Institution: University of Southampton		
Unit of Assessment: 10 Mathematical Sciences		
Title of case study: 10-03 How Long Do We Live? English Life Tables 17		
Period when the underpinning research was undertaken: 2009 – 2020		
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:**
Jonathan Forster Erengul Dodd Peter W.F. Smith	Professor Associate Professor Professor	September 1994 – June 2019 August 2013 – present September 1990 – present
Period when the claimed impact occurred: September 2015 – December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Research into estimating mortality at the University of Southampton has been used by the Office for National Statistics in developing the latest decennial life tables, the English Life Tables 17. The decennial life tables provide a snapshot mortality experience of a nation, and therefore they are good indicators of the health of the nation, life expectancy trends and age-specific mortality patterns. They also support the assessment of risk for life insurance companies and pension providers. By designing and implementing the new methodology for life table estimation, our work has become part of the UK official statistics and consequently has had an impact on areas such as healthcare, social security, and the life and health insurance sector. In our research, through developing innovative methods for estimating and forecasting mortality for all ages, including the infants and the oldest age groups, we facilitate better and more prudent policy and business decisions.

2. Underpinning research

Since its inception in 2009, the ESRC Centre for Population Change (CPC) [**G1**] has become a world-leading demographic research centre, establishing itself at the forefront of methodological innovation in statistical demography. One key pillar of the CPC research activity over that period has been to develop robust methods for estimating current and forecasting future populations, with focus on the United Kingdom [**3.1**, **3.2**]. Human mortality – how long people in the UK can be expected to live, what the perspectives for the future look like, and how uncertain the estimates and predictions are – is one of the individual demographic processes the CPC has been working on [**3.3**, **3.4**, **3.5**, **3.6**].

The methodological research into mortality estimates and forecasts has been carried out since 2015 within the CPC Modelling strand, jointly led by Professor Peter W F Smith and Professor Jakub Bijak. The work was part of ongoing research for the Office for National Statistics (ONS) on developing the life table estimation methodology, first commissioned in 2014, and subsequently followed up by further research on methodology for setting future mortality assumptions [**G2**]. Within the Modelling strand, the model development work was led by Professor Jonathan J Forster and Dr Erengul Dodd, who were subsequently joined by Dr Jason Hilton in 2016.

Besides contributing to overall population projections, mortality is also of direct interest to public and private stakeholders working on social security, healthcare provision, and in the life or health insurance industry. The uncertainty assessment is crucial for enabling prudent, yet efficient decisions in all these areas.

The research conducted by the CPC demonstrates the importance of proper assessment of uncertainty of future population projections, which include mortality as their key component [**3.1, 3.2**]. In particular, we have found that in order to provide the stakeholders with the best mortality estimates and forecasts, the variability of mortality needs to be properly calibrated for all different age groups, unlike in many state-of-the-art methods [**3.3**]. To fill this gap, as part of the work for

the ONS, we have developed flexible methods for estimating [**3.4**] and subsequently predicting future mortality [**3.5, 3.6**].

The key methodological innovation of our approach is to allow mortality at different stages of human life to be described by different, but closely interconnected models. This approach, involving a semi-parametric smoothing model over age ranges with sufficiently dense mortality data, combined with a parametrised curve for the oldest ages, where the mortality data are sparse or non-existent, was applied first to the English Life Tables No. 17 (ELT17) for 2010-12 **[3.4]**. The English Life Tables, the decennial life tables for England and Wales, are official publications which have been produced after every decennial census since 1841 (with the exception of 1941 when no census was carried out). The English life tables are designed to provide period life expectancy by age and single year of age in the three-year period around the census year.

In particular, we smoothed (or "graduated") crude mortality rates by using a combination of a generalized additive model and low dimensional parametric models. The approach to graduation acknowledges uncertainty, particularly in the highest age groups, by model averaging, using a simplified version of a full Bayesian analysis.

This innovative approach has enabled us to efficiently deal with the challenges posed by the sparse data in the oldest age groups. Our approach, and its subsequent extensions to models for mortality forecasting, offer an elegant, integrated solution to many practical challenges posed by an ageing population and uncertain increases in longevity.

3. References to the research

3.1 Wiśniowski A, **Smith PWF**, Bijak J, Raymer J and **Forster JJ** (2015). Bayesian population forecasting: extending the Lee-Carter Method. *Demography*, 52(3), 1035-1059. https://doi.org/10.1007/s13524-015-0389-y

3.2 Shang HL, **Smith PWF**, Bijak J and Wiśniowski A (2015). A multilevel functional data method for forecasting population, with an application to the United Kingdom. *International Journal of Forecasting*, 32(3), 629-649. https://doi.org/10.1016/j.ijforecast.2015.10.002

3.3 Wong JST, **Forster JJ** and **Smith PWF** (2018) Bayesian mortality forecasting with overdispersion. *Insurance: Mathematics and Economics*, 83, 206-221. https://doi.org/10.1016/j.insmatheco.2017.09.023

3.4 Dodd E, **Forster JJ**, Bijak J and **Smith PWF** (2018). Smoothing mortality data: the English life table, 2010-12. *Journal of the Royal Statistical Society. Series A: Statistics in Society*, 181(3), 717-735. https://doi.org/10.1111/rssa.12309

3.5 Hilton J, **Dodd E**, **Forster JJ** and **Smith PWF** (2019) Projecting UK mortality by using Bayesian generalized additive models. *Journal of the Royal Statistical Society. Series C: Applied Statistics,* 68(1), 29-49. https://doi.org/10.1111/rssc.12299

3.6 Dodd E, **Forster JJ**, Bijak J and **Smith PWF** (2020) Stochastic modelling and projection of mortality improvements using a hybrid parametric/semiparametric age-period-cohort model. *Scandinavian Actuarial Journal*. https://doi.org/10.1080/03461238.2020.1815238

Grants and contracts:

G1 ESRC Centre for Population Change, consortium led by the University of Southampton (PI: Jane Falkingham); Phase I 2009–2013 (£5,388,177), and Phase II 2014–2019 (£5,388,048)

G2 University of Southampton – Office for National Statistics research contract: Provision of Research Services in Statistical Methodology, 2010-2015 (£1,060,865), 2016-2020 (£585,881)

4. Details of the impact

There are both direct and indirect national-level impacts of our work on designing and implementing the new methodology for life table estimation.

The **direct impact** of the work has been achieved through the ONS taking up the methodology proposed by the CPC team and applying it to the official ELT17 release published on 1

September 2015. In this way, our work became an important part of the UK official statistics, providing continuity to the series that has been ongoing since 1841, and thus being “of historical significance” [**5.1**], while providing a much-needed update to its methodological novelty and rigour, especially for old-age mortality.

In methodological terms, the ONS stated that the approaches underpinning ELT17 "provide a better progression of mortality rates at [older] ages and, indeed, are the only officially published mortality rates by single year of age above age 99." Thus, the decennial ELT17 estimates offer a ‘gold standard’ benchmark for national life tables produced annually to verify them and to ensure they remain fit for purpose – it is widely acknowledged that the annual tables “do not provide a good indicator of the levels of and trends in mortality rates at the very oldest ages”[**5.1**].

The Principal Methodologist at the ONS stated “The decennial life tables provide insights into life expectancy trends and age-specific mortality patterns in the population over a long period of time. This makes them a valuable indicator of the health of the nation.” She added that life table work received widespread media coverage and “The single ELT17 was downloaded over 1100 times in the first few months after release”, with nearly 3000 visits to the webpage over that period [**5.10**].

Besides the English Life Tables, the on-going collaboration between the ONS and the CPC has ensured continuing impact on different aspects of mortality statistics. Most importantly, based on the ELT17 work, the ONS has further commissioned a review of mortality assumptions of the National Population Projections (NPP), carried out by the CPC team in 2016-18. The NPP inform policy, resource allocation and planning (e.g. pensions, health, education) at the national level. The team has also provided the ONS with ad hoc methodological advice on different aspects of mortality modelling.

In 2020, the impact of the CPC’s work, including the development of ELT17, was recognised with an ESRC Celebrating Impact Prize for Outstanding Public Policy Impact. On the award of the prize, the UK’s National Statistician said that he had “no doubt that the work of the CPC has had an impact on policymaking in the UK; it has improved the measurement of fertility, mortality and migration, enhanced statistical methods and accuracy, and it continues to provide vital socioeconomic evidence that will help our society to progress” [**5.9**].

In terms of **indirect impact**, there is a very wide reach of end-users of mortality estimates and projections, both across the public and private sectors.

Within the **public sector**, outside of the ONS and other statistical agencies within the UK, there are several key users of life tables and thus – more broadly – the resulting estimates and forecasts of mortality and life expectancy. These include the Government Actuary’s Department, Department of Work and Pensions (DWP) and HM Treasury, chiefly with respect to ensuring the stability and resilience of social security and pension systems, as well as the Department of Health and Health Authorities, mainly for estimating the demand for health and social care.

In particular, the Government Actuary’s Department uses estimates of life expectancy to provide direct impact into the national pension calculations [**5.2**] and thus to the ensuing policy decisions made by the DWP [**5.3, 5.11**]. The importance of the ELTs in that area is discussed by the head of the DWP Pensions Model Development and Forecasting Hub, who stated that work done by University of Southampton researchers is “helping us to more accurately estimate the impact of policy changes, and hence improve decision-making” **[5.11].**

In turn the health applications of period life tables, range from local ones (e.g. being used by the Public Health England in their reports on life expectancy at the oldest ages [**5.5**]), to ELT17 estimates becoming a part of a global picture through being directly adopted by the World Health Organisation [**5.6 p32**].

In the **private sector**, the life tables are widely used in insurance companies, financial services, and are also of interest to the media and the general public [**5.1**]. In particular, the applications in the actuarial industry are of crucial importance, as they lead to more realistic and fair pricing of life and health insurance products, such as life insurance policies or annuities. For the age range where the portfolio data of the insurance company lacks reliability, relevant population data may be used to inform the graduation and close-off portfolio mortality tables at the oldest ages [**5.4**].

For example, the Continuous Mortality Investigation (CMI) of the Institute and Faculty of Actuaries which carries out research on mortality and morbidity to provide tools that are widely used by actuaries, uses ELTs in their high age mortality research as these tables provide official figures for mortality by single year of age for the oldest ages. The old age methodology we developed in ELT17 is described in [**5.7**] and further used in [**5.4**] for comparison of their proposed methodology.

Life tables also have an important role to play in reducing systemic risks within the financial system. ELT17 has been used by financial organisations as a standard by which to assess their exposure to the risks associated with changes in mortality [**5.8 p58**]. Such calculations are requirements of the macro-prudential regulations set out by the Solvency II framework, as set out in point 3 of Art. 105 on the Calculation of the Basic Solvency Capital Requirement, as part of the life underwriting risk module.

5. Sources to corroborate the impact

Publications and reports:

5.1 Office for National Statistics (2015) Statistical bulletin: English Life Tables No.17: 2010 to 2012. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/bulletins/englishlifetablesno17/2015-09-01

5.2 GAD (2017) Periodic review of rules about State Pension age. Report by the Government Actuary. Government Actuary's Department, London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/603136/periodic-review-of-rules-about-state-pension-age-gad-report.pdf

5.3 DWP (2017) Press Release: New timetable for State Pension changes to maintain fair and sustainable pension. Department for Work and Pensions, London. https://www.gov.uk/government/news/new-timetable-for-state-pension-changes-to-maintain-fair-and-sustainable-pension

5.4 Continuous Mortality Investigation (2017) High Age Mortality Working Party, Working paper 100: A second report on high age mortality. Institute and Faculty of Actuaries, London. https://www.actuaries.org.uk/documents/cmi-working-paper-100-second-report-high-age-mortality

5.5 Public Health England (2016) Recent Trends in Life Expectancy at Older Ages: Update to 2014. Public Health England, London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/499252/Recent_trends_in_life_expectancy_at_older_ages_2014_update.pdf

5.6 WHO (2016 p32) WHO methods and data sources for life tables 1990-2016. World Health Organization, Geneva. http://www.who.int/healthinfo/statistics/LT_method.pdf

5.7 Continuous Mortality Investigation (2015) High Age Mortality Working Party, Working paper 85: Initial report on the features of high age mortality. Institute and Faculty of Actuaries, London. https://www.actuaries.org.uk/system/files/field/document/cmiwp85-v2.pdf

5.8 Healthy Investment (2019) Annual Report and Accounts 2018. https://www.healthyinvestment.co.uk/storage/2019/04/Annual-Report-and-Accounts-2018.pdf

5.9 Economic and Social Research Council (2020), Celebrating Impact Price 2020. ESRC, Swindon. https://esrc.ukri.org/files/research/celebrating-impact-prize/esrc-celebrating-impact-prize-2020/

User / beneficiary statements:

5.10 Letter from Principal Methodologist, Demographic Methods Centre, Office for National Statistics 03 December 2019.

5.11 Letter from Head of Pensions Model Development and Forecasting Hub, Pensions and Later Life Analysis, Department for Work and Pensions 31 October 2020.