International mortality modelling — An economic perspective

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Outline

Overview

- Recent literature on modelling multiple populations together.
- Motivation

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  1. Demographic - to improve the accuracy of forecasts in smaller populations
  2. Actuarial - mortality hedging instrument for pension plan priced according to mortality in different population.

Literature

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1. Using robust information from mortality trends for large populations may help to give more accurate or more reasonable forecasts in smaller populations for the purposes of public financing decisions or health care planning (Li and Lee, 2005; Jarner and Kryger, 2009).
2. The mortality experience of the population used in pricing the hedging instrument may differ from the population of the pension plan (Li and Hardy, 2011; Dowd et al., 2011).

Theoretical background 1

- Lee and Carter (1992)

$$m_{tx} = a_x + b_x \kappa_t + \varepsilon_{tx} \tag{1}$$

- Li and Lee (2005)

$$m_{tx} = a_x + B_x K_t + b_x \kappa_t + \varepsilon_{tx} \tag{2}$$

- Li and Hardy (2011)

$$\kappa_t = \alpha + \beta \kappa_t^* + \varepsilon_t \tag{3}$$

* denotes larger population

Theoretical background 2

- Dowd et al. (2011)

$$
\begin{aligned}
{\kappa_t}^* &= \kappa^*_{t-1} + \mu^* + \varepsilon^*_{t-1} \\
\Delta\kappa_t &= \phi(\kappa_{t-1} - \kappa^*_{t-1}) + \mu + C{\varepsilon_t}^* + \varepsilon_t, \quad -1 < \phi < 0
\end{aligned}
$$

  * denotes larger population
  error structure is also allowed to be correlated

Model 1

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- Lee-Carter in matrix form

$$\boldsymbol{m} = \mathbf{1}_{\boldsymbol{T}} \boldsymbol{a}' + \boldsymbol{\kappa} \boldsymbol{b}' \tag{6}$$

Model 2

- Combining (4),(5) and (6) we get

$$\Delta\kappa_t = \phi(\kappa_{t-1} - \frac{b^*}{b}\kappa^*_{t-1}) - \phi\frac{\beta}{b}(y_t - y^*_t) + \sum_{m=1}^{M}\lambda_m\Delta\kappa_{t-1} + \phi C \tag{7}$$

Dowd et al. (2011) implicitly assuming $(y_t - y^*_t) = constant$

Table 1 : Ten leaders in health technology patents - percentage of world total

Medical technology		Pharmaceuticals	
United States	53%	United States	47%
Germany	8%	Japan	9%
Japan	6%	Germany	8%
United Kingdom	5%	United Kingdom	7%
France	3%	France	4%
Sweden	3%	Canada	3%
Israel	3%	Italy	2%
Netherlands	2%	Sweden	2%
Switzerland	2%	Switzerland	1%
Canada	2%	Australia	1%

Patent counts — Patent applications filed under the Patent Co-operation Treaty by inventor's country of residence by classes of the International Patent Classification (OECD, 2013)

Data collection

- UK/US Male mortality data 1970-2008 - Source : Human Mortality Database.
- Health production inputs - Source : OECD Health Data 2012 .
    - Pharmaceutical expenditure
    - Smoking
    - Alcohol
    - Health expenditure
    - GDP

Table 5 : Estimation of the cointegrating relationship

Dependent variable κ_{UK}	Model(2) coeff. (s.e.)	Model(3) coeff. (s.e.)
Constant	-80.82^{**}	-83.74^{**}
	(6.32)	(8.91)
κ_{USA}	1.09^{**}	1.06^{**}
	(0.02)	(0.06)
Pharmaceutical expenditure	-6.15^{**}	-8.48^{**}
	(2.15)	(1.95)
Smoking	-	$-$ 2.12
	-	(1.46)
Education	-173.98^{**}	-179.85^{**}
	(12.89)	(18.09)
Alcohol	-	– 2.80
	-	(2.77)
Health expenditure	-	3.48
	-	(2.77)
GDP	-	-6.44
	-	(7.95)

Cointegration tests and forecasts

Table 4 : Testing for cointegration between $\kappa_{UK,t}$ and $\kappa_{USA,t}$: Engle–Granger test statistics.

	Model(1)	Model(2)
Test statistic	-1.77	-4.75^{***}

Table 6 : Goodness of fit measures for forecasts of UK mortality rates, 1999–2008.

	1. Mean percentage error		2. Mean absolute percentage error (MAPE)		3. Root mean square of the percentage error	
	UK	USA	UK	USA	UK	USA
Lee-Carter	3.6%	3.5%	10.6%	10.1%	12.7%	13.7%
Model	-0.7%	–	9.9%	–	12.4%	–

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- I have developed a theoretical model which highlights the deficiencies in current approaches.
- An empirical analysis based on US and UK mortality data validates this approach.
- Insights from this paper may help to provide better mortality models for related populations and also help to deepen understanding of the processes driving international longevity trends.