737
62	0.01496	0.01472	0.01395	0.01446	0.013369	0.013133	0.0129
63	0.01605	0.01573	0.01533	0.01511	0.014391	0.014141	0.013896
64	0.01746	0.0171	0.0165	0.01653	0.015602	0.015336	0.015074
65	0.01881	0.01852	0.01784	0.01759	0.016874	0.016577	0.016285

Mortality rate for given year and age

Observed mortality **Projected mortality**

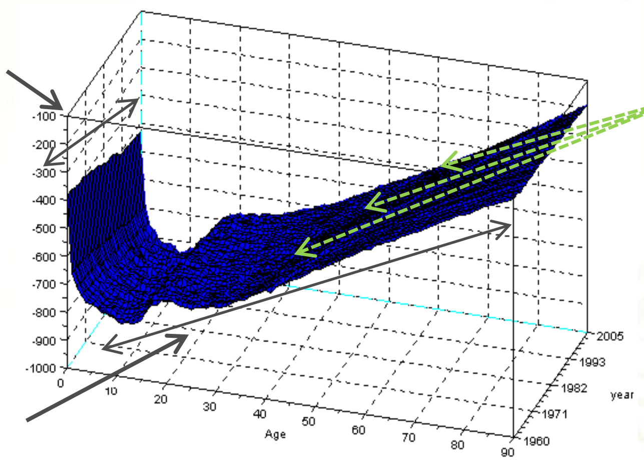
Mortality rate of American men – source HMD

Introduction
Analysis

- Analysis of mortality rates through 3 main factors:

Evolution of ln[q(x,t)] (English and Welsh populations)

Period Effect

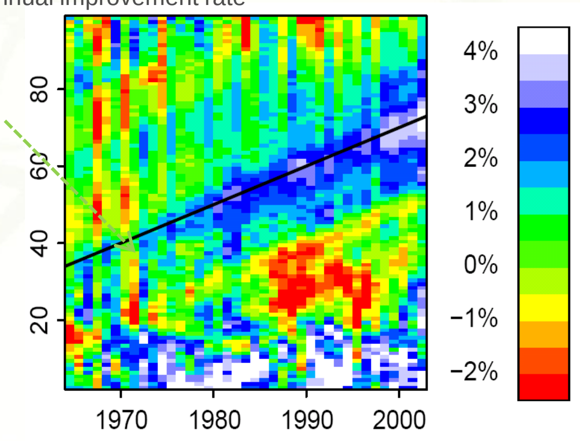


Age Effect

Cohort Effect

Structural factor specific to each generation

Annual improvement rate



English and Welsh 1930 generation

Sources : Cairns J. G.et al., 2007, A quantitative comparison of stochastic mortality models using data from England & Wales and the United States

Introduction
Implications (1/2)

- **Pricing / EV implications**. Companies usually use flat percentages of the regulatory mortality tables as mortality assumptions for the purposes of pricing / valuation. Using a mortality model helps to better assess the future mortality rates of an insurance portfolio.

- **Capital requirement / internal models / stress tests analysis**. Modelling mortality risks allows to integrate the mortality scenarios within an internal model / or calibrate mortality stress tests more in line with the specificities of the country / insurance company.

- **Capital market solutions**. Modelling mortality is a must to price / understand the risk of securitization products like Mortality CAT bonds (catastrophic mortality risk), longevity bonds (longevity risk), longevity swaps (longevity risk - current market activity focused on longevity swaps).

Introduction
Implications (2/2)

AXA France and Hannover Re announce the conclusion of the first longevity swap on the French market

Hannover, 8 August 2014:

The reinsurance treaty covers more than 22,000 insured with associated pension liabilities which represent nearly EUR 750 million.

Source: Hannover Re website

Contents

- Introduction
- Stochastic mortality modeling
- Case study 1 – Pricing an annuity product
- Case study 2 – Mortality / longevity stress test

Stochastic mortality modeling

Overview (1/2)

- Models rely on a dynamic of instantaneous mortality rates m(x,t) or of annual mortality rates q(x,t)

- **Modeling instantaneous mortality rate**

Pure age effect

Period effect

Cohort effect

–Lee-Carter *(1992)/* Brouhns Denuit *(2002)*

$$\ln \mu(x,t) = \beta_x^{(1)} + \beta_x^{(2)} k_t$$

–Renshaw-Haberman *(2006)*

$$\ln \mu(x,t) = \beta_x^{(1)} + \beta_x^{(2)} k_t + \beta_x^{(3)} \gamma_{t-x}$$

–Currie Age-Period-Cohort *(2006)*

$$\ln \mu(x,t) = \beta_x + k_t + \gamma_{t-x}$$

- **Modeling mortality rate**

–CBD2 *(2007)*

$$logit\ q(x,t) = \ln\left(\frac{q(x,t)}{1-q(x,t)}\right) = k_t^{(1)} + k_t^{(2)}(x-\bar{x}) + k_t^{(3)}((x-\bar{x})^2 - \sigma_x^2) + \gamma_{t-x}$$

–CBD3 *(2007)*

$$logit\ q(x,t) = k_t^{(1)} + k_t^{(2)}(x-\bar{x}) + \gamma_{t-x}(x_c - x)$$

- **P-Splines *(2004)***

$$\ln \mu(x,t) = \sum_{i,j} \theta_{i,j} B_{i,j}^{ay}(x,t)$$

Stochastic mortality modeling
Overview (2/2)

- Other approaches have been developed more recently such as Luciano-Vigna ‘s model, Gourieroux-Monfort’s model
- Key idea: create a risk-neutral measure based on both market risk and demographic risk
- Transposition of the interest rate theory to mortality modeling:

Modeling the mortality	**Modeling the interest rate**
Instantaneous mortality rate for a person at the age of *x* at time *s*: $\mu(x,s)$	Instantaneous interest rate at time *s*: $r(s)$
Probability to be alive in *t* for an insured person with age of *x* in 0: $${}_t p_x = E\left[\exp\left(-\int_0^t \mu(x+s,s)ds\right)\right]$$	Price in 0 of a t-maturity bond: $$P(0,t) = E\left[\exp\left(-\int_0^t r(s)ds\right)\right]$$

Stochastic mortality modeling

Calibration (1/3)

- Example - Brouhns-Denuit model: $\ln \mu(x,t) = \beta_x^{(1)} + \beta_x^{(2)} k_t$

Stage 1 – Estimation

Probability of death

âge\année	1965	1966	...	2004	2005
30	0,00941	0,00926	...	0,01143	0,00948
31	0,00938	0,00933	...	0,01109	0,00947
...	...	...	...	...	...
76	0,10933	0,10938	...	0,12837	0,10852
77	0,11742	0,11709	...	0,13933	0,11628
78	0,12777	0,12602	...	0,14802	0,1248
79	0,1296	0,13708	...	0,15311	0,1305
80	0,15267	0,15115	...	0,17359	0,14579

âge\année	1965	1966	...	2004	2005
30	553	565	...	426	388
31	620	655	...	463	449
...	...	...	...	...	...
76	7565	6964	...	7827	7670
77	7451	7049	...	8168	8098
78	7450	7159	...	8275	8495
79	7404	6885	...	8709	8712
80	7113	6633	...	8919	9051

Number of deaths

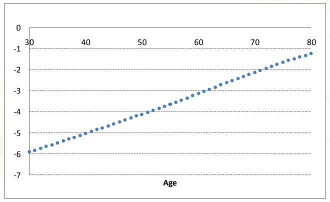
Maximum likelihood

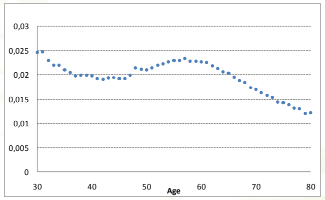
$$l^*(\beta^{(1)}, \beta^{(2)}, k) = \sum_{t,x} \left(D^*(x,t)(\beta_x^{(1)} + \beta_x^{(2)} k_t) - \frac{D^*(x,t)}{\mu^*(x,t)} \exp(\beta_x^{(1)} + \beta_x^{(2)} k_t) \right)$$

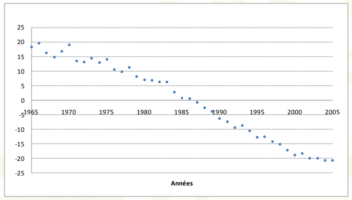
Actual number of deaths and instantaneous mortality rates

Parameters to estimate

$$\ln \mu(x,t) = \beta_x^{(1)} + \beta_x^{(2)} k_t$$







Step 1 :

Inputs based on national population data (HMD database)

Step 2 :

Calibration of the model parameters by maximum likelihood

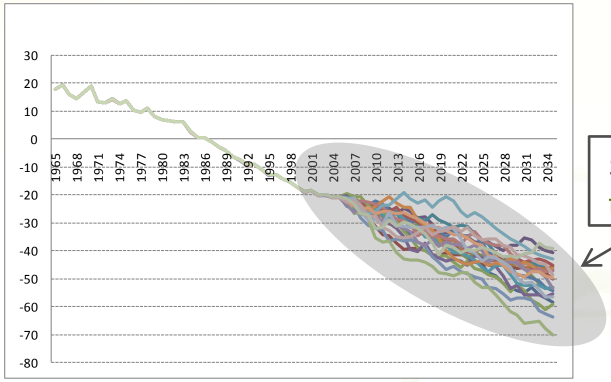
Stochastic mortality modeling

Calibration (2/3)

- Example (cont'd) - Brouhns-Denuit model : $\ln \mu(x,t) = \beta_x^{(1)} + \beta_x^{(2)} k_t$

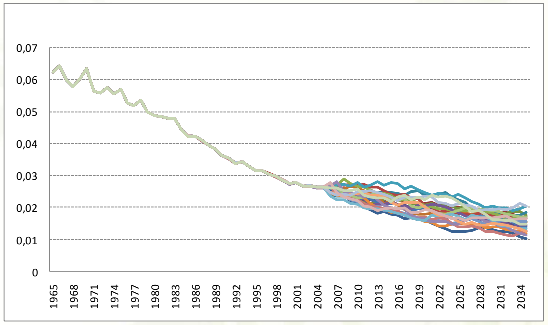
Stage 2 – Simulation

$$k_{t+1} = k_t + c + \sigma \times \varepsilon_{t+1} \quad \text{with} \quad \varepsilon_{t+1} \sim N(0,1)$$



Simulation of paths for the time component

$$q(x,t) = 1 - \exp(-\mu(x,t))$$
$$\mu(x,t) = \exp\left(\beta^{(1)}(x) + \beta^{(2)}(x)\kappa_t\right)$$



Step 3 :

Extrapolation *of the time series k_t using a process ARIMA(0,1,0)*

Step 4 :

Simulation of the probability of death

Stochastic mortality modeling

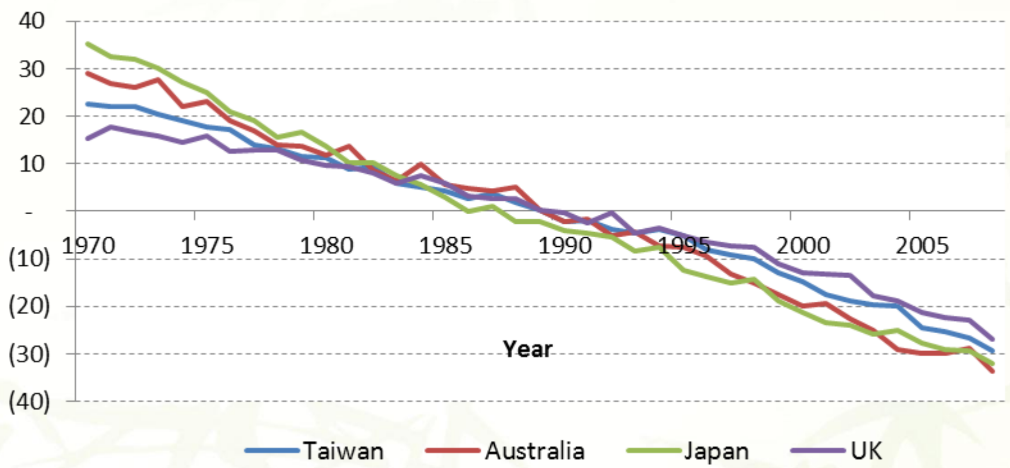
Calibration (3/3)

- Illustration : estimation of the Brouhns-Denuit model on Taiwanese, Japanese, Australian and UK data:

The **Period Effect** (κ_t):

$$\ln \mu(x,t) = \alpha_x + \beta_x \boxed{k_t}$$

The probability of death is decreasing with years



Stochastic mortality modeling

Models comparison (1/5)

Key criteria to compare mortality models

- ☑ Reasonableness of future projected mortality rates (back-testing / comparison with publicly available forecasts)
- ☑ Ability to generate distribution of future mortality rates
- ☑ Check key statistical properties / reasonable pattern of standardised residuals
- ☑ Ability to capture the cohort effect
- ☑ Computation time (calibration process + simulation process)
- ☑ Parsimony (models with few parameters are recommended)
- ☑ Robustness of parameter estimates

Some of these criteria can be conflictual (e.g. ability to capture cohort effect versus parsimony)

Stochastic mortality modeling

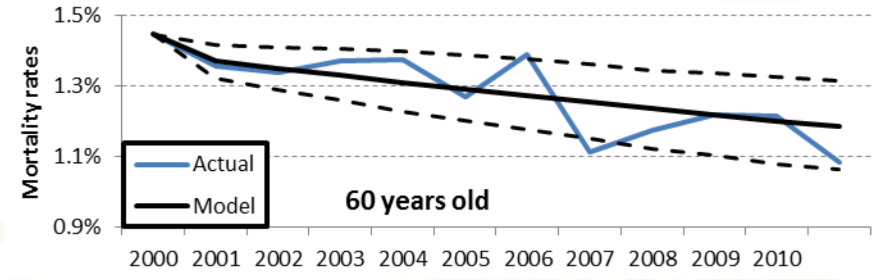
Models comparison (2/5)

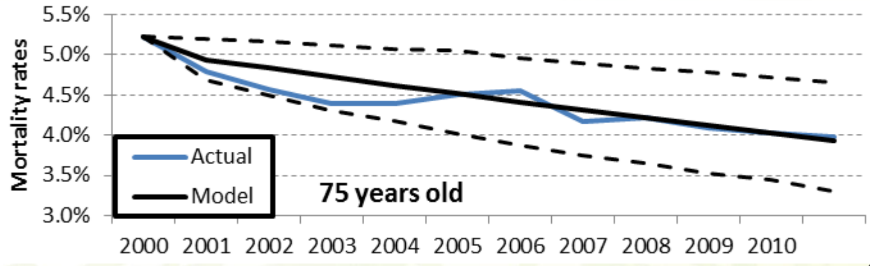
Key criteria to compare mortality models

- ☑ Reasonableness of future projected mortality rates
- ☑ Distribution of mortality rates
- ☑ Statistical properties
- ☑ Cohort effect
- ☑ Computation time
- ☑ Parsimony
- ☑ Robustness

Illustration – Back-testing Lee Carter (Taiwanese Male population)

1. Actual mortality rates from 2000 to 2010 (source HMD)
2. Projected mortality rates from 2000 to 2010 (estimation based on period from





Stochastic mortality modeling

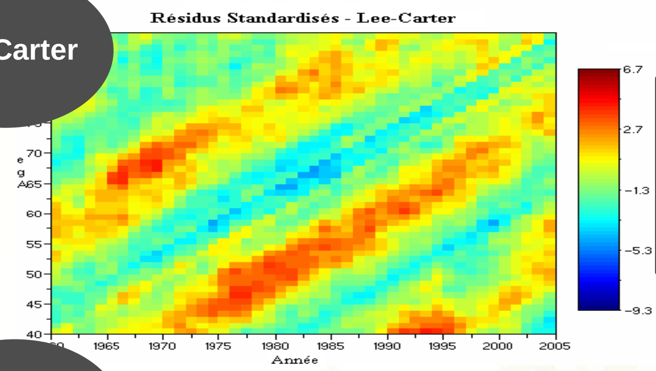
Models comparison (3/5)

Key criteria to compare mortality models

- ✓ Reasonableness of future projected mortality rates
- ✓ Distribution of mortality rates
- ✓ Statistical properties
- ✓ Cohort effect
- ✓ Computation time
- ✓ Parsimony
- ✓ Robustness

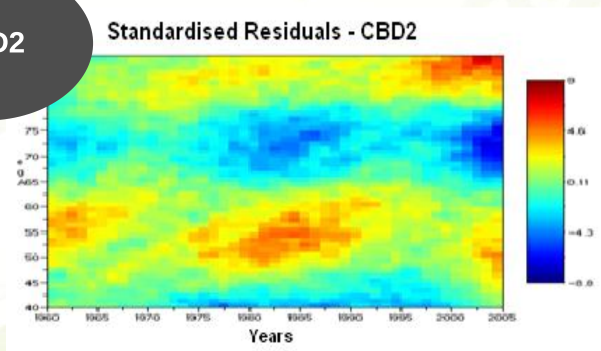
Standardised residuals for Lee Carter and CBD2 models

Lee Carter



Does it capture the concentration issue over specific age cohorts?

CBD2



Does it capture the trend across all age bands?

Stochastic mortality modeling

Models comparison (4/5)

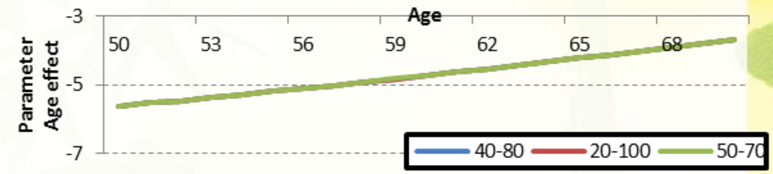
Key criteria to compare mortality models

- ☑ Reasonableness of future projected mortality rates
- ☑ Distribution of mortality rates
- ☑ Statistical properties
- ☑ Cohort effect
- ☑ Computation time
- ☑ Parsimony
- ☑ Robustness

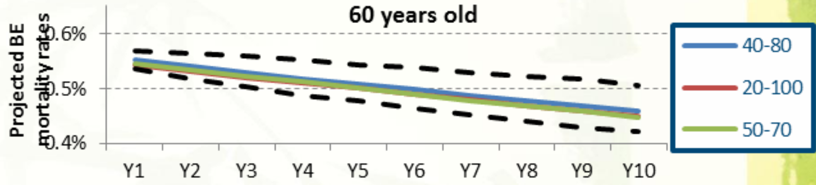
Estimation of Lee Carter model using different sets of historical data:

1. Different sets of ages (base case age 40 to 80)

Impact on estimated parameters



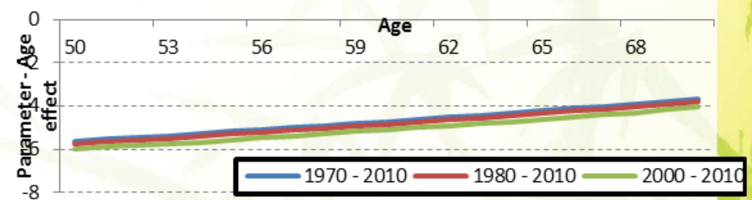
Impact on projected mortality rates



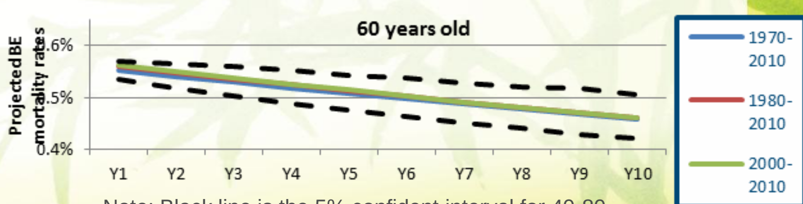
Note: Black line is the 5% confident interval for 40-80

2. Different periods (base case 1970-2010)

Impact on estimated parameters



Impact on projected mortality rates



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Stochastic mortality modeling

Models comparison (5/5)

- **Modeling instantaneous mortality rate**

  Pure age effect

  Period effect

  Cohort effect

  –Lee-Carter *(1992)/* Brouhns Denuit *(2002)*

  $$\ln \mu(x,t) = \beta_x^{(1)} + \beta_x^{(2)} k_t$$

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- **Modeling mortality rate**

  –CBD2 *(2007)*

  $$logit\ \ q(x,t) = \ln\left(\frac{q(x,t)}{1-q(x,t)}\right) = k_t^{(1)} + k_t^{(2)}(x-\bar{x}) + k_t^{(3)}((x-\bar{x})^2 - \sigma_x^2) + \gamma_{t-x}$$

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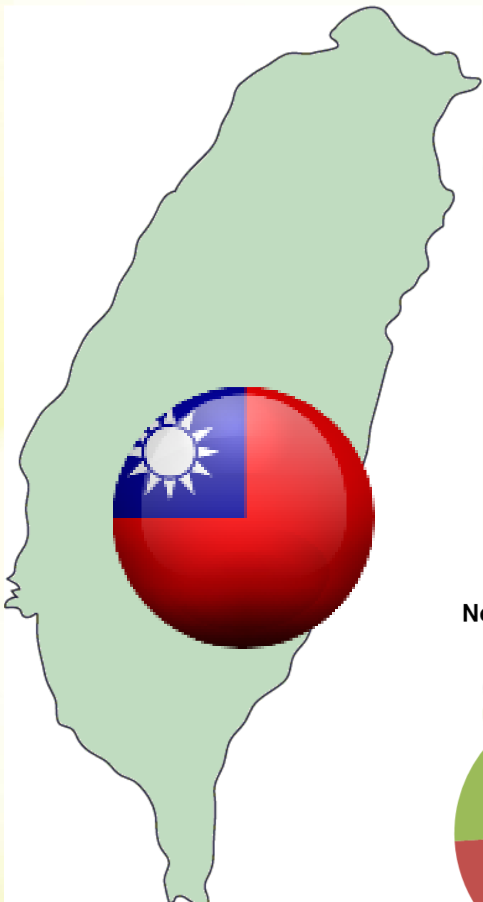
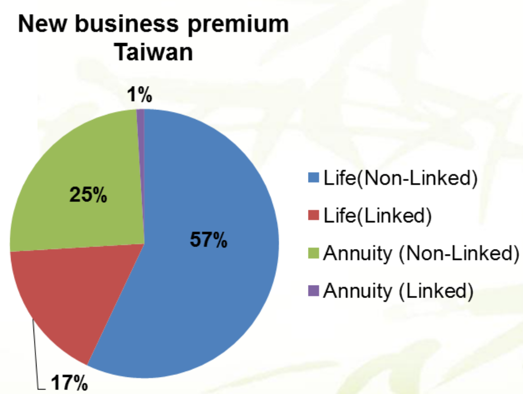
Annuity business in Asia
Taiwan



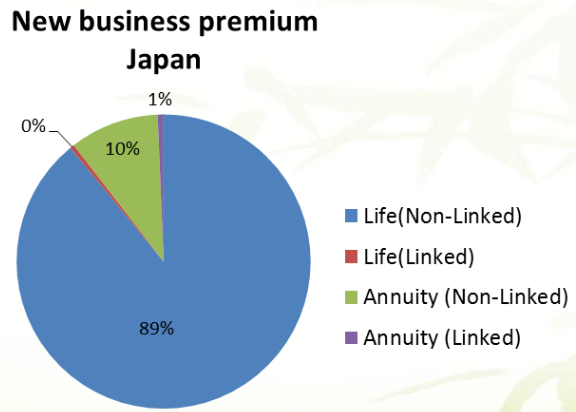
- Fixed annuity and variable annuity account for 25% and 1% of the market in terms of new business premium in 2013.
  - The most popular product is interest sensitive deferred annuity which competes with other deposit replacement type products.
- The pricing of traditional payout annuity is difficult due to long stagnantly low interest rate and the lack of tax benefit in retirement plans.
- The government has initiated enterprise annuity scheme since 2005 but the minimum guarantee of 2-year CD rate is considered too stringent and thus not many players are eager in this market so far. But it is likely that the government will allow more asset types for investment under annuity insurance scheme, even risky assets.

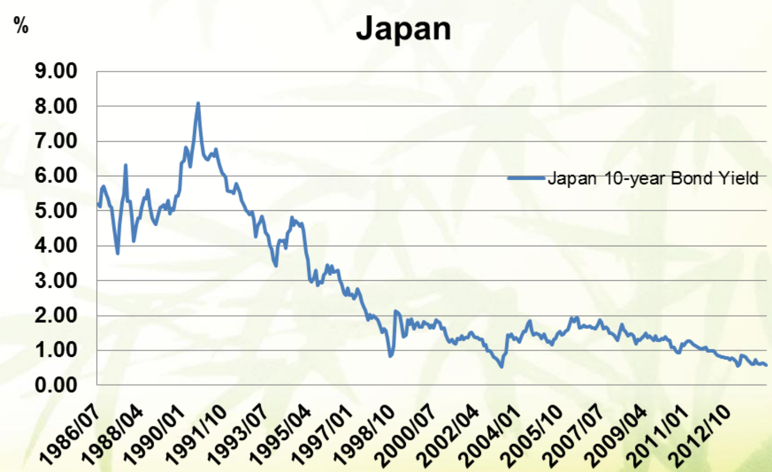


Source: Taiwan Life Insurance Association, 2013

Annuity business in Asia
Japan

- Japan has faced the aging population for a period of time, and the annuity has captured a significant share in the market in terms of new business premium in 2012, most of which are fixed (deferred and immediate) annuities.
- Japan is the world's second largest variable annuity market with ¥18 trillion of assets under management as at 2012. But the variable annuity market is struggling to recover its pre-crisis momentum.
- Despite of the asset deflation and the extremely low interest rates, the general public is reluctant to put their savings at risk into the capital market considering the remaining shaky market. It naturally follows that the aging population is moving towards investment with principal guarantees with some potentially upside gains.



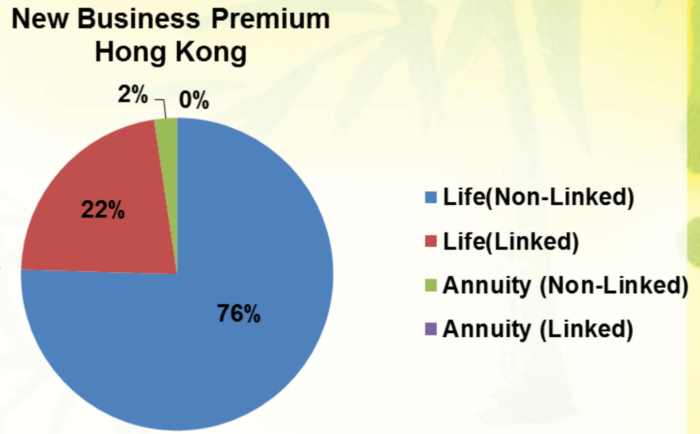


Source: Life Insurance Association of Japan, 2012

Annuity business in Asia
Singapore and Hong Kong

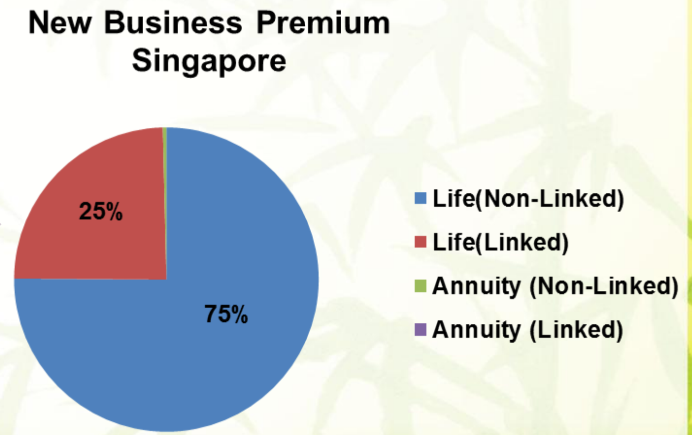
Hong Kong

- Annuity business sales (mainly fixed deferred annuities) are not significant which account for only 2% of the new business premium
- Main distributors include China Life, Prudential plc, AIA and Mass Mutual



Singapore

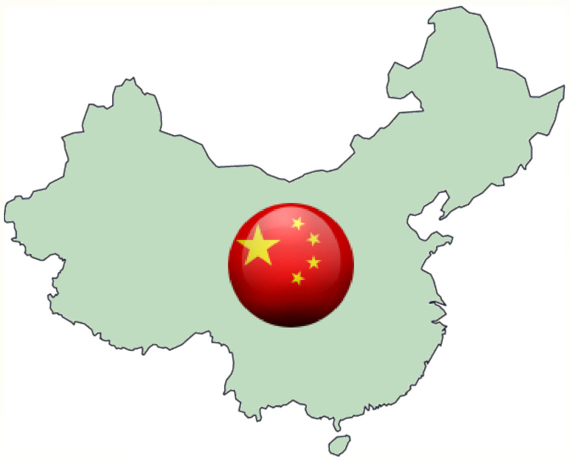
- Fixed annuities only capture a small piece of new business in 2013.
- Under the scheme of Supplementary Retirement Scheme (SRS) initiated by the government, citizens can open an account for investment using qualified plans. Some companies have launched variable life products under SRS, but no qualified variable annuity products



Source: Life Insurance Association of Hong Kong, 2012; Life Insurance Association of Singapore, 2013

Annuity business in Asia

China and South Korea



China

- The Enterprise Annuity Fund Management Regulation was initiated on May 1, 2011, to ensure sustainable performance of enterprise annuities and to devise a framework to regulate fund investments.
- Ping An Annuity is the leading provider of enterprise annuities, and is also the only pension insurer with a nationwide network, with over RMB 60 billion in investment assets in 2012.
- The government has been in the process of devising the tax-deferred policy for annuity products.

South Korea

- Variable annuity is continuously growing while fixed annuity is rather silent in the market.
- Despite a short history since the introduction of VA, most products offered contain ancillary benefits (GMXBs) with occasional high benefit designs for which the major risks are interest rate risk, equity risk…etc but longevity risk is rather insignificant considering the product designs.

Annuity business in Asia
Presence of Longevity risk

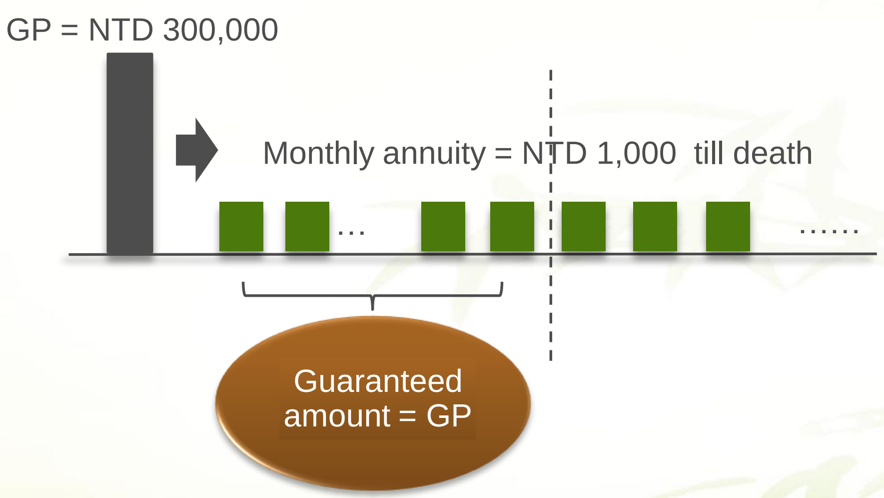
- In these markets just discussed, the annuity products generally account for a relatively small part of the market (except Japan) or the longevity risk is not significant given the product features (e.g. deferred annuities with small annuitization probabilities). This is mainly because
  - the interest rates have remained low for the past decade, hence it is difficult to have an attractive annuity products in these markets;
  - lack of incentives to enter annuity markets due to regulation constraints
  - investors or policyholders generally prefer deposit replacement type of products.
  - it is difficult and expensive to offer attractive guarantees in annuity products, making it less competitive.

- But there are some initiatives to offer enterprise annuities under the public pension schemes. We expect the longevity risk may gradually become an issue with aging population and more people looking for income protection towards retirement.

Pricing an annuity product
Base case (1/3)

- Consider an old immediate annuity that was priced based on 95TIA

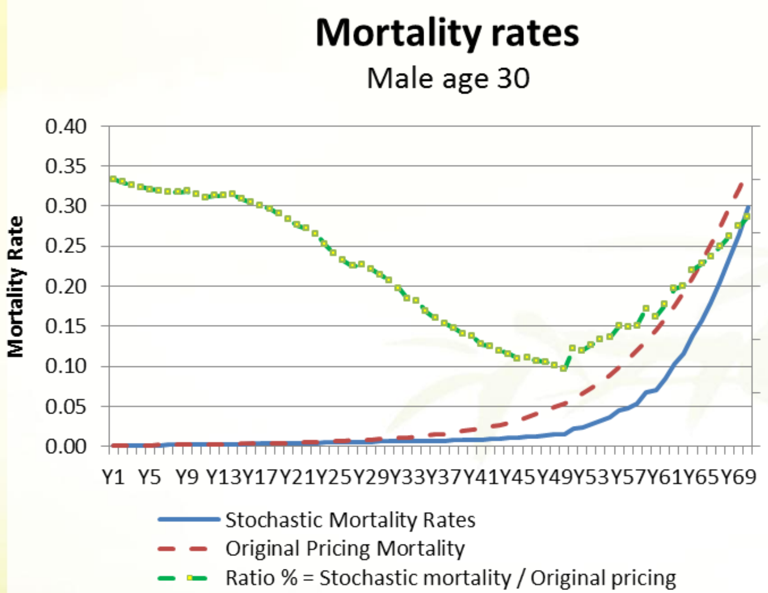
The immediate annuity receives GP in exchanges for a series of monthly annuity payment till death, subjected to the guaranteed amount (GP)

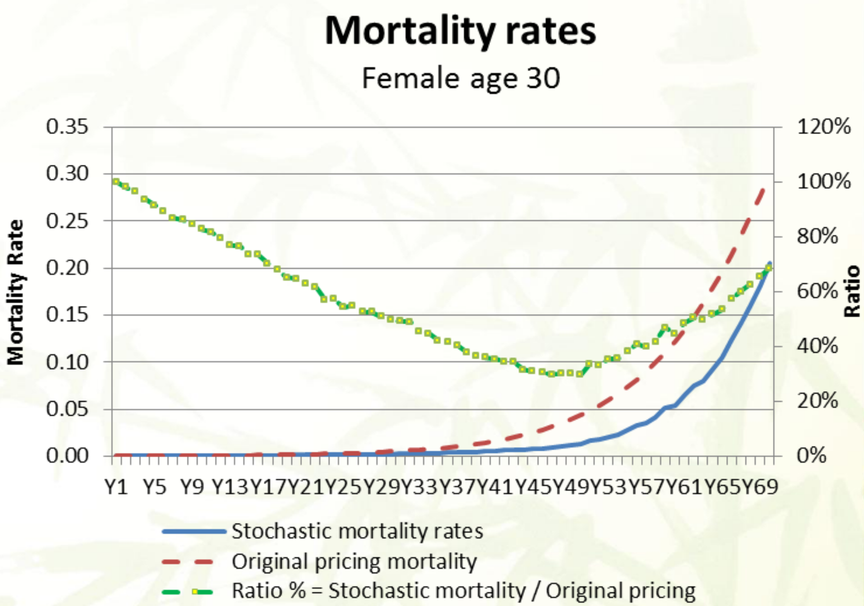


Pricing Assumption	
Mortality	100% 95TIA
Withdrawal Rate	0%
General operating expense	NTD 1,100 upfront
Pricing interest rate	4% level
Guaranteed interest rate	3% level
Commission	1%

Pricing an annuity product (Cont'd)
Base case (2/3)

- The best estimate mortality implied by the stochastic model is lower.
  - The original pricing mortality table is 95TIA, but the best estimate simulated from stochastic mortality model is much lower.
  - The ratio of stochastic mortality rate to 95TIA may drop as much as to 40% of 95TIA.





Pricing an annuity product (Cont'd)

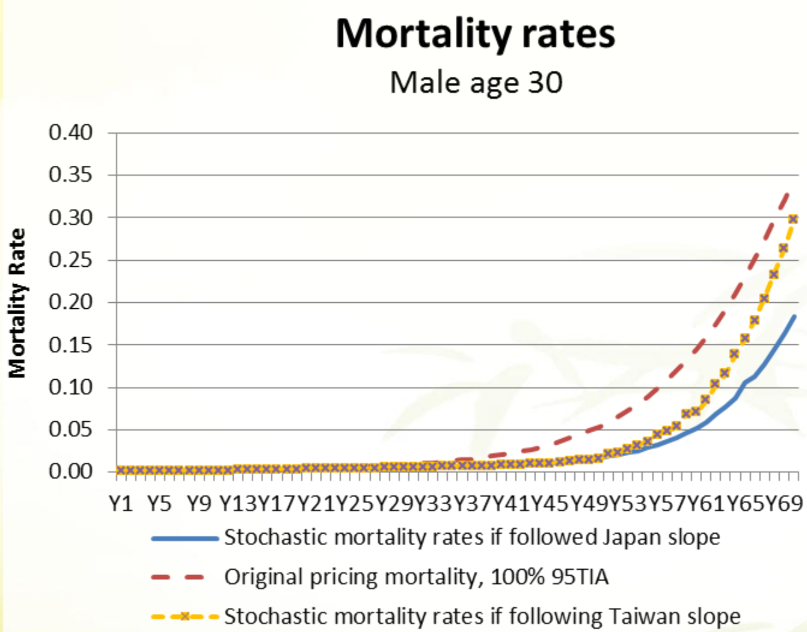
Base case (3/3)

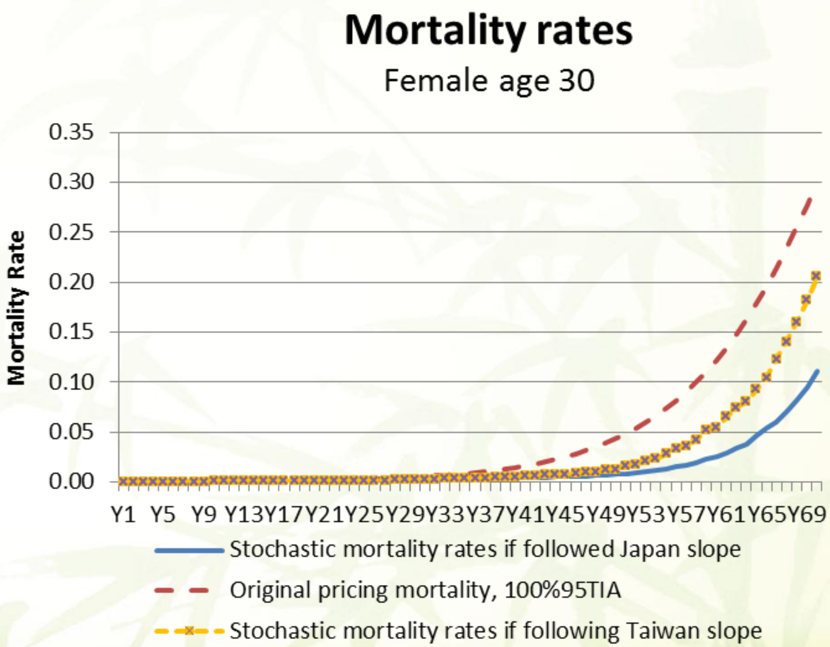
- By applying the best estimate mortality rates from Lee-Carter model, the profit margin significantly drops.

Profit margin by issue age and gender					
Male	Original pricing	Stochastic mortality rates	Female	Original pricing	Stochastic mortality rates
20	16.1%	13.5%	20	16.7%	14.2%
30	14.5%	11.2%	30	15.1%	11.9%
40	12.6%	8.6%	40	13.3%	9.3%
50	10.4%	6.0%	50	11.1%	6.6%
60	8.0%	3.9%	60	8.6%	4.3%
70	5.6%	2.7%	70	6.1%	2.9%

Pricing an annuity product (Cont'd)
Sensitivity (1/2)

- The aging population has long become an issue in Japan, with more experience accumulated regarding to mortality improvement.
- If the Taiwan experience followed that Japan, let's test the impact on the annuity profit margin.





Pricing an annuity product (Cont'd)

Sensitivity (2/2)

- Sensitivity result if the Taiwan mortality improvement trends followed that of Japan

Profit margin by issue age and gender							
Male	Original pricing	Stochastic mortality rates – Slope follows Taiwan	Stochastic mortality rates – Slope follows Japan	Female	Original pricing	Stochastic mortality rates – Slope follows Taiwan	Stochastic mortality rates – Slope follows Japan
20	16.1%	13.5%	12.9%	20	16.7%	14.2%	13.4%
30	14.5%	11.2%	10.5%	30	15.1%	11.9%	10.7%
40	12.6%	8.6%	7.9%	40	13.3%	9.3%	7.6%
50	10.4%	6.0%	5.3%	50	11.1%	6.6%	4.3%
60	8.0%	3.9%	3.0%	60	8.6%	4.3%	1.5%
70	5.6%	2.7%	1.7%	70	6.1%	2.9%	0.2%

Contents

- Introduction
- Stochastic mortality modeling
- Case study 1 – Pricing an annuity product
- Case study 2 – Mortality / longevity stress test
- Bibliography

Mortality / longevity stress tests
Introduction

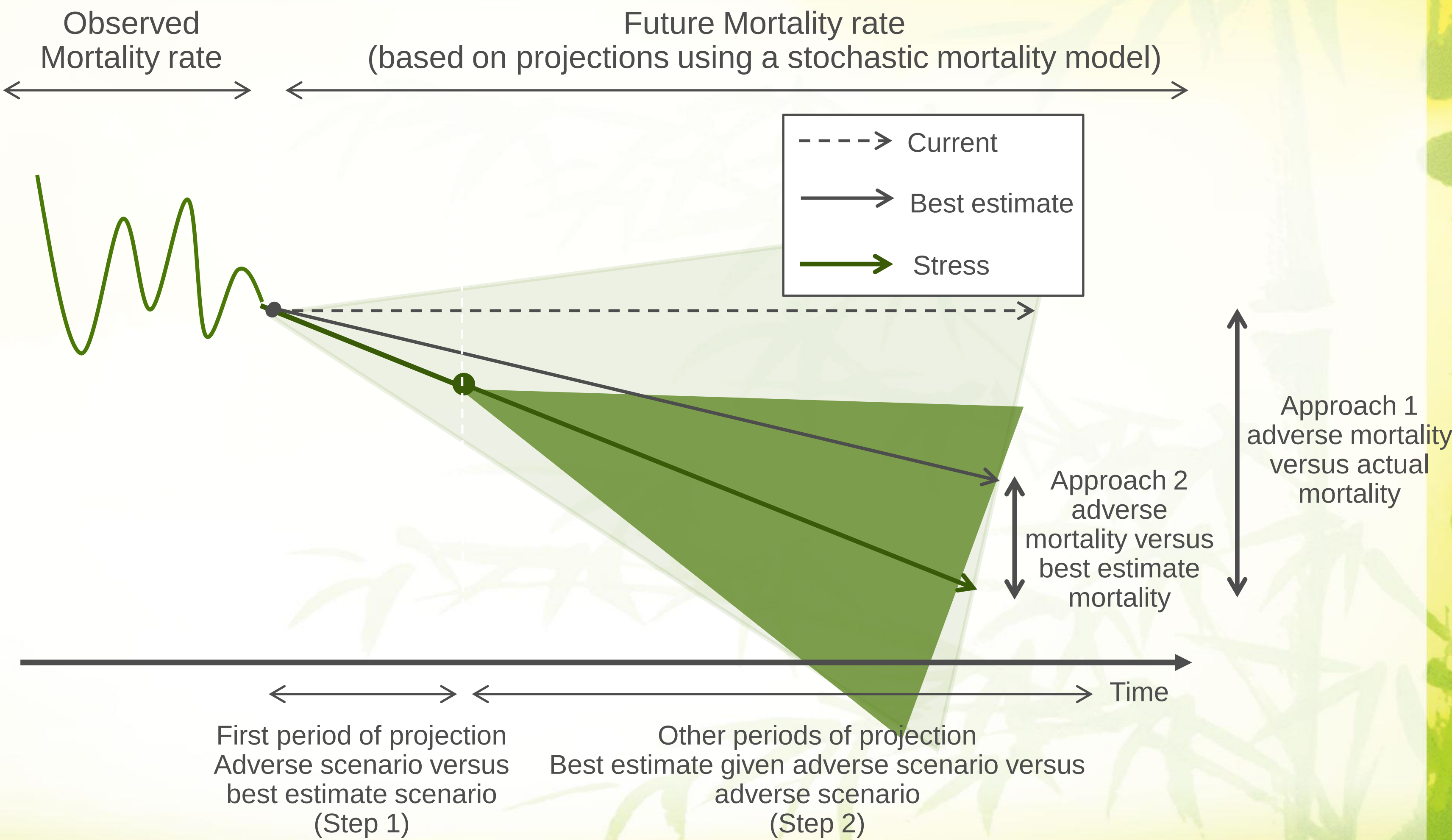
- Solvency II and RBC frameworks provide standardized stress tests to apply on mortality rates

Capital requirement	Risk	Stress test based on SII standard formula
$Life_{mort}$=ΔNAV|mortality stress	Mortality risk	A **permanent 15% increase** in mortality rates for each age and each policy where the payment of benefits is contingent on mortality risk
$Life_{long}$=ΔNAV|longevity stress	Longevity risk	A **permanent 20% decrease** on mortality rates for each age and each policy where the payment of benefits is contingent on longevity risk
$Life_{CAT}$=ΔNAV|Life catastrophe stress	Life catastrophe risk	**Absolute increase** in the rate of policyholders dying over the following year of **1.5 per mille**

- Using a stochastic mortality model can be useful to assess a more country specific mortality / longevity set of stress tests:

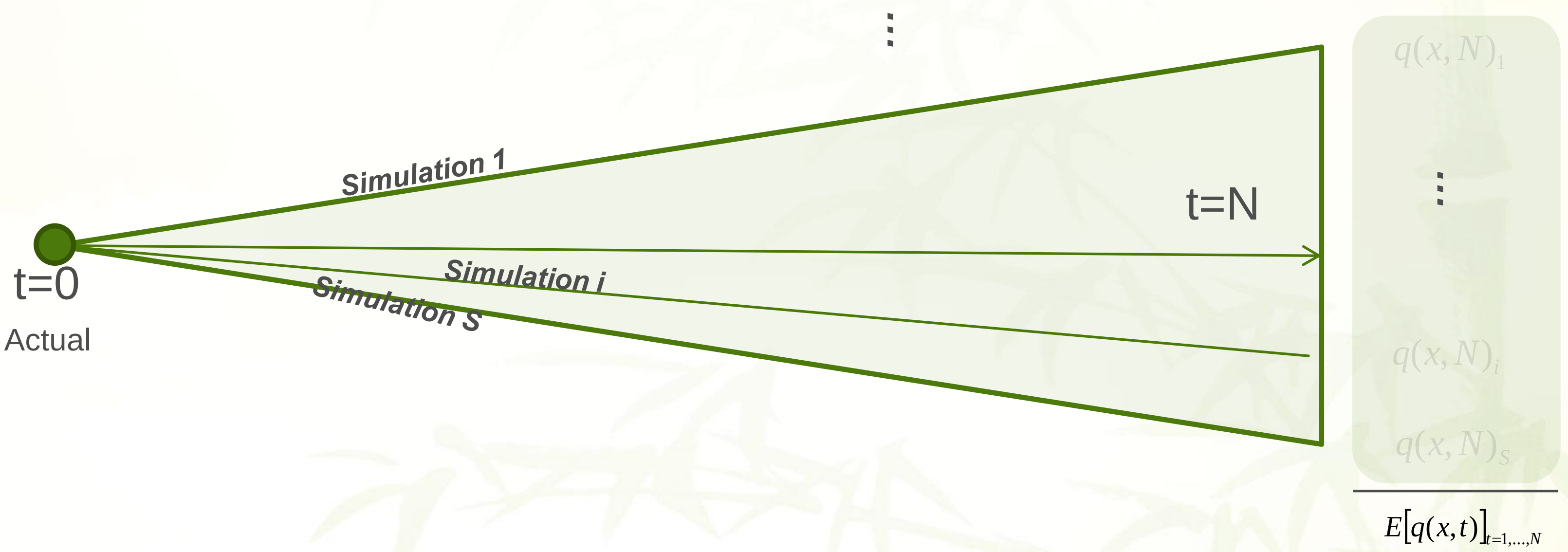
Mortality / longevity stress tests

Proposed approach (1/4)



Mortality / longevity stress tests
Proposed approach (2/4)

- How to project the best estimate stress scenario?...

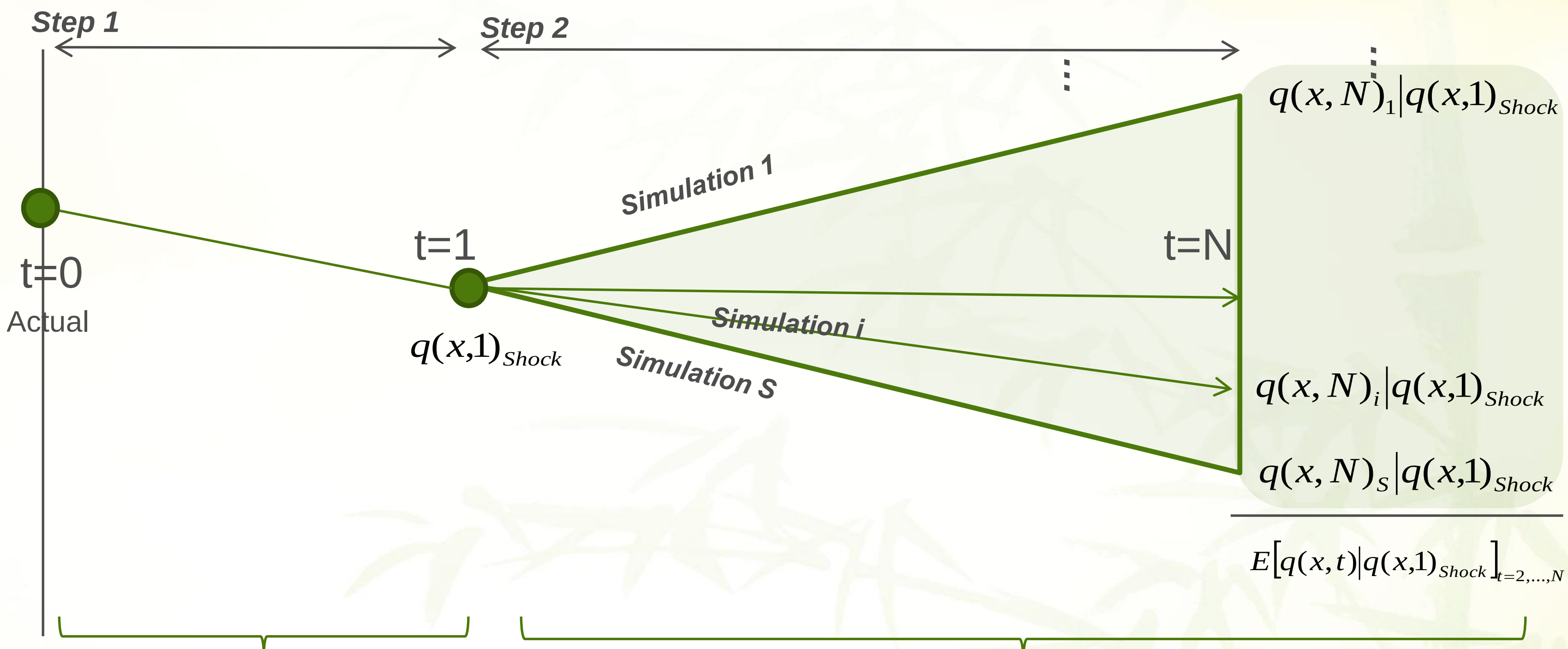


...Using one of the different stochastic mortality models shown in the previous slides

Mortality / longevity stress tests

Proposed approach (3/4)

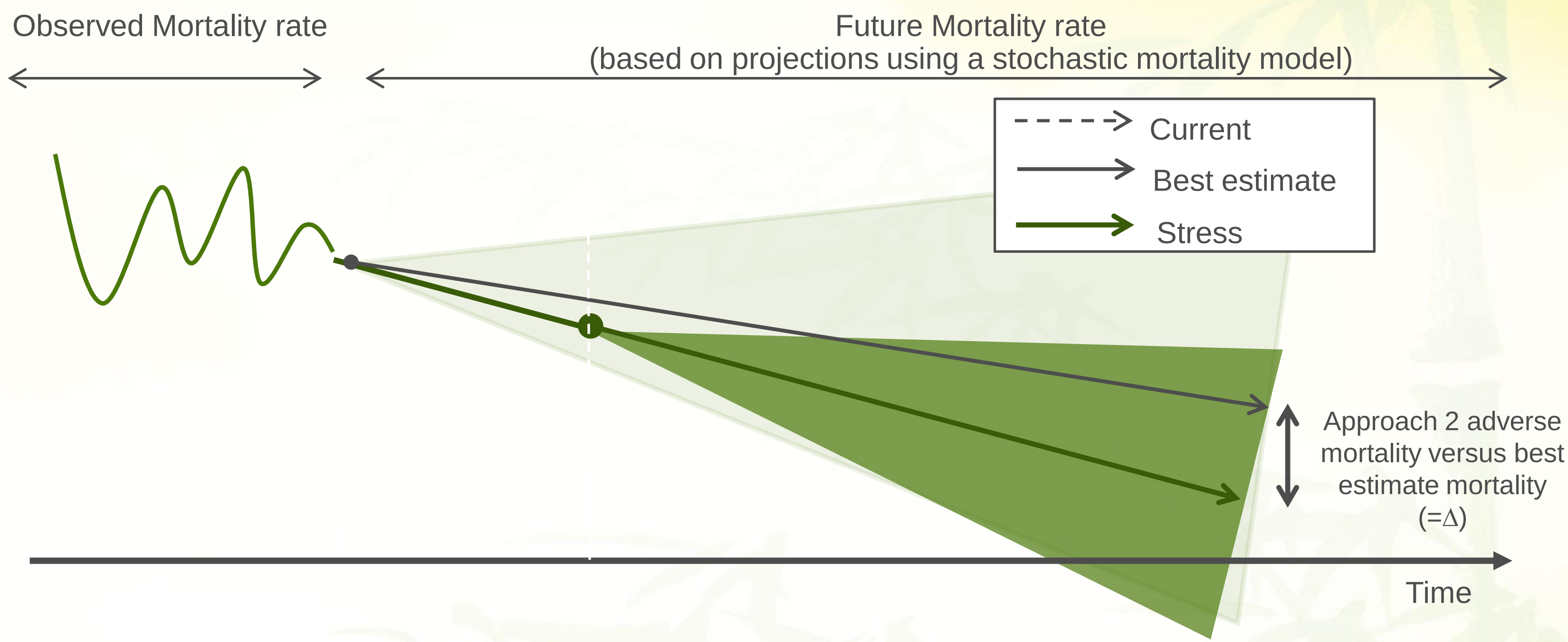
- How to project the stress scenario?



Projection of an adverse scenario using a stochastic mortality model
(e.g. 0.5 percentile of the mortality distribution)

Project the future mortality rates conditionally to the first period adverse scenario and then deduce the conditional best estimate mortality rates
(see the trend component of the Lee Carter model)

Mortality / longevity stress tests
Proposed approach (4/4)



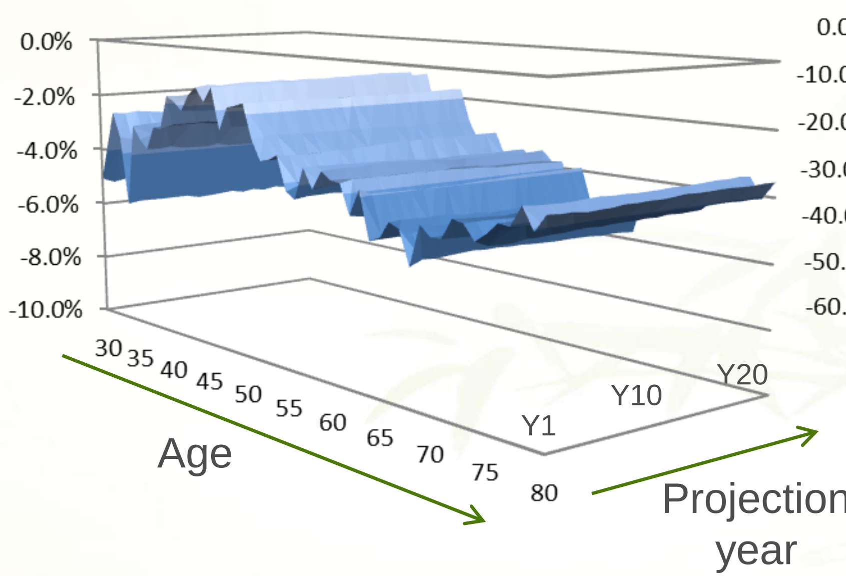
	t=1	t ={2, …, T}
x = {x_{min}, …, x_{max}}	$\Delta_{x,1} = \dfrac{q^{Choc,\varepsilon}(x,1) - \frac{1}{S}\sum_{s=1}^{S} q^{s}(x,1)}{\frac{1}{S}\sum_{s=1}^{S} q^{s}(x,1)}$	$\Delta_{x,t} = \dfrac{\frac{1}{S}\sum_{s=1}^{S}\left\{q(x,t) \mid q^{Shock}(x,1)\right\} - \frac{1}{S}\sum_{s=1}^{S} q^{s}(x,t)}{\frac{1}{S}\sum_{s=1}^{S} q^{s}(x,t)}$

Case study 2 – Mortality / longevity stress tests

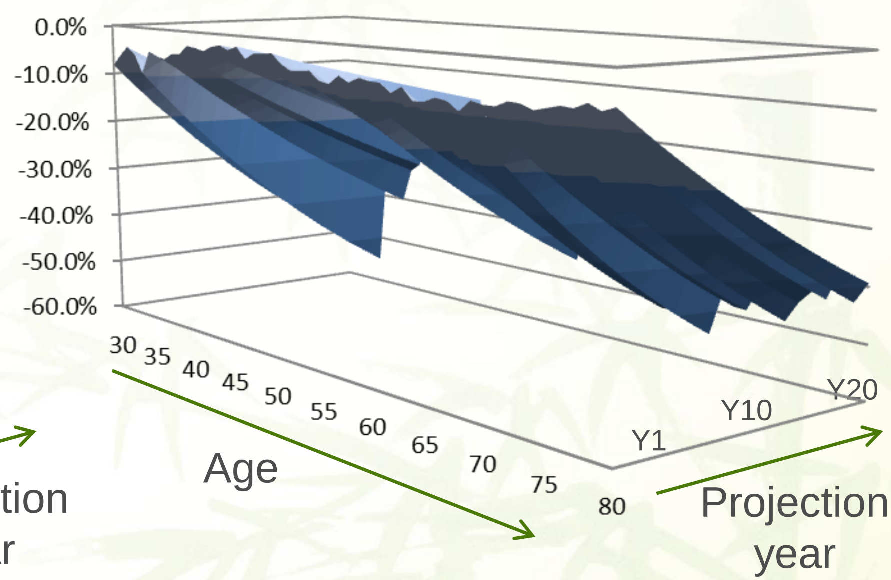
Results (1/2)

- Stress tests - Illustration on Taiwan total population (Male + Female):

Approach 2
projected adverse mortality
versus
projected best estimate
mortality



Approach 1
Projected adverse mortality
versus
actual mortality (constant along
the projection period)



In approach 2, part of the longevity trend is already factored in the projected best estimate mortality, hence a lower shock

Case study 2 – Mortality / longevity stress tests
Results (2/2)

- CEIOPS, Consultation paper No. 49 « Standard formula SCR – Article 109 c – Life underwriting risk » (2009)

  «

  - 3.42 Subsequent to QIS4, an investigation has been carried out by the Polish FSA which analysed the mortality data for nine countries indicated based both on historic improvements and a stochastic model of future mortality improvements.

  - 3.43 “The results of this analysis indicated that, on average (across the nine countries for which data was analysed), historic improvements in mortality rates over 15 years from 1992 to 2006 were higher than 25%. **Although the results of the stochastic model of future mortality improvements may imply a lower stress, CEIOPS has attached more weight to the analysis of historic improvements** because of the significant uncertainty inherent in modelling mortality

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Contents

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