Mortality decomposition model and its application in the graded longevity bond building in China

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Outline

- What and Why
- Multi-scale analysis of longevity risk
- Graded longevity bond building
- Some other work and future work

1. Why and what

- 1.1 Chinese longevity data problem
- 1.2 Go deep into longevity risk
- 1.3 Market chance
- 1.4 Government behavior

1.1
Chinese longevity data problem

the longevity data which many studies used :

- Different sources
- Short data and missing data
- Outlier

1.1 continue… different sources

- 1982-1987 from "birth and birth control survey: data analysis part"
- 1986, 1989-2010 from " Chinese population statistical year book" (national bureau of statistics of China, population division)
- Summary from different provinces (1993)
- Most data is from sampling survey
- Some data is from population cencus

1.1 continue… Short data and missing data

- 1983~2010 : 28 years
- 1991~1993: summary from provinces
- 1986: different samples
- 1988: blank
- 82~87: 80+
- 1990 4th population census; 2000 5th population census; 2010 6th population census : 100+
- Others : 90+

1.1 continue… ourlier

- ourlier over time
- ourlier over age

1.1 continue…

- Some research results can help alleviate the above problems
- Completing data, Smoothing data and fitting data are necessary (like multiple imputation, Rubin, 1978)
- We can introduce methods from signal processing field: like wavelet, HHT (Hilbert-Huang transform)

1.2 Go deep into longevity risk: apple or onion

- Hierarchical view: Different levels of risk
- longevity risk over age: mortality change of old people, middle-age, young people
- Longevity risk over time: period effect, cohort effect and so on
- Multi-resolution analysis or multi-scale analysis from signal processing field

1.3 Market chance

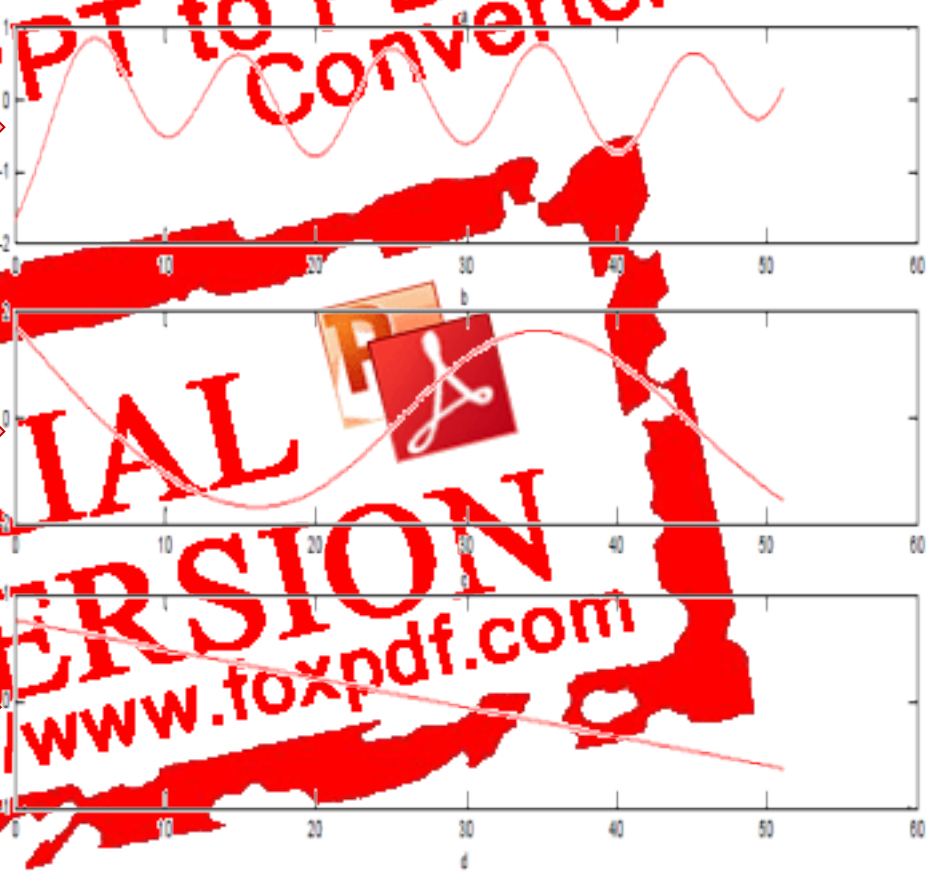
- Great investing chance demand
- Different field has different ability to absorb risk
- Frequency field analysis
- Risk should be transferred into different fields (like government, capital market , considering their absorbing risk ability!
- Graded longevity bond building

1.3 Continues…

Capital market, Hedging Funds

Long term bond

Governments



1.4 Government view

- Social Security system : Pay as you go to personal account gradually
- Central government : long-term fixed risk / trend
- Local government : short-term fixed risk/trend
- other risk : bond for different markets/ investors

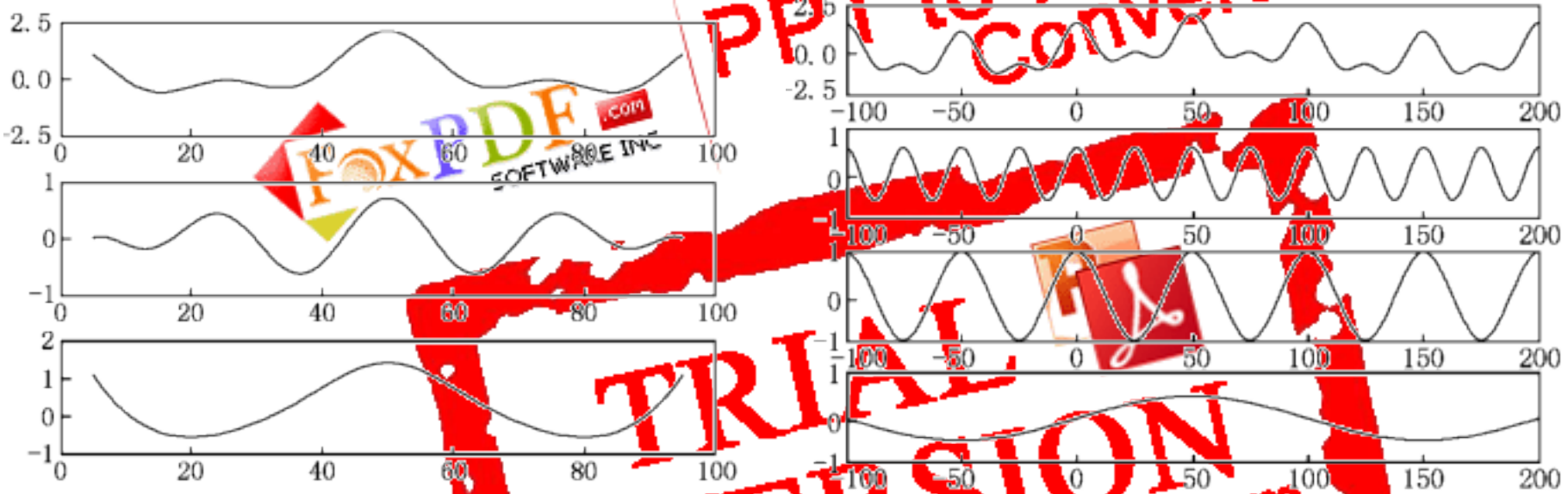
2 Multi-level analysis of longevity risk

- 2.1 Hilbert-Huang transform and EMD decomposition
- 2.2 How to use: mode 1
- 2.3 How to use: mode 2
- 2.4 Chinese data processing and results

2.1 HHT and EMD

- Empirical Mode Decomposition, EMD , Huang N.E., 1998
- For non-linear and non-stationary time series
- Thought: time series consists of information with different time scale, called intrinsic mode function (IMF)
- Linked with Hilbert phase analysis, Called HHT (NASA)

2.1 continue… example



2000 samples
Just for test

HHT details can be find in the paper "The empirical mode decomposition and the Hilbert spectrum for nonlinear
and non-stationary time series analysis" 1998

2.1 continue…

- Don’t depend on the primary function (like Flourier or Wavelet)
- Local information of series can be expressed in intrinsic mode function
- The residual part gives a simple trend
- Hilbert Phase can provide other information
- Empirical Completeness & Orthogonality

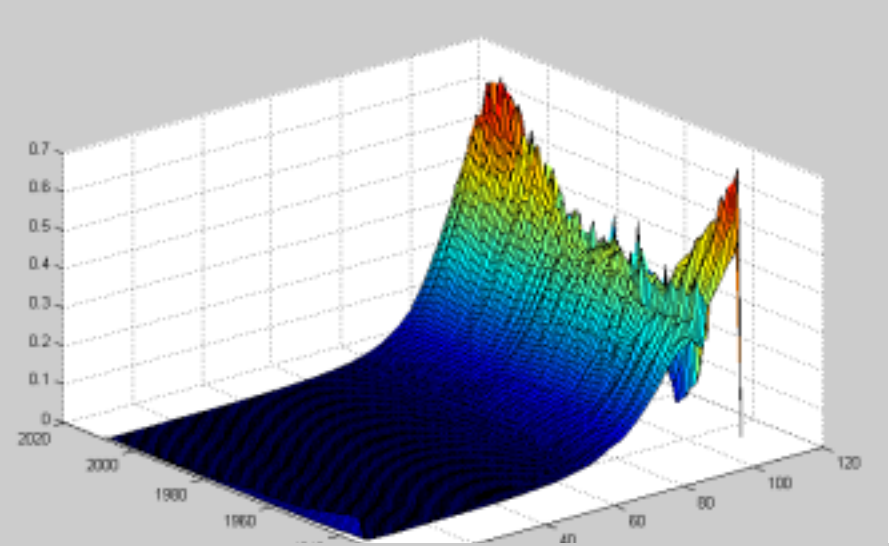
2.2 how to use , mode 1

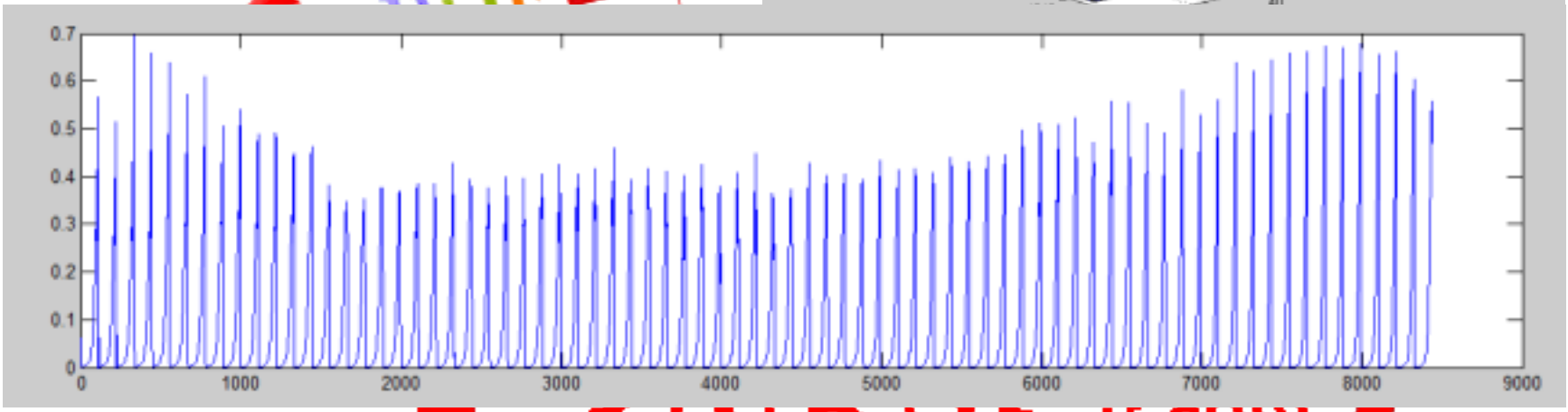
- 1. Panel data to time series, because the designing aim of HHT is to multi-scale: the time factor will "repeat" in the same age of different time. Just like normal signal.
- 2. Find the trend after several EMDs.
- 3. Use time series method (like ARIMA) to forecast the trend.
- 4. Reconstruct the future mortality by utilizing signal processing method
- 5. Using Hilbert spectrum analysis to find other information

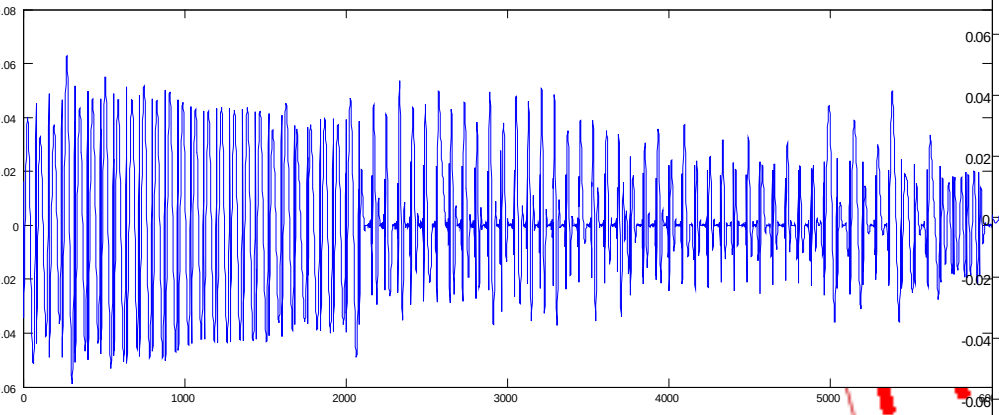
Tips: HHT also can be used for filtering, smoothing & completing the data

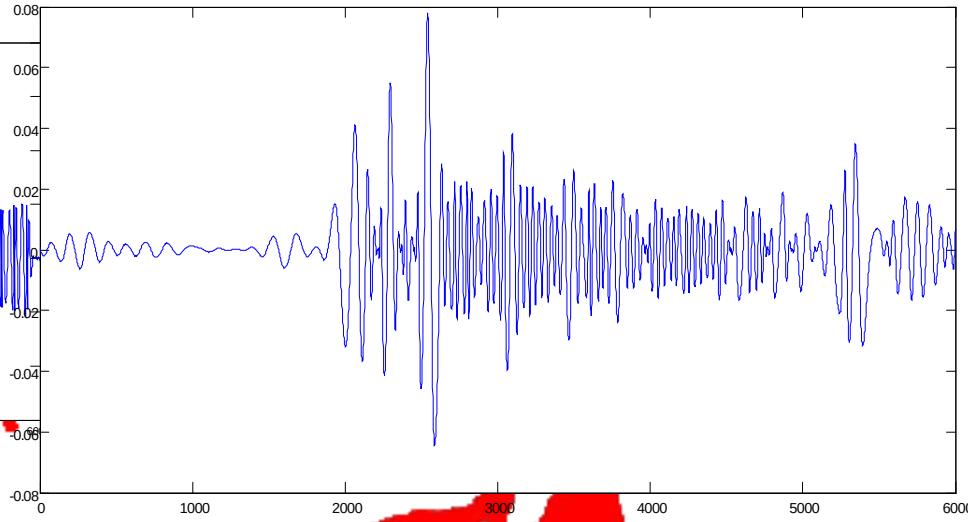
2.2 continue…

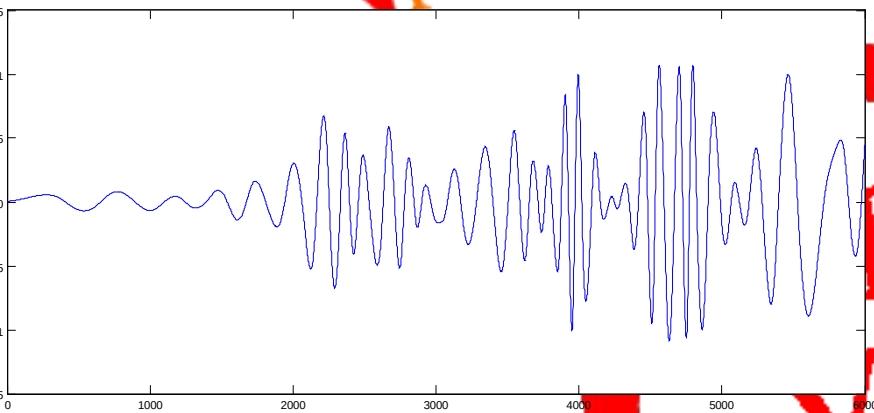
75*111, age 0~110+
time 2008~1934

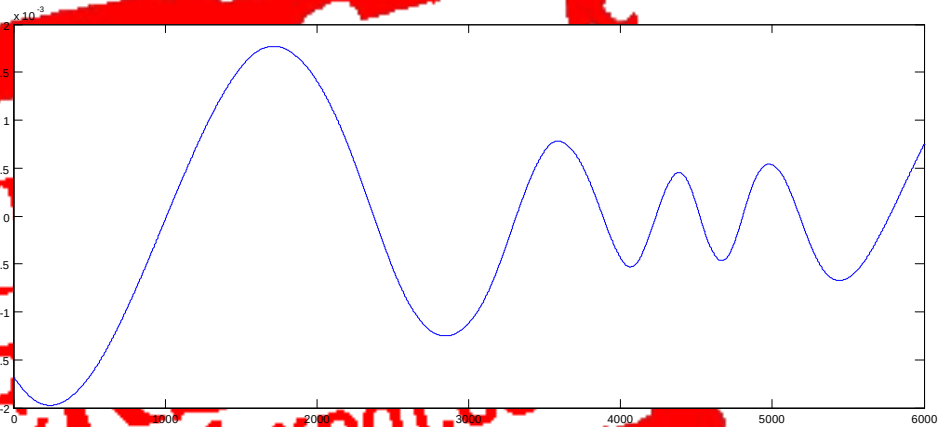




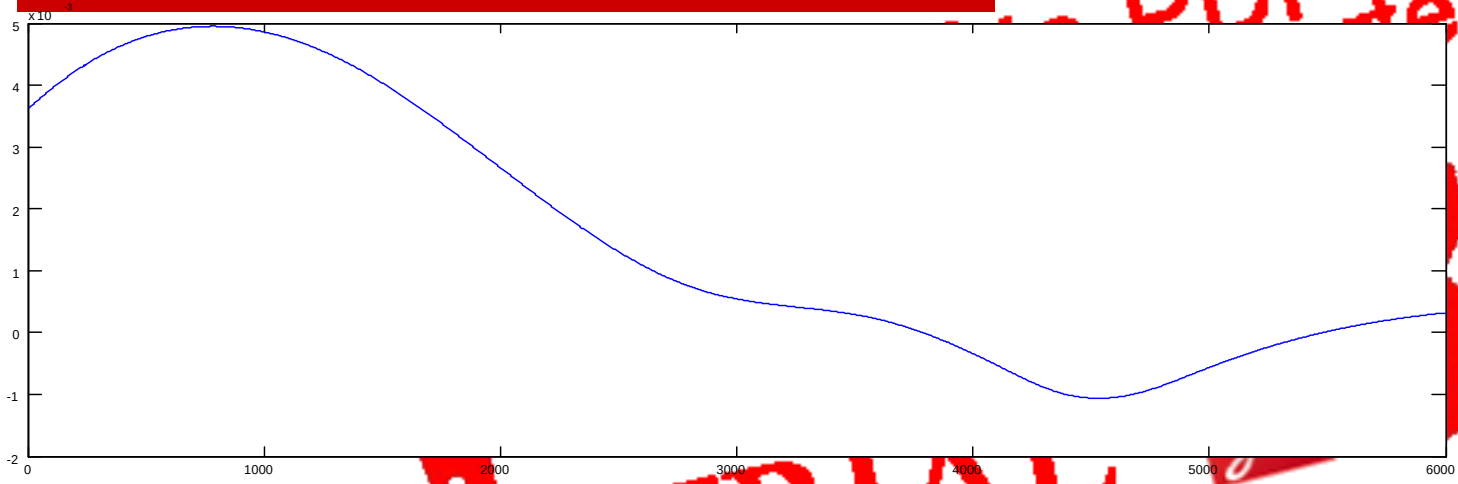


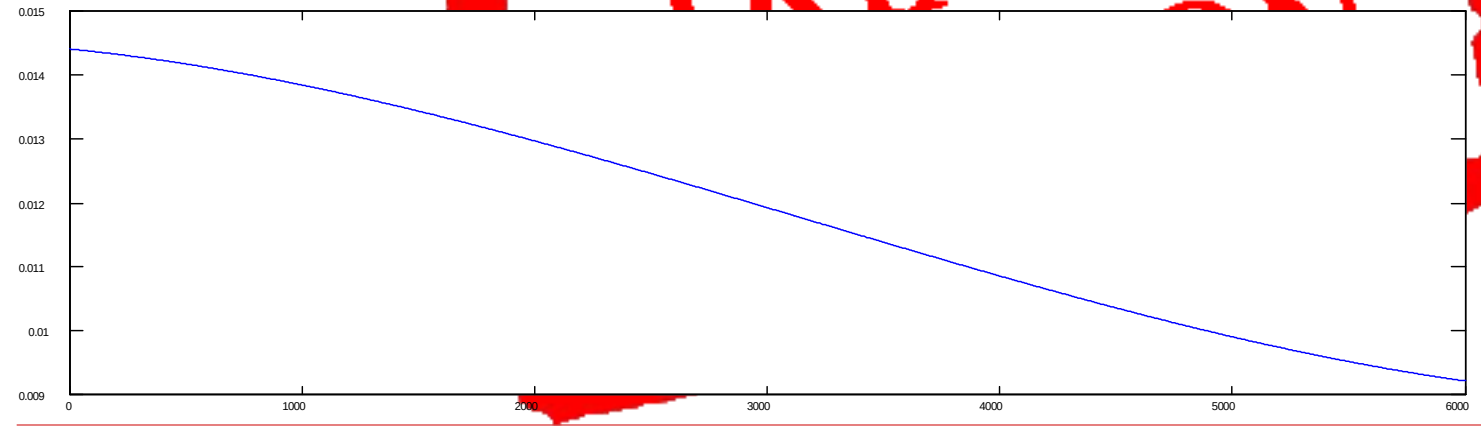




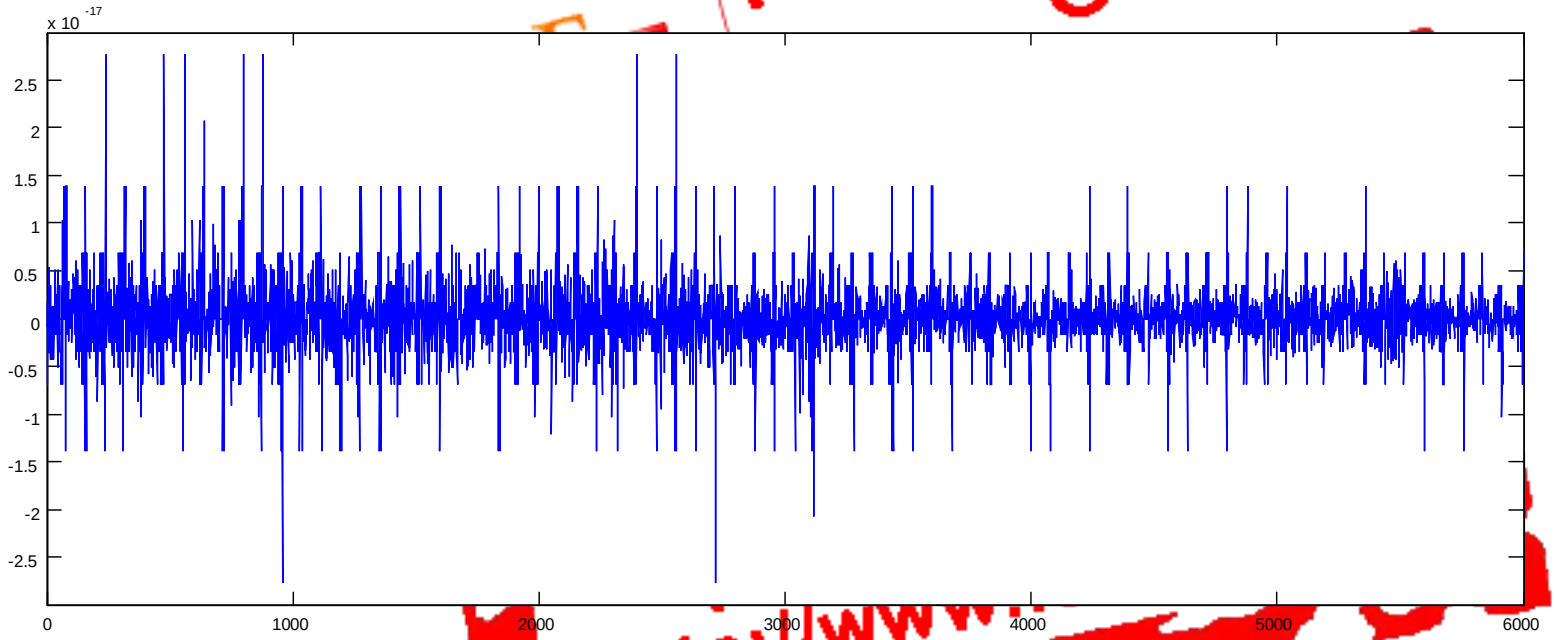


2.2 continue… the last two IMFs , the trend part





2.2 continue… residual error



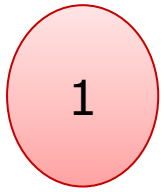
2.2 continue… result

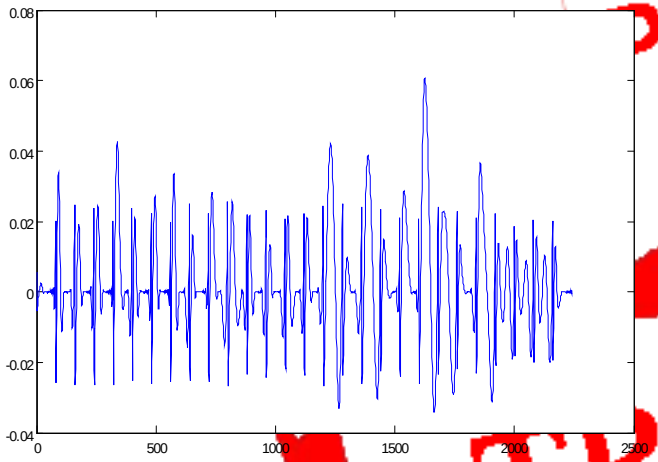
per 100000	5+	10+	15+	20+	25+	30+	35+	40+	45+	50+
2010 Lee Carter	10	11	48	58	54	62	90	150	267	464
2010 HHT	11.3	12.1	53	56	57	61	85	139	217	417

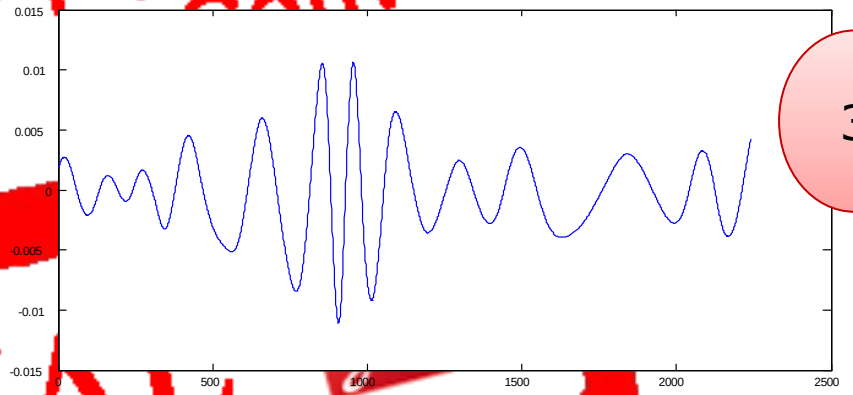
2.3 How to use: mode 2

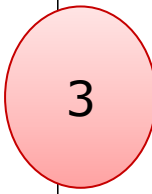
- Just use the first IMF result and the last IMF result.
- Using Lee-Carter model or other model to process the result after removing the first and the last IMF. (As filtering tools)
- It seems to fit Chinese longevity data better.
- Removing the first IMF: smooth the data and removing the impact of outliers

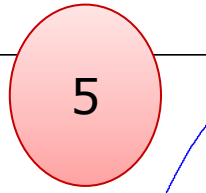
2.4 Chinese result mode 1

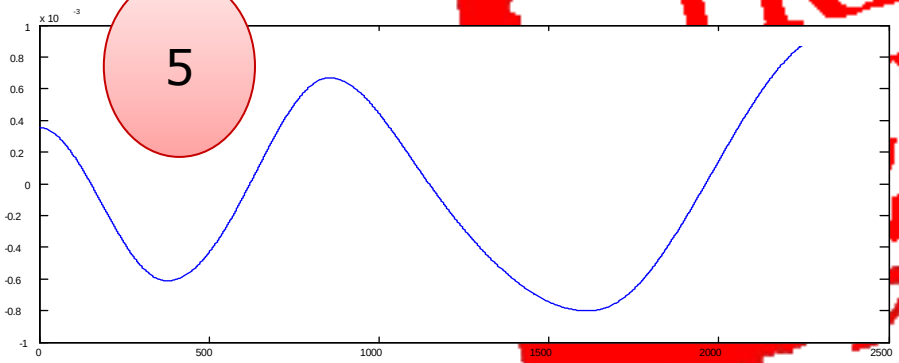


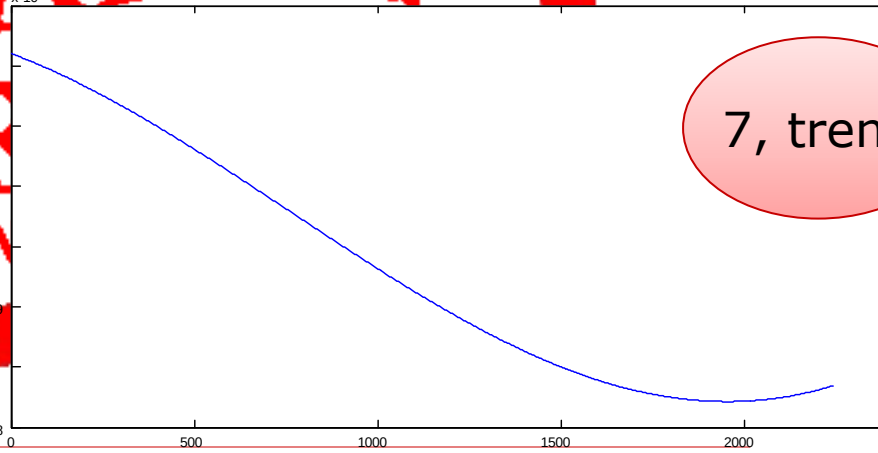






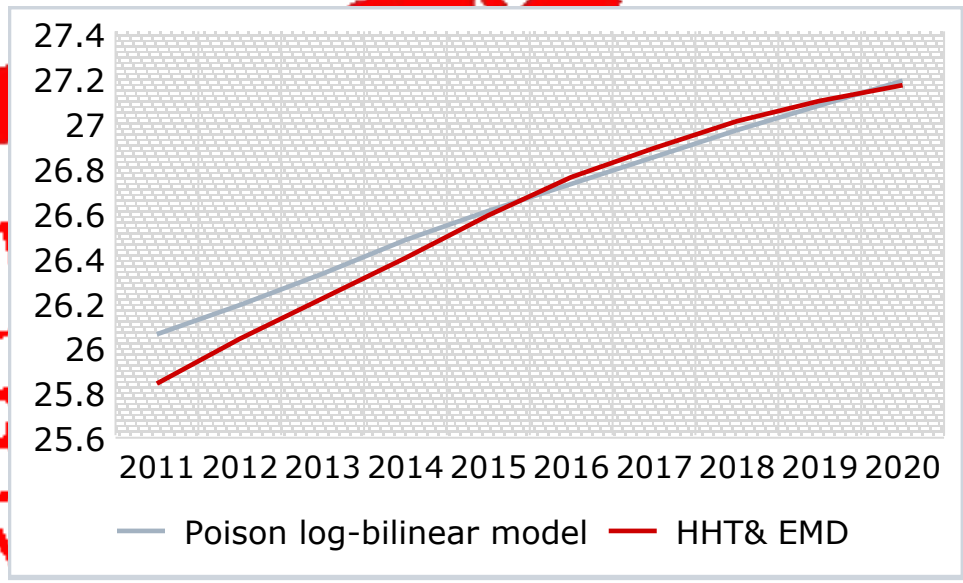






2.4 continue… female residual life (age 60)

Period	Poisson log-bilinear model	HHT& EMD
2011	26.05	25.83
2012	26.18	26.03
2013	26.32	26.21
2014	26.47	26.39
2015	26.6	26.58
2016	26.72	26.75
2017	26.84	26.88
2018	26.96	27
2019	27.07	27.09
2020	27.18	27.16



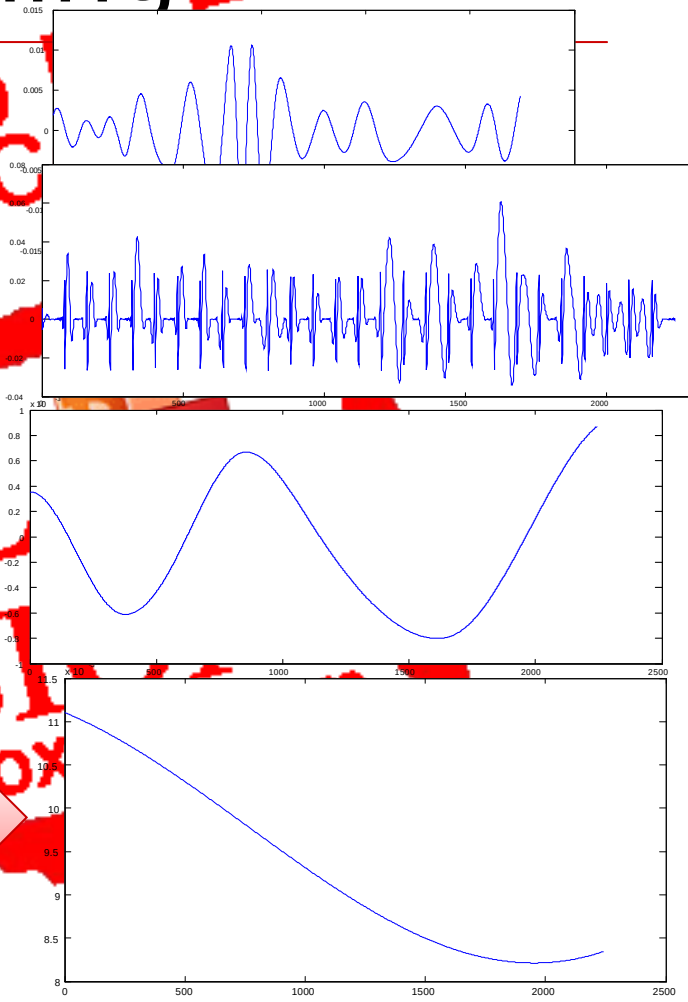
2.4 Continue… mode 2

- Simple comparison
- Data: 1983-2010, (total 6, remove 2,1)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Lee Carter	-0.58	0.79	0.64	-1.45	-1.37	-1.57	-1.42	-1.39	-1.67	-1.81	-1.63
Lee Carter after HHT	-0.45	-0.57	-0.67	-0.73	-0.89	-1.21	-1.42	-1.67	-1.72	-1.79	-1.93

3 graded bonds building

- Stochastic risk can be transferred to capital market
- Local Government
- Central Government



3 graded bond building advice

- Different level of risks are combined into a graded bond.
- The government issues it.
- The first-level risk is taken by central government;
- The second-level risk is taken by local government;
- The other risk is taken by investors

3 graded bonds building

- Based on 1983-2009 data, Computing Public pension burden (Gap to make up the pension to keep fixed substitution rate)
- Assume : fixed other conditions
- 2020 Central Government: 980 trillion
  Local Government: 530 trillion
- 2030 Central Government: 1370 trillion
  Local Government: 670 trillion

4 Some other work and future work

- Chinese aging index
- Hilbert spectrum analysis of Longevity risk
- More detailed calculation of the graded bond
- Accurate calculation in public finance's view

Beijing	0.0038
Shanghai	0.00372
Tianjin	0.00221
Liaoning Province*	0.0039
Zhejiang Province	0.00376
Shandong Province	0.0039

Thanks for your patience !

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