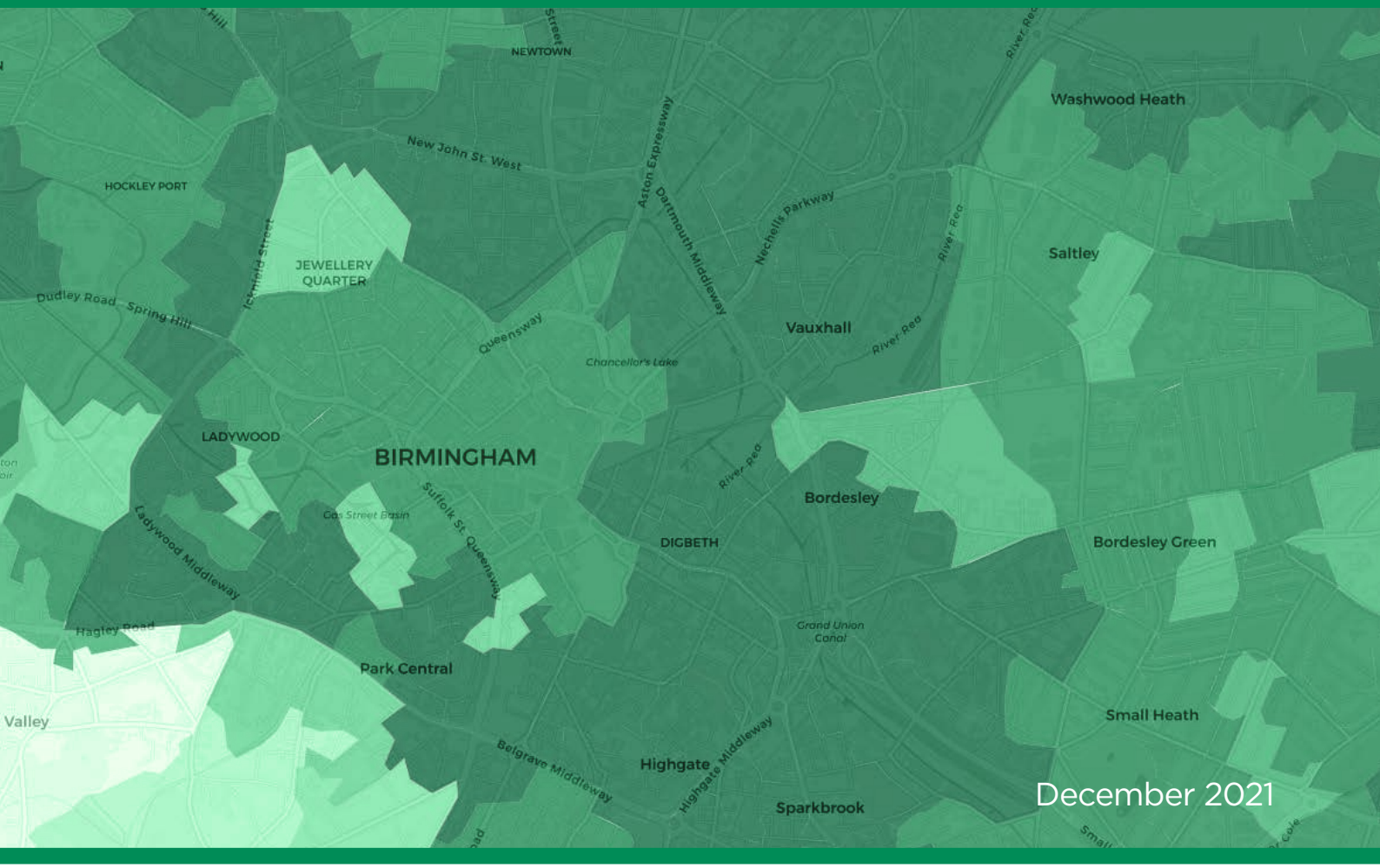
Actuarial Research Centre®
Institute and Faculty of Actuaries

Modelling, measurement and management of longevity and morbidity risk 2016–2021

Programme summary



December 2021

Canadian Institute of Actuaries / Institut canadien des actuaires

Heriot-Watt University

Society of Actuaries

Longevity and morbidity risk research impact summary

This paper summarises the work and impact of the five-year research project entitled ***Modelling, measurement and management of longevity and morbidity risk*** funded by the Actuarial Research Centre (ARC) of the Institute and Faculty of Actuaries (IFoA) and co-sponsored by the Society of Actuaries (SoA) and the Canadian Institute of Actuaries (CIA). The full Research Impact Report is **available on request** and more information is available on the **IFoA programme pages.**

Alongside the substantial research findings, this programme has provided the IFoA with a wide range of outreach opportunities including 120 presentations, 1,621 CPD claims, and partnership-working with other international bodies.

The original research proposal covered a wide range of objectives:

- Development of new models for assessing longevity, mortality and morbidity risk, widening the range of potential applications
- Development of new tools
- Development of new calibration methods
- Development of innovative methods and tools to help with the measurement and management of longevity risk and to guide practitioners in the use of these methods and tools
- Development of new insights into the underlying drivers of mortality
- Provide practitioners and regulators with opportunities to learn about existing and new methods, and to get the most out of these
- Development of new approaches to modelling that can be applied in non-actuarial settings, such as cause-of-death analysis for the National Health Service
- Provide specific insights into causes of death in the US including inequalities by education group (eg how inequality varies by cause of death)
- Provide specific insights into differential trends by socio-economic group in Canadian mortality.

32
articles
with co-authors
across the world

Untied Kingdom	City University of London Durham University University of Southampton Longevitas
Denmark	Aarhus University
The Netherlands	University of Amsterdam
Germany	University of Kaiserslautern
United States of America	Human Mortality Database University of California at Berkeley Societe Generale North America

Highlights of the research programme include

- Sourcing of new datasets subdivided by socio-economic group. This work was key to addressing the main objectives of modelling and measuring socio-economic differences in mortality. With the help of external collaborators, the Research Team developed or obtained datasets for England, Denmark, the US and Canada, helping researchers to gain considerable country-specific insights, as well as facilitating comparison of inequalities and dynamics in different countries. For example, the Danish data led to the conclusion that affluence was a better predictor of high or low mortality than education level.
- A significant bonus arising from these datasets was the development of the new Longevity Index for England (LIFE). This improves substantially on the alternative Index of Multiple Deprivation. The team developed a **simple open access application** which is being used to reach out to external stakeholders, as well as to provide a basic tool for actuaries. Over 50 actuaries volunteered to test the app, of which 30% provided feedback to the team. Actuaries and others can contact the team to access the full LIFE index.
- Using these varied datasets, the Research Team was able to develop a new generation of multiple population mortality models, with a detailed comparison of alternative models covering the advantages and disadvantages of each. The team finally settled on a new version of the common age effect model (CAE) that has the flexibility to cover a wide range of potential populations. This analysis will become important to actuaries, with the increasing desire to measure longevity risk at the portfolio or pension-fund level accounting for differences between the specific population and the national population.
- Considerable effort has also gone into developing datasets for the US and England by cause of death at the socio-economic level. This has led to new insights into the drivers of mortality improvements (or reversals) over the last 20-30 years. A specific element of this work is the link between specific causes of death and so-called controllable risk factors, such as smoking. Analysis leads to crucial but indirect inferences about differences, eg in smoking prevalence, over time and by socio-economic group.
- Market developments meant that the team spent less time than planned on longevity risk management. Nevertheless, the team published a key work on how to handle index-based longevity transactions in a Solvency-II-type setting.
- Finally, the team has developed new models for analysing cancer morbidity and mortality with links to critical illness insurance (CII). CII claim rates have been rising but it has been found that they still fall below national cancer morbidity rates.

The researchers published 19 papers in leading international journals (exceeding its aim of 12 papers), as well as one longer report and three magazine articles. Andrew Cairns and co-author Ghali El Boukfaoui were awarded a Best Paper prize by the International Congress of Actuaries for *Basis Risk in Index Based Longevity Hedges: A Guide for Longevity Hedgers.* Several more papers are in preparation.

Considerable time and care were put into the knowledge-exchange programme. There have been over 120 presentations of various types including webinars, IFoA conferences and international conferences. The Research Team's webinars and recordings of sessional meetings have had over 4,500 views on YouTube.

>50

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Attendee feedback from 2021 Webinar Series

"Very clear and engaging presentation."

"A good introduction to the research that is being/will be carried out and how it could be used in different actuarial fields."

"Best webinar I have attended in a long time. Super interesting content, really good quality slides – couldn't have been better!"

"Presenter was good and interesting."

> Best webinar I have attended in a long time

	Agree or strongly agree
The research presented is relevant and useful to me	86%
It was clear to me what the goals of the research are	89%
It was clear to me that the quality of the research being carried out is of a high standard	100%
I am keen to learn more about this research programme	77%
This webinar advanced my knowledge of the subject matter	94%

Feedback from the programme Steering Group

"One thing I particularly liked about the programme was the involvement of the SOA and the CIA. Pooling funds, avoiding duplication (of management oversight and research) and adding an international perspective were all valuable and should be repeated."

"The research programme shouldn't necessarily be awarded as a large block in future. Smaller individual grants would allow for greater diversity."

"I liked the support – including the webcasts – and reporting structure around the project. The output had many items relevant to an international (and US) audience, so I definitely think there was value for money. There was good dissemination effort in the US, unfortunately curtailed somewhat by Covid, which also stole some of our project's 'thunder'. Professor Cairns has been very responsive to our needs for dissemination."

"I thought the research team produced many quality papers and have appreciated the research team being available to help disseminate the research. That has helped practitioners understand the applicability of the research."

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ARC webinars, CPD, registrations, views and global reach

Webinar title and link	Date, Presenter	CPD	Registrations	YouTube views	Global Reach*
Forecasting Socio-Economic Differences in the Mortality of Danish Males	December 2016, Cairns, A.J.G.	N/A	N/A	153	N/A
Modelling, measurement and management of longevity and morbidity risk	May 2017, Cairns, A.J.G., Haberman, S.	442	422	893	28 (75%)
A stochastic implementation of the APCI model for mortality projections	Sessional, October, 2017 Richards, S.J., Currie, I.D., Kleinow, T., Ritchie, G.P.	58	63	328	6 (92%)
ARC Sessional Research Event: Still Living with Mortality: The Longevity Risk Transfer Market after One Decade	Sessional, January, 2018, Blake, D., Cairns, A.J.G., Dowd, K., Kessler, A.	319	157	210	2 (98%)
ARC Webinar Series 2018: Modelling, Measurement and Management of Longevity and Morbidity Risk	October, 2018, Kleinow, T., Streftaris, G., Wood, G.	227	422	348	26 (80%)
ARC Webinar: Mortality and Longevity Symposium, Longevity and Morbidity Risk Programme	October, 2018, Cairns, A.J.G.	370	N/A	350	N/A
Session 1: What Types of Data Are Available for Mortality Data	ARC Technical Workshop, December, 2019, Cairns, A.J.G., Kleinow, T., Wen, J.	N/A	N/A	259	N/A
Session 2: Mortality and Deprivation				278	
Session 3: Factor-Based GLM Model with Socio-Economic Inputs				300	
Session 4: Using Local Linear Regression to Model Socio-Economic and Geographical Effects				316	
Session 5: Mortality Data By Socio-Economic Group, Region and Cause of Death: What Do the Patterns Tell Us?				429	
US Mortality: Underlying Trends By Socioeconomic Group and Cause of Death	September 2020, Cairns, A.J.G., Redondo Loures, C.	N/A	N/A	N/A	N/A
ARC Webinar Series 2021: Introducing the new Longevity Index for England (LIFE) app	June, 2021, Cairns, A.J.G., Kleinow, T., Funnell, J.	175	284	346	25 (82%)

*Number of countries with % of attendees from UK in brackets.

Webinar title and link	Date, Presenter	CPD	Registrations	YouTube views	Global Reach*
Modelling Neighbourhood Mortality Using the Random Forest	August, 2021, Wie, J.	2	N/A	234	N/A
ARC Webinar Series 2021: Modelling cancer risk: regional and socioeconomic disparities	September, 2021, Arık A., Streftaris G.	12	208	72	25 (74%)
ARC Webinar Series 2021: Mortality inequality: what insights can we gain from cause of death data?	October, 2021, Cairns, A.J.G.	16	272	65	19 (80%)
TOTALS		**1621**	**1828**	**4581**	

*Number of countries with % of attendees from UK in brackets.

List of published papers, submitted paper, and working papers available online

Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G., Jones, O. and Rowney, J. (2022) **University professors are built to last: Analysis of mortality in the Universities Superannuation Scheme.** (Submitted paper.)

Arık, A., Dodd, E., Cairns, A., and Streftaris, G. (2021) **Socioeconomic disparities in cancer incidence and mortality in England and the impact of age-at-diagnosis on cancer mortality.** PLoS ONE, 16(7): e0253854.

Redondo Loures, C., and Cairns, A.J.G. (2021) **Cause of death specific cohort effects in U.S. mortality.** Insurance: Mathematics and Economics, 99: 190-199.

Schnurch, S., Kleinow, T., and Korn, R., (2021) **Clustering-Based Extensions of the Common Age Effect Multi-Population Mortality Model.** Risks 9: 45.

Blake, D., and Cairns, A.J.G. (2021) **Longevity risk and capital markets: The 2019-20 update.** Insurance: Mathematics and Economics, 99: 395-431.

Glei, D., Barajas Paz, A., Aburto, J.M., and Barbieri, M., (2021) **Mexican mortality 1990-2016: Comparison of adjusted and unadjusted estimates.** Demographic Research, 44: 719-758.

Wen, J., Cairns, A.J.G., and Kleinow, T., (2021) **Fitting Multi-Population Mortality Models to Socio-Economic Groups.** Annals of Actuarial Science, 15: 144-172.

Hacariz, O., Kleinow, T., and Macdonald, A.S. (2021) **Genetics, insurance and hypertrophic cardiomyopathy.** Scandinavian Actuarial Journal, 2021, 54-81.

Arik, A., Dodd, E., Streftaris, G. (2020) **Cancer morbidity trends and regional differences in England - A Bayesian analysis.** PLoS One 15(5): e0232844.

Andrew J.G.Cairns, Torsten Kleinow and Jie Wen (2020) **Drivers of Mortality - Risk Factors and Inequality** (Working paper)

Dowd, K., Cairns, A.J.G., and Blake, D. (2020) CBDX: **A Workhorse Mortality Model from the Cairns-Blake-Dowd Family.** Annals of Actuarial Science 14: 445-460.

Redondo Loures, C., and Cairns, A.J.G. (2019) **Mortality In The US By Education Level.** Annals of Actuarial Science, 14: 384-419.

Wen, J., Kleinow, T., and Cairns, A.J.G. (2020) **Trends in Canadian Mortality By Pension Level: Evidence From the CPP and QPP.** North American Actuarial Journal. 24: 533-561.

Cairns, A.J.G., and El Boukfaoui, G. (2021) **Basis Risk in Index Based Longevity Hedges: A Guide For Longevity Hedgers.** North American Actuarial Journal, 25:sup1, S97-S118.

Wen, J., Kleinow, T., and Cairns, A.J.G. (2019) **Trends in Canadian Mortality By Pension Level: Evidence From the CPP and QPP.** Full report (2019) published by the Canadian Institute of Actuaries and the Institute and Faculty of Actuaries.

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

Kleinow, T., and Vellekoop, M.H. (2018) **Minimum reversion in multivariate time series.** (Working paper)

Blake, D., Cairns, A.J.G., Dowd, K., and Kessler, A.R. (2019) **Still living with mortality: the longevity risk transfer market after one decade.** Presented at a Sessional Research Meeting of the Institute and Faculty of Actuaries, Edinburgh, 29 January, 2018. British Actuarial Journal, 24: e1; 1-80.

Richards, Stephen J., Currie, Iain. D., Kleinow, Torsten, Ritchie, Gavin P. (2017) **A stochastic implementation of the APCI model for mortality projections.** Presented at a Sessional Research Meeting of the Institute and Faculty of Actuaries, London, 16 October, 2017. British Actuarial Journal 24: e13; 1-26.

Chen, L., Cairns, A.J.G., and Kleinow, T. (2017) **Small Population Bias and Sampling Effects in Stochastic Mortality Modelling.** European Actuarial Journal 7: 193-230.

Mavros, G., Cairns, A.J.G., Streftaris, G., and Kleinow, T. (2017) **Stochastic Mortality Modelling: Key Drivers and Dependent Residuals.** North American Actuarial Journal 21: 343-368.

Further information

For further information or to request the Research Impact Report please email **research@actuaries.org.uk** or contact Professor Andrew Cairns in the Heriot Watt University Research Team **A.J.G.Cairns@hw.ac.uk**.

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Canadian Institute of Actuaries
Institut canadien des actuaires

HERIOT WATT UNIVERSITY

SOCIETY OF ACTUARIES®

Beijing
14F China World Office 1 · 1 Jianwai Avenue · Beijing · China 100004
Tel: +86 (10) 6535 0248

Edinburgh
Level 2 · Exchange Crescent · 7 Conference Square · Edinburgh · EH3 8RA
Tel: +44 (0) 131 240 1300

Hong Kong
1803 Tower One · Lippo Centre · 89 Queensway · Hong Kong
Tel: +852 2147 9418

London (registered office)
7th Floor · Holborn Gate · 326-330 High Holborn · London · WC1V 7PP
Tel: +44 (0) 20 7632 2100

Oxford
1st Floor · Park Central · 40/41 Park End Street · Oxford · OX1 1JD
Tel: +44 (0) 1865 268 200

Singapore
5 Shenton Way · UIC Building · #10-01 · Singapore 068808
Tel: +65 8778 1784

www.actuaries.org.uk/arc