Granular mortality modeling with temperature and epidemic shocks: a three-state regime-switching approach

Jens Robben[1,*], Karim Barigou[2], and Torsten Kleinow[1]

[1] *Research Centre for Longevity Risk, Faculty of Economics and Business, University of Amsterdam, The Netherlands.*

[3] *Institute of Statistics, Biostatistics and Actuarial Science (ISBA), Louvain Institute of Data Analysis and Modeling (LIDAM), UCLouvain, Louvain-la-Neuve, Belgium*

[*] *Corresponding author: j.robben@uva.nl*

May 13, 2025

Abstract

This paper develops a granular regime-switching framework to model mortality deviations from seasonal baseline trends driven by temperature and epidemic shocks. The framework features three states: (1) a baseline state that captures observed seasonal mortality patterns, (2) an environmental shock state for heat waves, and (3) a respiratory shock state that addresses mortality deviations caused by strong outbreaks of respiratory diseases due to influenza and COVID-19. Transition probabilities between states are modeled using covariate-dependent multinomial logit functions. These functions incorporate, among others, lagged temperature and influenza incidence rates as predictors, allowing dynamic adjustments to evolving shocks. Calibrated on weekly mortality data across 21 French regions and six age groups, the regime-switching framework accounts for spatial and demographic heterogeneity. Under various projection scenarios for temperature and influenza, we quantify uncertainty in mortality forecasts through prediction intervals constructed using an extensive bootstrap approach. These projections can guide insurance companies, healthcare providers, and hospitals in managing risks and planning resources for potential future shocks.

Keywords: granular mortality modeling; regime-switching; environmental shocks; respiratory shocks