Mortality Risk Modelling:
Applications to Insurance Securitization

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1. INTRODUCTION

Over the past half century, and especially in the most recent decades, we witness remarkable mortality improvements and the growth of the population of older people (Bourguignon and Morrission,2002; Lakdawalla and Philipson, 2002; Vaupel, 1998; Lin and Cox, 2005). This progress in longevity has a worrying impact on a pension plan and an annuity insurer who provide for old age benefits. In the US, private defined benefit (DB) pension fund currently holds close to $US 6 trillion liabilities and the life insurance industry around $US 2 trillion annuity reserves.[1] Unanticipated mortality improvement has meant that the value of the sponsor's (the annuity insurer's) obligation to its members (annuitants) rises since survival benefits need to be paid much longer than expectation.

Significant underestimates of longevity improvements imply a high profile risk for pension funds and annuity insurers. Given a recent study on the companies in the UK's FTSE100 index, these firms were found to be overly optimistic on longevity assumptions in their pension valuations. In particular, they failed to consider those scenarios that a life expectancy by 2050 could be 90 years or more given improvements in health conditions across the world (J.P. Morgan Securities Ltd., 2007). Accordingly, their ignorance suggests a potential aggregate deficit by more than £50 billion.[2]

In contrast, other scenarios are less optimistic or pessimistic about mortality improvement because of new threats and epidemics (Hardy, 2005; Rogers, 2002; Goss et al., 1998; Cox and Lin,2007; Lin and Cox, 2008). Genetic analysis has confirmed that the virus of “Spanish flu” which killed 40 to 100 million persons in 1918 developed in birds and was similar to the “bird flu” today(Juckett, 2006). Although the theory of a predictable pandemic cycle has been discarded, this finding has spurred fears of another worldwide epidemic. For instance, many public health experts think that a pandemic is overdue and another is inevitable to occur (Dowdle, 2006). Should a pandemic occur, an insurer who sells life insurance and pays death benefits (a life insurer) will suffer financially. Given the reserves for US life insurance policies stand at around $US 1 trillion in the US,[3] a catastrophic death event could trigger turbulence in the life insurance industry.

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[1]See Pension Markets in Focus, OECD, Oct 2006, and Life Insurers Fact Book 2006, American Council of Life Insurers.

[2]Pension Capital Strategies and Jardine Lloyd Thompson, 2006, The FTSE100 and their pension disclosures.

[3]See Pension Markets in Focus, OECD, Oct 2006, and Life Insurers Fact Book 2006, American Council of LifeInsurers.

To handle the uncertainty of life expectancy going forward, the existing literature considers different scenarios of mortality risk and/or stochastic death distributions, for instance, Marocco and Pitacco (1998); Milevsky and Promislow (2001); Dahl (2004); Bauer and Kramer (2007); Biffis (2005); Miltersen and Persson (2005); Cairns et al. (2006); Dahl and Møller (2006); Gr¨undl et al.(2006) and Ballotta and Haberman (2006). However, longevity jumps which do not follow a deterministic mortality improvement trend and mortality shocks are seldom modelled in a single model: most of the existing papers on pension plans and annuity business only consider longevity risk while those on life insurers focus on catastrophic death events (Biffis, 2005; Cox et al., 2006;Lin and Cox, 2008). Moreover, few studies take into account the correlation and distinct impacts of a mortality shock on different ages. Importantly, to obtain relevant results, a stochastic mortality model must reflect three major features of the current mortality universe: (a) both mortality improvement and deterioration jump factors, (b) correlation among different ages and over time,(c) uneven effects of a mortality jump across different ages. In this paper we build a mathematical framework to address these issues. Importantly, while one can always build a very rich stochastic model, we must care about parsimony and ease of use. As such, we will also provide a parsimonious version of our model and show how to estimate it with the historical data