

# On the modeling and estimation of health changes in the U.S.

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# [Outline

- Motivation & Contribution
- Theoretical framework
- Data
- Results
- Sensitivity analysis
- Conclusions

# Background: uncertainty of health

- Unprecedented improvements in health and longevity in the U.S.
- Unclear direction of recent health changes.
- The future health trend is uncertain.
  - Economic changes, Technological advances,
  - Obesity and diabetes
  - Smoking and drinking behavior, etc.
- Modeling past trends of health, relatively little literature on investigating its future developments.

# [ Who cares... ]

Health uncertainty affects:

- Insurance companies, pension funds, social security, government institutes, etc
- Retirement age (healthy life expectancy)
- Medical expenditure, etc

# [ Contribution ]

- Stochastic approach based on Lee and Carter (1992) for health
- Quantification of uncertainty
- Identification of observed factors (GDP and unemployment rate) to capture time trends in the general health.

# Methodology

- Health Status Index (HSI)

$$\hat{\pi}_{x,t} = \frac{1}{N_{x,t}} \sum_{j=1}^{N_{x,t}} H_{j,x,t}.$$

- $H_{j,x,t}$  : indicator for “lower” health of the  $j^{\text{th}}$  respondent of age  $x$  at time  $t$  .
- $N_{x,t}$  : total number of survey respondents of age  $x$  at the time  $t$
- HSI represents the proportion of population in “lower” health condition

# Modeling health: Lee-Carter Model

$$\log(\pi_{x,t}) = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t},$$

$$t = 1, \dots, T, \quad x = 1, \dots, X$$

Constraints:  $\sum_t \kappa_t = 0, \quad \sum_x \beta_x = 1$

- $\alpha_x$  and  $\beta_x$  : age-specific parameters
- $\kappa_t$  : univariate time varying index
- $\varepsilon_{x,t}$ : error term  $\sim (0, \sigma_\varepsilon^2)$

# Lee-Carter model with observed variables

$$\log(\pi_{x,t}) = \alpha_x + \beta_x \kappa_t + \rho'_x Z_t + \varepsilon_{x,t},$$

$$t = 1, \dots, T, \quad x = 1, \dots, X$$

where  $Z_t = (Z_{1,t}, Z_{2,t}, \dots, Z_{K,t})'$  is a vector of  $K$  (standardized) macroeconomic variables (GDP, unemployment rate)

Constraints: 
$$\sum_t \kappa_t = 0, \quad \sum_x \beta_x = 1, \quad \sum_x \rho_x = 1$$



# [ Data (1972-2010) ]

- National Health Interview Survey:  
Self-assessed health status
- OECD:  
GDP, Total unemployment rate,  
Annual alcohol consumption per capita (liters, age 15+)  
Annual tobacco consumption per capita (grams, age 15+)
- Human Mortality Database:  
Mortality rates

# Health Status Index

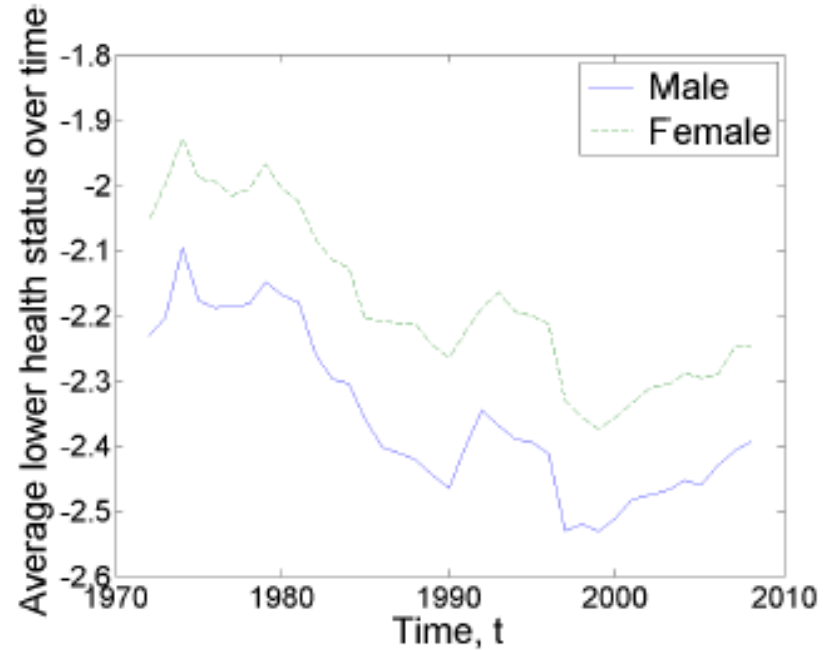
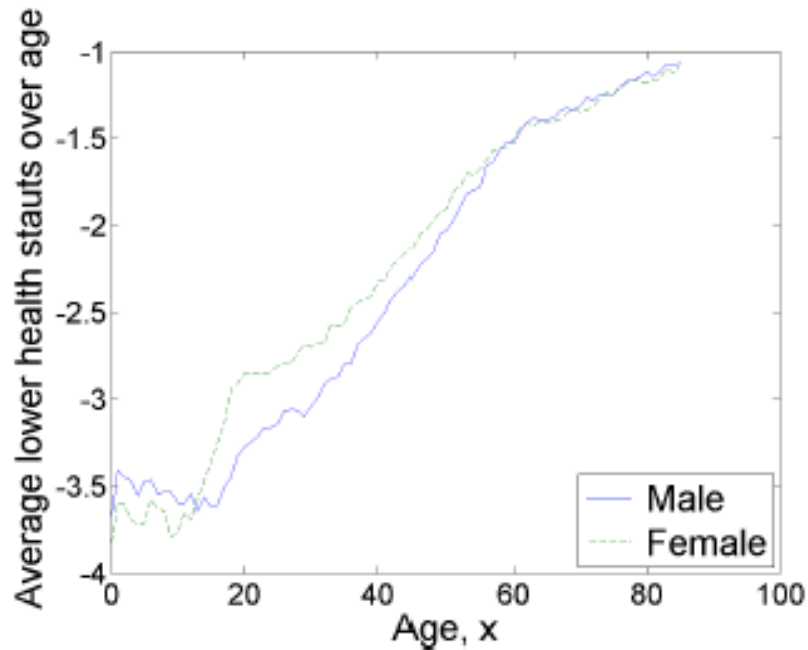


Figure 1: Description of the lower health in the U.S. The left graph shows the average lower health condition over age. The right graph shows the average lower health condition over time.

# Health modeling (Lee-Carter model)

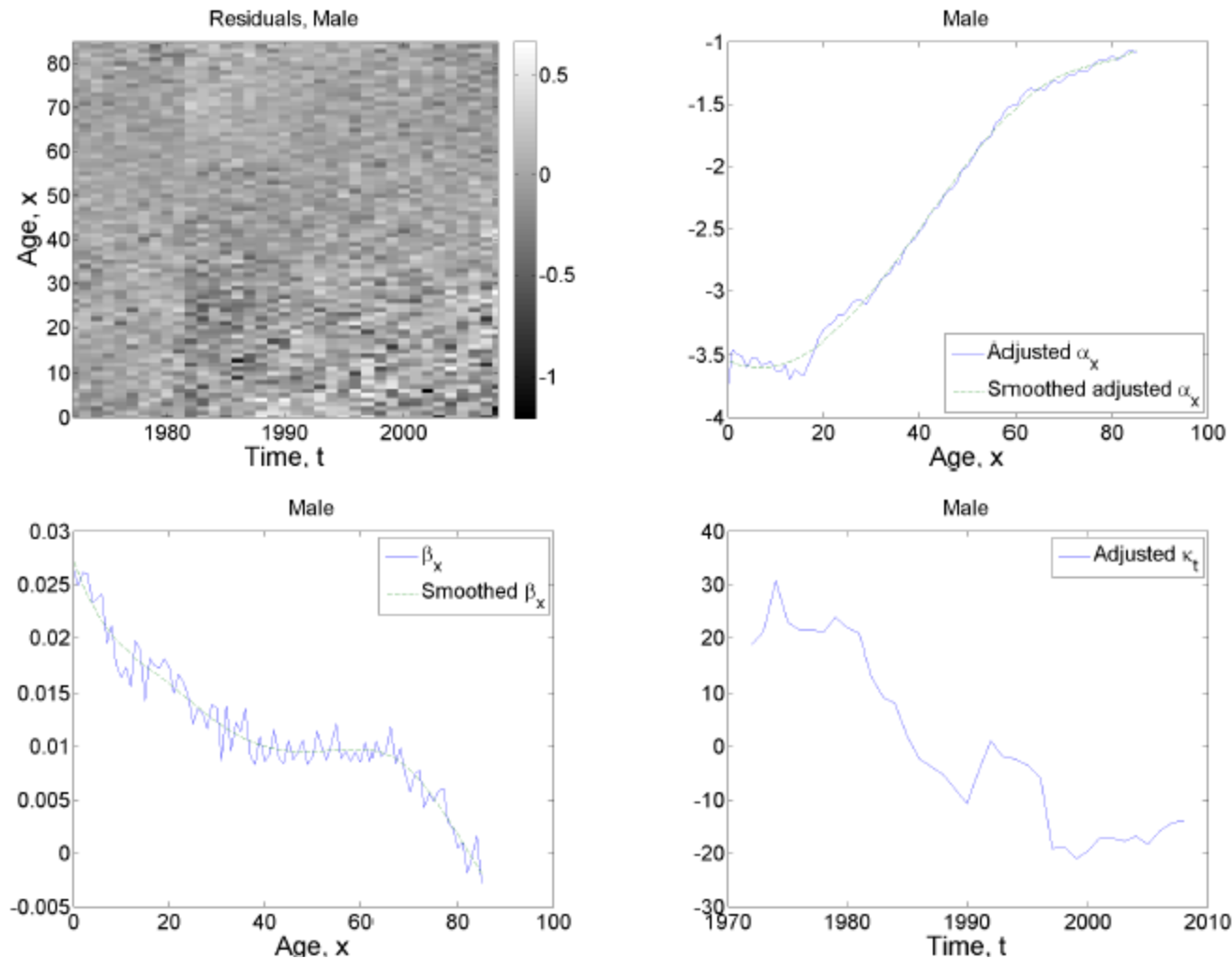
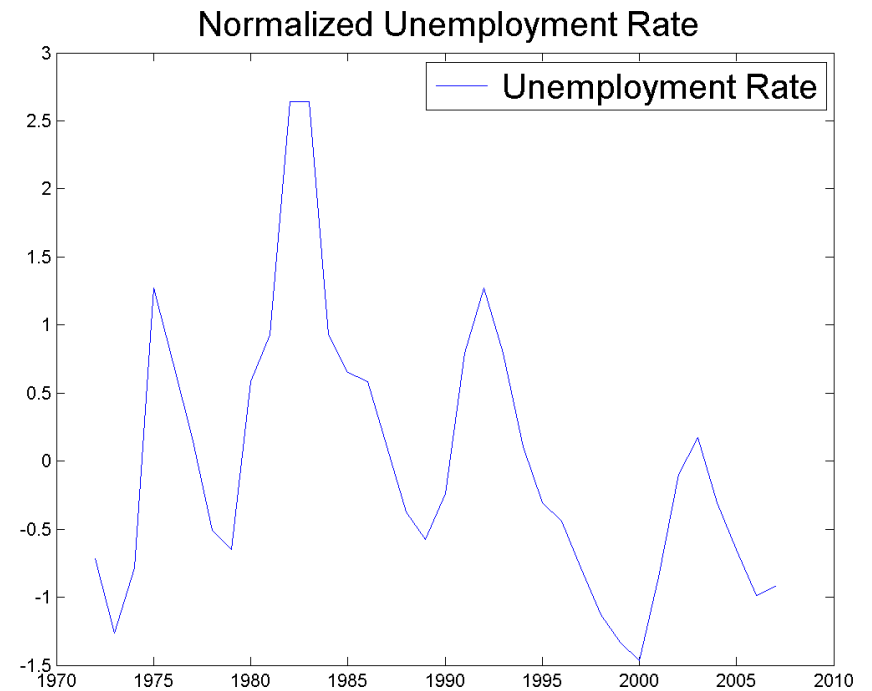
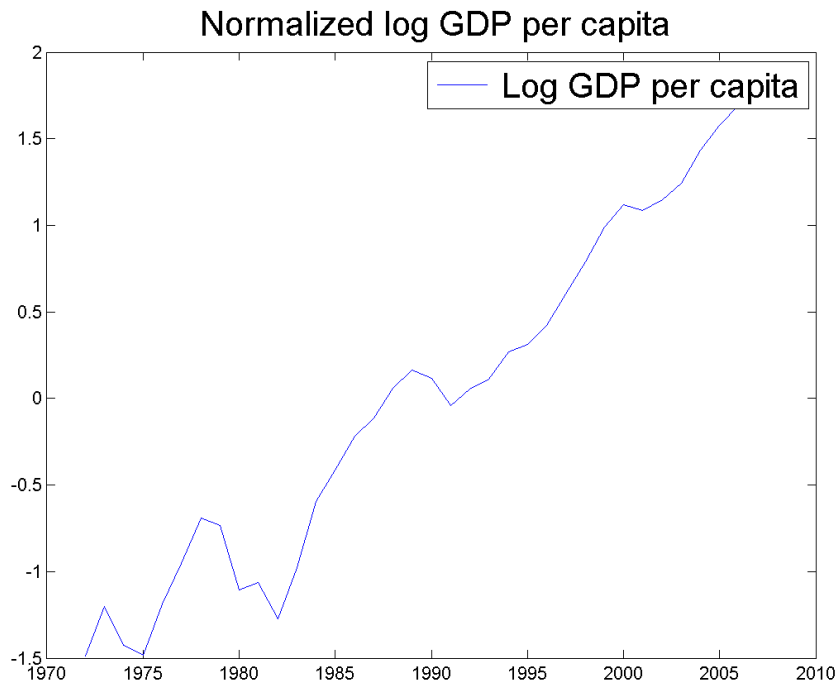


Figure 3: Estimates of Lee-Carter model for health, Male: 0-85. The upper left panel shows the estimated residuals. The upper right panel shows the adjusted (smoothed)  $\alpha_x$ . The lower left panel shows the estimated (smoothed)  $\beta_x$ . And the lower right panel shows the adjusted  $\kappa_t$ .

# Macroeconomic fluctuations



# Health modeling (Lee-Carter model with observed variables)

We rewrite  $\kappa_t$  by  $\tilde{\kappa}_t$  in the following equation

$$\log(\pi_{x,t}) = \alpha_x + \beta_x \tilde{\kappa}_t + \tilde{\rho}'_x Z_t + \varepsilon_{x,t}$$

with

$$\begin{aligned} \tilde{\kappa}_t &= \kappa_t - ((\sum_t Z_t Z_t')^{-1} (\sum_t Z_t \kappa_t))' Z_t \\ \tilde{\rho}_x &= \rho_x - ((\sum_t Z_t Z_t')^{-1} (\sum_t Z_t \kappa_t))' \beta_x \end{aligned}$$

$\tilde{\kappa}_t$  is orthogonal to  $Z_t$

$\tilde{\rho}_x$  measures the 'real' effect of  $Z_t$

# Lee-Carter model with observed variables. Estimation results

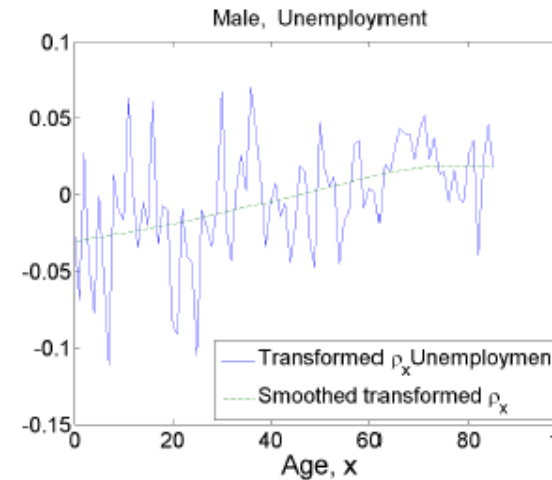
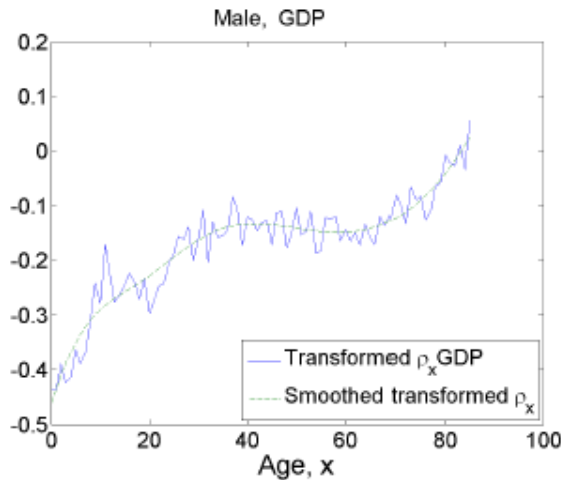
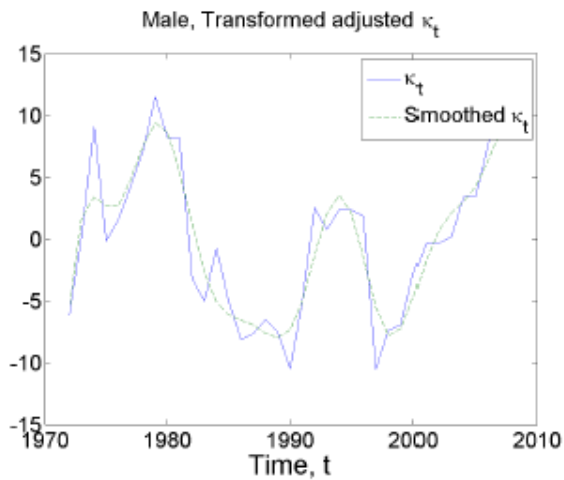


Figure 5: Transformed  $\kappa_t$  and  $\rho_x$  in the Lee-Carter model with GDP and unemployment rate for health

# Model fit

Table 1: Quality of the model fit of Lee-Carter model and Lee-Carter model with macroeconomic variables. The first panel shows the results for males and the second panel shows the results for females. In each panel, the first row is the mean square error (MSE), the second row shows the improvement of MSE in percentage compared with the Lee-Carter model, the last row shows the BIC value.

	LC	LC with GDP & Unemployment rate
	Male	
MSE $\times 10^{-4}$	5.1029	4.1277
Improvement		(23.6%)
BIC	-7.1446	-7.1387
	Female	
MSE $\times 10^{-4}$	4.1211	3.3044
Improvement		(24.7%)
BIC	-7.3583	-7.3611

# [ Significance tests ]

Table 2: Test statistics of observed variables in the Lee-Carter model with macroeconomic variables for health over the period 1972-2008 for ages 0-85. '\*' denotes the estimates are significantly different from 0 at the 5% level. P-Values are presented in the brackets.

Lee-Carter with GDP & Unemployment rate, ( $H_0 : \hat{\rho} = \vec{0}$ )		
	Male	Female
GDP	60428* (0.0000)	40307* (0.0000)
Unemployment rate	136* (0.00051)	124* (0.0044)



# Health Forecast

Table 4: The comparison of forecast accuracy. The first and the second panels are for males and females separately, containing MSFE, MAFE, and MFE of the Lee-Carter model and the Lee-Carter model with macroeconomic variables for males and females. The bottom panel shows MSFE, MAFE, and MFE based on the forecasted  $\kappa_t$  from the Lee-Carter with macroeconomic variables and real observed variables for males and females.

Forecast HSI based on forecasted $\kappa_t$ and observed variables using VAR model			
	MSFE( $10^{-3}$ )	MAFE	MFE
Lee-Carter with	Male		
no OV	0.7249	0.0184	-0.0019
OV	0.5625	0.0162	-0.0053
	Female		
no OV	0.7387	0.0196	-0.0045
OV	0.5665	0.0171	-0.0061
Forecast HSI based on forecasted $\kappa_t$ and real observed variables			
Male	0.5802	0.0163	-0.0029
Female	0.5866	0.0173	-0.0043

# Life expectancy (LE) & Healthy life expectancy (HLE)

Relative increases of LE and HLE for males and females compared to year 1972

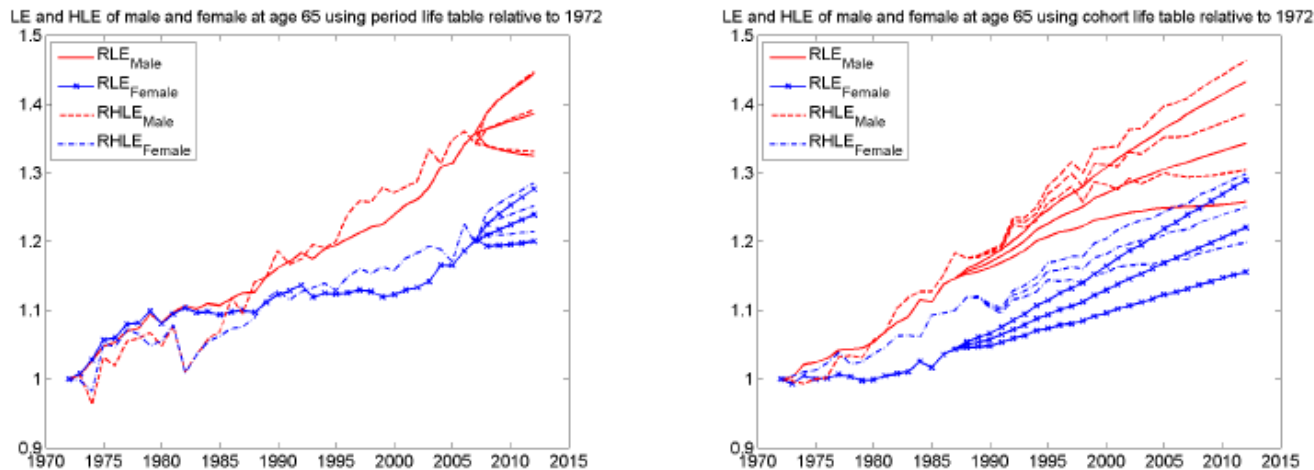


Figure 10: Relative increase of life expectancy and healthy life expectancy from period and cohort life tables for both genders of age 65. The left panel is from the period life table. The right panel is from the cohort life table.

# Sensitivity Analysis

- Different transformations of health status index.
- Sub age group analysis.
- Choice of alternative observed variables: life-style related variables, alcohol and tobacco consumption.
- ... ..

# Conclusions

- Lee-Carter model works well for health modeling
- Including GDP and unemployment rate: significant improvement in the model fit and the forecast efficiency
- Effects of macroeconomic variables on health are generally different for different age groups
- HLE increases faster than LE.
- Males' LE and HLE are lower than females', but increasing faster but with larger uncertainties.

*THANK YOU!*