Institution: Maxwell Institute for Mathematical Sciences

Unit of Assessment: UoA 10 – Mathematical Sciences

Title of case study: Adoption of CBD Mortality Models in the International Insurance and Pensions Industry

Period when the underpinning research was undertaken: 2006-2019

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Andrew Cairns	Professor	1992-date

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Pension funds, life insurers and regulators are concerned about the financial consequences of *longevity risk*: the financial risk that, in aggregate, people live longer than anticipated.

Novel stochastic models for the assessment of longevity risk (the Cairns-Blake-Dowd – CBD – family) in life insurance and pensions proposed by Cairns and co-authors in two landmark papers have been adopted by insurers in the UK, France and the US, actuarial consultancies in the UK and Germany, UK and European insurance regulators, specialist software providers, and in professional education.

The CBD models have played a central role in the transfer of GBP10's of billions of pension liabilities from pension funds to multinational insurers including the GBP16,000,000,000 transfer of [text removed for publication] pension liabilities in [text removed for publication].

Use of the models provides an improved assessment of the financial consequences of longevity risk. This has enhanced the security of both pension funds and insurers and, through good risk management and regulation, has reduced the risk of insolvency.

2. Underpinning research

Context: Adverse market conditions and other industry developments at the beginning of the 2000's caused pension funds and insurance companies to focus attention on risk assessment and risk management of both assets and liabilities. For pension funds and annuity providers, *longevity risk* – the risk that, in aggregate, people live longer than anticipated – was identified as a specific risk that needed to be addressed. This led Cairns and co-authors Blake (City University) and Dowd (Durham) to develop a new family of stochastic models for future mortality (now widely known as the *CBD family,* after the three authors).

Underpinning research: [3.1] introduced what is popularly known as the CBD model with application to English & Welsh mortality. This paper recognised that, although mortality improvements at different ages are correlated with each other, they are not perfectly correlated. This led to the proposal of a robust two-factor model (period or calendar-year effects) that would be particularly suitable for pension funds and life insurance annuity portfolios. Additionally, the structural simplicity of the model helped it to gain popularity.

Publication of this paper led to a collaborative project with the international bank [text removed for publication]. This collaboration resulted in several journal articles co-authored with members of the [text removed for publication] longevity team, of which the most important were [3.2] and [3.3]. In [3.2], the original CBD model was generalised to the second generation of CBD models, the most popular of which is known as "M7". M7 included a third period effect. This paper also confirmed earlier research that cohort effects linked to year of birth were also

significant factors in forecasting mortality. Papers [3.2] and [3.3] also highlighted the significance of model risk – the risk associated with excessive reliance on a single model – and the robustness of models. The collaboration also led to the development of the LifeMetrics open source software [3.4], the purpose of which was to help potential users gain confidence in the use of the CBD and other stochastic mortality models.

The original work has now been extended to modelling of multiple populations (e.g. stratified by socio-economic group) as exemplified by [3.5] and [3.6].

In each of [3.1, 3.2, 3.3], Cairns led the mathematical developments of the models and quantitative analysis.

Pathway to Impact

Research collaborator Blake organised the first of a successful series of conferences in 2005 on longevity risk and capital markets that continues to this day. This annual conference is a key meeting place for researchers and practitioners and acted as a key conduit for Cairns to promote the merits of the CBD family of models to practitioners. Following the 2006 conference and publication of [3.1], Cairns, Blake and Dowd began work with [text removed for publication] to develop the modelling and risk measurement theme as part of their objective to develop the longevity market. This collaboration led to several papers, the most notable of which was Cairns et al. (2009) [3.2].

[3.1,3.2] are now amongst the most cited papers in actuarial science.

3. References to the research

[3.1] Cairns, A.J.G., Blake, D., and Dowd, K. (2006). A two-factor model for stochastic mortality with parameter uncertainty: Theory and calibration. *Journal of Risk and Insurance*, 73: 687-718. DOI: 10.1111/j.1539-6975.2006.00195.x

[3.2] Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G.D., Epstein, D., Ong, A., and Balevich, I. (2009). A quantitative comparison of stochastic mortality models using data from England & Wales and the United States. *North American Actuarial Journal*, 13: 1-35. DOI: 10.1080/10920277.2009.10597538

[3.3] Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G.D., Epstein, D., and Khalaf-Allah, M. (2011) Mortality density forecasts: an analysis of six stochastic mortality models. *Insurance: Mathematics and Economics*, 48: 355-367. DOI: 10.1016/j.insmatheco.2010.12.005

[3.4] Cairns, A.J.G. (2007+updates) LifeMetrics open source software. Originally www.lifemetrics.com. Now available at www.macs.hw.ac.uk/~andrewc/CBD.html

[3.5] Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G.D., and Khalaf-Allah, M. (2011) Bayesian Stochastic Mortality Modelling for Two Populations. ASTIN Bulletin 41: 29-59. DOI: 10.2143/AST.41.1.2084385

[3.6] Cairns, A.J.G., Kallestrup-Lamb, M., Rosenskjold, C.P.T., Blake, D., and Dowd, K., (2019) Modelling Socio-Economic Differences in Mortality Using a New Affluence Index. *ASTIN Bulletin* 49: 555-590. DOI: 10.1017/asb.2019.14

4. Details of the impact

Introduction

CBD models [3.1, 3.2] have been used to assess the potential impact of longevity risk on the future solvency of insurance companies writing annuities and pension funds in the UK, Europe and the US. Use of the models helps these institutions to (a) assess more accurately their capital requirements (including regulatory) to ensure a secure future for policyholders, and (b) price more accurately longevity risk transfers between institutions. In turn, this provides policyholders and pensioners with greater confidence that their promised benefits will be covered for the next 30, 40, 50 years.

Members of the CBD family are often referred to by practitioners by their "M" numbers, e.g. M5, M7 (see e.g., [5.1, 5.2, 5.3, 5.4]).

Impacts

Software

Growing interest in the CBD family from insurance companies led the specialist actuarial software provider Longevitas to incorporate the CBD family into its *Projections Toolkit* [5.1]. This software is used by UK and US insurers (e.g. [text removed for publication] [5.2]) and its embedded suite of models facilitates insurance company compliance with the UK's Prudential Regulatory Authority (PRA) guidance on the use of stochastic mortality models.

Other stakeholders, including [text removed for publication] [5.5] and the European insurance regulator EIOPA [5.6, p 65], made use of an open-source R stochastic mortality modelling package, *StMoMo*, [5.4], first released in 2015 that builds on [3.4]. A significant proportion of *StMoMo* is devoted to the CBD family (see [5.4, pages 1, 3, 6-7, 20, 27-35, 39, 49-50]).

Regulation of European Insurers

Insurers in the EU have, since 2016, been subject to the Solvency II regulatory environment. This governs how much capital insurers are required to hold to cover their future uncertain liabilities. Required capital consists of the market consistent value (MCV) plus the Solvency Capital Requirement (SCR). The SCR is an additional amount over the MCV to cover the risk that, alongside other risks, mortality rates fall at a faster rate than anticipated. The SCR can be calculated using a simple stress test or through use of a stochastic *internal model*. Larger insurers often prefer to use the latter, as these allow for a more accurate, company-specific analysis of all major risks.

Two distinct but related regulatory impacts can be identified.

1. For insurers using *stochastic internal models*, the UK's Prudential Regulatory Authority (PRA) recommends use of the CBD family [5.7, p 8] alongside three other families of model (with the use of distinct families to address model risk) to assess capital requirements for longevity risk. Out of these families, [text removed for publication] recommends CBD-M9 as being one of only two models suitable for a wide age range [5.8, slide 68].
2. For insurers using the simpler longevity stress test, the CBD model was used by the EU insurance regulator, EIOPA, alongside one other model, to verify the suitability of the 20% longevity stress [5.6, pages 60-73] using the *StMoMo* software package [5.4]. Responses to the EIOPA consultation (including institutions in the Netherlands, France and Ireland and pan-European professional bodies) indicate that the CBD model is in widespread use around Europe.

The PRA approach to the assessment of model risk and the range of models employed reflects the influence of Cairns et al. (2009) (see e.g. [5.5]). As a result of the PRA guidance, CBD models and the model-risk framework of Cairns et al. (2009) are widely used by insurers in the UK and elsewhere [5.9, 5.10]. Quoting UK and EU insurers, [3.2] "*was cited in the governance of our* [text removed for publication] *Solvency II internal model and helped to mould our approach to the assessment of longevity risk.*" [5.9], and "*has impacted significantly on our work in three ways: their proposal of a number of new and innovative stochastic mortality models; their finding that model risk can be quite significant; and their approach to model selection using multiple criteria*" [5.10].

Derisking of Defined Benefit (DB) Pension Funds

Many DB pension funds are seeking to reduce their exposure to longevity and investment risks. Derisking is often achieved, in part, through longevity hedges such as longevity swaps and bulk buy-outs with insurers in the UK or overseas (such as [text removed for publication] [5.2]). Insurers receiving the risk from pension funds use CBD models (a) to assess a best estimate price, (b) to assess the degree of longevity risk embedded within each portfolio of pensions and then (c) to determine a risk premium to be charged for acceptance of the risk. UK insurers (e.g. [5.9]) taking on such risks are then subject to the Solvency II regulations discussed above.

Longevity Risk Transfers

There has been "*approximately $200 billion* [USD] *of longevity risk transfer since 2014*" ([5.2]). [text removed for publication] states [5.2] "*Over the period 2014-2017, we used the CBD models for pricing all of our global transactions, covering a total transfer of liabilities of approximately $40 billion [USD]. This included the* [text removed for publication] *longevity transaction* [text removed for publication]*, covering* [text removed for publication] *of pension liabilities in the* [text removed for publication] *pension scheme in* [text removed for publication]*. … The use of the CBD models was central in establishing confidence in the pricing of all of these transactions.*"

Actuarial Consultancies

CBD models and their descendants are used by actuarial consultancies in the UK and elsewhere in their advisory and development work [5.5, 5.3]. [text removed for publication] [5.5] states that [3.2] is the go-to, fundamental reference that has brought order and rigour to what had, at times, been a somewhat naïve longevity risk-transfer market. [5.5] also states that [3.5] and e.g. [3.6] are fundamental works in helping his firm and clients understand and model socio-economic mortality differentials.

Professional Education

Recognising the role of CBD models and model risk in longevity risk management, the German Actuarial Association (DAV) recommends [3.2] as part of the DAV's reading for its Chartered Enterprise Risk Actuary qualification (CERA) [5.11].

5. Sources to corroborate the impact

[5.1] Longevitas Projections Toolkit software *(*updates highlighting inclusion of CBD models in versions 2.7.1/3/7), https://www.longevitas.co.uk/site/news/version2.7.7oftheprojectionstoolkit.html

[5.2] Letter of support [text removed for publication].

[5.3] [text removed for publication]. Presentation at the Longevity 14 Conference, Amsterdam, 2018 by [text removed for publication].

[5.4] StMoMo: An R package for Stochastic Mortality Modelling reference manual, https://cran.r-project.org/web/packages/StMoMo/StMoMo.pdf

[5.5] Letter of Support [text removed for publication].

[5.6] EIOPA (2018) (the EU insurance regulator) EIOPA's second set of advice to the European Commission on specific items in the Solvency II Delegated Regulation. EIOPA-BoS-18/075, https://www.eiopa.europa.eu/sites/default/files/publications/submissions/eiopa-18-075-eiopa_second_set_of_advice_on_sii_dr_review.pdf

[5.7] Prudential Regulatory Authority guidance (PRA; part of the Bank of England and responsible for the regulation of UK insurance companies) "Reflections on the 2015 Solvency II internal model approval process", https://www.bankofengland.co.uk/prudential-regulation/letter/2016/sam-woods-reflections-on-2015-solvency-ii-model-approved-process

[5.8] [text removed for publication]. Presentation at the International Mortality and Longevity Symposium, London, September 2016 by [text removed for publication].

[5.9] Letter of support from [text removed for publication].

[5.10] Letter of support from [text removed for publication].

[5.11] European Actuarial Academy, CERA Education seminar in Underwriting Risks in Life and Health Insurance. Block 11, DAV CERA Module B: Taxonomy, Modelling and Mitigation of Risks, 2019. (p. 39), Professional teaching materials not available online, pdf provided.