Stagnation or Measurement Artefact? Re-evaluating the Recent Mortality Slowdown in Selected Low Mortality Countries

Tamara Vaz

Magdalena Muszynska-Spielauer

Marc Luy

Introduction

During the 2010–2019 decade, many high-income countries experienced a slowdown, stagnation, or reversal in life expectancy gains. This shift, beginning around 2011, marked a departure from the steady improvements of previous decades (Murphy & Grundy, 2022). The slowdown was most evident in the United States, United Kingdom, and Canada but also affected France, Germany, Sweden, the Netherlands, and Australia (Dowd et al., 2024; Raleigh, 2019). Japan was an exception, continuing to improve its longevity, suggesting that the trend was shaped by country-specific factors rather than biological limits (Raleigh, 2019). Some studies indicate that women in Britain experienced a greater effect than men, a pattern observed across other high-income countries as well (Dowd et al., 2024; Raleigh, 2019).

Several factors contributed to this slowdown. The primary driver was a reduced pace of decline in cardiovascular disease (CVD) mortality, which had previously driven most gains in life expectancy (Murphy & Grundy, 2022; OECD & The King's Fund, 2020). Slower improvements in cancer and respiratory disease mortality, along with mortality spikes from influenza epidemics (especially in 2015), also played a role (Goldstein & Lee, 2024; Raleigh, 2019). In countries such as the United States, rising deaths from drug overdoses, alcohol-related causes, and suicide among working-age adults added further downward pressure (Case & Deaton, 2015; Dowd et al., 2024).

The slowdown is also linked to broader changes in population health and social conditions. In several countries, progress against smoking-related diseases was offset by increasing rates of obesity and diabetes (Raleigh, 2019; OECD/The King's Fund, 2020). Mortality inequalities widened, with higher death rates in more deprived areas, especially in the United Kingdom (Raleigh, 2019). Although some researchers have suggested that post-2008 austerity policies may have contributed, evidence across Europe remains mixed (Raleigh, 2019; Murphy & Grundy, 2022). Demographically, most countries saw slower mortality improvement at older ages, while nations like the United States and the United Kingdom also faced higher midlife mortality. These combined trends indicate that both chronic disease patterns and social inequalities shaped the recent slowdown (Dowd et al., 2024; Murphy & Grundy, 2022).

Beyond these demographic and health factors, measurement issues may also contribute to the appearance of a slowdown. Most studies focus on life expectancy at birth (e_0) or standardized death rates (SDRs), disaggregated by sex, age, or cause of death. Summary measures like life expectancy at birth, what Schoen (1970) termed "aggregative indices," become less sensitive to mortality improvements as survival curves flatten and deaths concentrate at older ages. When mortality declines occur mainly among the elderly, gains registered by these measures are smaller (Kitagawa & Hauser, 1973; Schoen, 1970), creating an impression of stagnation even as mortality at advanced ages continues to improve.

Another source of measurement variation is the choice of indicators and time frames. Many studies do not clearly separate short-term fluctuations from long-term trends, leading to different conclusions based on baseline years (Murphy & Grundy, 2022). Analyses often use fixed time windows or identify breakpoints in a single aggregated series, producing inconsistent estimates of the slowdown's timing and scale.

To address these limitations, this paper proposes the Segmented Interpretable Lee-Carter (SI–LC) model, which models the full age–period mortality surface, identifies structural breaks, and produces a longevity index that weights proportional changes in mortality equally across ages. Preliminary results show that the SI–LC index captures trends that appear smaller or stagnant when measured by life expectancy alone. The analysis initially focuses on four high-income countries, with future results planned to include European countries that have continuous mortality data available in the Human Mortality Database since the 1950s.

Future results will also expand comparisons to include Standardized Mortality Rates (SMRs) and analyses using fixed time windows not aligned with the model's detected breakpoints. This will highlight how conventional approaches may obscure underlying mortality dynamics.

This work re-examines the apparent slowdown in mortality improvements and provides a methodological framework that more accurately reflects recent mortality changes patterns in high-longevity countries.

Measuring Mortality: Synthetic Indicators and Their Limitations

Summarizing a population's mortality experience into a single number is a foundational task in demography. Synthetic mortality indicators condense complex age-specific mortality schedules into a single index, facilitating comparisons across populations and time, while simplifying communication about mortality trends.

Mortality indices generally fall into two categories: aggregative indexes and average relative indexes (Kitagawa & Hauser, 1973; Schoen, 1970). Aggregative indexes, such as directly standardized rates and life expectancy at birth (e_0), reflect absolute differences in age-specific mortality. Life expectancy at birth, defined as the average years a newborn would live if subjected to current age-specific mortality rates, is widely used to track mortality improvement. Its rate of change weights reductions in mortality by remaining life expectancy at each age (Vaupel & Canudas-Romo, 2002).

However, period life expectancy has important limitations. The phenomenon of survivorship rectangularization means that as deaths concentrate at older ages, e_0 becomes less responsive to further mortality declines (Canudas-Romo & Schoen, 2005; Kitagawa & Hauser, 1973; Vaupel & Canudas-Romo, 2002). Consequently, apparent stalls in life expectancy may reflect a measurement artifact rather than a true halt in mortality improvement (Keyfitz, 2013). Simulations based on French mortality data (1975–79) showed that a uniform 35% decline in mortality for both sexes would still reduce the life expectancy gap by only 0.9 years, because female deaths were concentrated at older ages (Glei & Horiuchi, 2007).

To address the insensitivity of e_0 to changes at older ages, Schoen (1970) proposed the Geometric Mean of Age-Specific Death Rates (GAMR). This "average of relatives" index reflects proportional, rather than absolute, differences in mortality, giving equal weight to changes at all ages. A 1% reduction in mortality at age 85 has the same impact on GAMR as a 1% reduction at age 5, making it a robust tool for assessing relative mortality improvements across the entire age spectrum.

Building on this rationale, we propose a related measurement strategy derived from a modified Lee–Carter model. This approach allows the construction of an index analogous to GAMR while simultaneously identifying periods marked by shifts in mortality dynamics, overcoming limitations of both traditional aggregative measures and fixed-time analyses.

The Segmented Interpretable Lee-Carter (SI-LC) Model

The classic Lee-Carter (LC) model expresses age-specific mortality $m_{\{x,t\}}$ as

$$\ln(m_{x,t}) = \alpha_x + \beta_x k_t + \varepsilon_{x,t},$$

where $\alpha_{(x)}$ captures age effects, k_t is a time-varying mortality index, and β_x measures the age-specific response. In standard LC, β_x is constant over time, which can bias k_t when the age pattern of mortality change shifts.

The original LC parameters are relatively scaled due to identifiability constraints ($\sum_x \beta_x = 1 \; and \sum_t k_t = 0$), which prevents direct comparison of k_t between segments or populations (Basellini et al., 2023). To address this, we apply the reparameterization of de Jong et al. (2020), transforming k_t into a relative index $\mathrm{n_t}$ based on needed exposures $n_{x,t} = 1/m_{x,t}$:

$$n\_t = e\^\{-(k\_t - \mu)/\sigma)\}, \quad min \_\{\mu,\sigma\} \sum\_\{x,t\} w\_x \, (ln \, (n\_\{x,t\}) - ln \, (n\_t))\^2,$$

where weights w_x are set equal across ages so that proportional changes in mortality contribute uniformly. This yields a synthetic index $\mathrm{n_t}$ reflecting the overall mortality trend independently of age-structure changes.

To account for shifts in the age-specific pattern of mortality, we segment the time series into contiguous intervals T_j, fitting an independent LC model in each segment. The optimal number and location of breakpoints are determined by dynamic programming, minimizing the penalized cost

$$F(i) = \min_{j \in L_{min},\ldots,i-L_{min}} \backslash Big\left[F(j) + C\left(T_{[j+1,i]}\right) + \Delta\left(\mathrm{mBIC}, \left|T_{[j+1,i]}\right|\right)\backslash Big\right],$$

where $C\left(T_j\right)$ is the BIC of segment T_j and $\Delta\left(\mathrm{mBIC}, \left|T_j\right|\right)$ penalizes short or excessive segments. This procedure ensures globally optimal breakpoints and defines periods with stable age-specific mortality patterns. The combination of equal-weight and segments produces an index that accurately captures the overall longevity trend while highlighting structural shifts in mortality regimes.

Data

The analysis uses age- and sex-specific mortality and exposure data from the Human Mortality Database (HMD). We focused on four high-income countries. The United States, Canada, and the United Kingdom were selected due to their recent mortality stall. Japan was included as a benchmark because of its consistently strong longevity improvements.

Preliminary Findings

An analysis of life expectancy at birth (e_0) across the four countries confirms the widely observed trend of mortality deceleration. As indicated by the $\%\Delta e_0$ yearly (Table 1 and 2), the average annual percentage gains in e_0 have generally diminished over time. For instance, Canadian female gains declined from 0.64% (1921-1953) to 0.16% (2003-2019). This trend is also pronounced in the recent data for the United States and Canada, with periods of stagnation or even negative growth (e.g., -0.06% for U.S. males, 2012-2017; 0.07% for Canadian males, 2016-2019).

However, these conclusions, based solely on e_0, are not consistently supported and, in some cases, differ when evaluating mortality trends using the overall longevity index ($\%\Delta n_t$ yearly). This

index, reflecting proportional changes in mortality across all ages, reveals different and more complex dynamics.

A clear difference is evident in the United Kingdom, particularly for males. While the e_0 trend suggests modest and stabilizing gains (0.30% in 1983-1998; 0.28% in 1999-2019), the n_t index reveals an acceleration in mortality improvements. The annual n_t gain for UK males increased from 0.88% (1952-1967) to 2.08% in the 1999-2019 period. This finding suggests that mortality improvements, which are not visible in the e_0 metric, have been concentrated at older ages.

The Japanese case highlights the contrast between the two metrics. The e_0 data, for both sexes, depicts a steady deceleration in gains following the post-war improvements (e.g., male $\%\Delta e_0$ dropping from 3.89% to 0.24% in the final period). This deceleration curve, however, does not align with the trend revealed by the n_t index. The $n_t$trend is characterized by alternating periods of acceleration and deceleration. For instance, Japanese males saw $\%\Delta n_t$ gains accelerate (to 3.17% in 1971-1981), then slow (to 1.38% in 1991-2000), and subsequently enter a period of re-acceleration (climbing to 2.56% in 2010-2018). This finding challenges a simple "slowdown" narrative.

In North America, the n_t index also shows different patterns. In the United States, the recent deterioration is quantified as a -0.49% annual decline for females (2010-2016) and a -0.98% decline for males (2012-2017), which are more pronounced than the stagnation shown by e_0. For Canadian males, the e_0 trend does not show the pattern seen in n_t, which consisted of two decades of improvements (2.17% and 2.06%) followed by a period of stagnation (0.12%) in 2016-2019.

In summary, these preliminary findings indicate that relying on e_0 alone provides an incomplete assessment of mortality dynamics. The n_t index reveals that trends of deceleration, stagnation, and acceleration are different across countries and sexes, pointing to complex underlying age-specific patterns not captured by period life expectancy.

Table 1 – Segmented life expectancy trends at birth (e_0) and generalized longevity index (SI-LC), Females – Selected High-Income Countries

Country	Period	e0 t0	%Δe0 yearly	%Δnt yearly
Canada	1921-1953	58.2	0.64	2.59
Canada	1954-1980	72.7	0.29	1.41
Canada	1981-2002	79.1	0.16	1.61
Canada	2003-2019	82.1	0.16	0.55
U.K.	1922-1930	58.9	0.73	1.88
U.K.	1931-1939	62.0	0.66	2.46
U.K.	1940-1943	63.5	1.21	5.45
U.K.	1944-1947	67.6	0.45	3.05
U.K.	1948-1951	70.6	0.02	2.69
U.K.	1952-1974	72.1	0.20	1.24
U.K.	1975-1994	75.7	0.23	1.79
U.K.	1995-2014	79.2	0.23	1.85
U.K.	2015-2019	82.7	0.13	0.23
U.S.A.	1933-1935	62.8	0.13	0.17
U.S.A.	1936-1942	62.6	1.00	4.56
U.S.A.	1943-1946	67.0	0.71	3.90
U.S.A.	1947-1958	69.6	0.40	2.74
U.S.A.	1959-1970	73.3	0.15	0.50
U.S.A.	1971-1979	75.0	0.39	2.51
U.S.A.	1980-1984	77.5	0.18	1.65
U.S.A.	1985-1992	78.2	0.16	0.96
U.S.A.	1993-1998	78.9	0.10	1.38
U.S.A.	1999-2009	79.4	0.18	1.17
U.S.A.	2010-2016	81.1	0.02	-0.49
U.S.A.	2017-2019	77.9	0.12	0.73
Japan	1947-1949	53.7	3.41	7.08
Japan	1950-1953	60.9	1.66	6.81
Japan	1954-1957	66.6	0.39	1.85
Japan	1958-1962	69.3	0.52	3.50
Japan	1963-1976	72.3	0.48	3.46
Japan	1977-1990	77.9	0.36	2.77
Japan	1991-2004	82.2	0.28	1.95
Japan	2005-2019	85.4	0.16	2.04

Table 2 - Segmented life expectancy trends at birth (e_0) and generalized longevity index (SI-LC), Males – Selected High-Income Countries

Country	Period	e0 t0	%Δe0 yearly	%Δnt yearly
Canada	1921-1953	56.0	0.53	1.40
Canada	1954-1976	67.5	0.18	0.54
Canada	1977-1996	70.6	0.33	2.17
Canada	1997-2015	75.7	0.28	2.06
Canada	2016-2019	79.9	0.07	0.12
U.K.	1922-1930	55.2	0.68	1.54
U.K.	1931-1939	58.0	0.64	1.83
U.K.	1940-1943	58.2	1.09	4.24
U.K.	1944-1947	61.4	1.06	5.74
U.K.	1948-1951	66.0	-0.11	0.76
U.K.	1952-1967	66.8	0.19	0.88
U.K.	1968-1982	68.6	0.24	1.34
U.K.	1983-1998	71.3	0.30	1.54
U.K.	1999-2019	74.9	0.28	2.08
U.S.A.	1933-1935	59.2	-0.12	-0.07
U.S.A.	1936-1938	58.4	1.18	4.60
U.S.A.	1939-1942	61.1	0.44	1.54
U.S.A.	1943-1946	62.0	0.65	3.19
U.S.A.	1947-1956	64.3	0.35	1.73
U.S.A.	1957-1962	66.4	0.13	0.73
U.S.A.	1963-1967	66.6	0.09	-0.14
U.S.A.	1968-1978	66.6	0.41	1.88
U.S.A.	1979-1985	70.0	0.22	1.49
U.S.A.	1986-1993	71.1	0.18	0.85
U.S.A.	1994-1999	72.4	0.35	2.77
U.S.A.	2000-2005	74.1	0.19	1.02
U.S.A.	2006-2011	75.2	0.24	1.79
U.S.A.	2012-2017	76.4	-0.06	-0.98
U.S.A.	2018-2019	76.3	0.09	0.53
Japan	1947-1949	49.8	3.89	8.13
Japan	1950-1952	57.6	2.07	7.37
Japan	1953-1955	61.5	1.11	3.86
Japan	1956-1959	63.4	0.66	2.41
Japan	1960-1970	65.3	0.54	2.60
Japan	1971-1981	70.1	0.46	3.17
Japan	1982-1990	74.3	0.25	1.84
Japan	1991-2000	76.2	0.20	1.38
Japan	2001-2009	78.0	0.21	1.84
Japan	2010-2018	79.5	0.24	2.56

References

Basellini, U., Camarda, C. G., & Booth, H. (2023). Thirty years on: A review of the Lee–Carter method for forecasting mortality. *International Journal of Forecasting*, *39*(3), 1033–1049. https://doi.org/10.1016/j.ijforecast.2022.11.002

Canudas-Romo, V., & Schoen, R. (2005). Age-specific contributions to changes in the period and cohort life expectancy. *Demographic Research*, *13*, 63–82. https://doi.org/10.4054/DemRes.2005.13.3

Case, A., & Deaton, A. (2015). Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. *Proceedings of the National Academy of Sciences*, *112*(49), 15078–15083. https://doi.org/10.1073/pnas.1518393112

de Jong, P., Tickle, L., & Xu, J. (2020). A more meaningful parameterization of the Lee–Carter model. *Insurance: Mathematics and Economics*, *94*, 1–8. https://doi.org/10.1016/j.insmatheco.2020.05.009

Dowd, J. B., Polizzi, A., & Tilstra, A. M. (2024). Progress Stalled? The Uncertain Future of Mortality in High-Income Countries. *Population and Development Review*, padr.12687. https://doi.org/10.1111/padr.12687

Glei, D. A., & Horiuchi, S. (2007). The Narrowing Sex Differential in Life Expectancy in High-Income Populations: Effects of Differences in the Age Pattern of Mortality. *Population Studies*, *61*(2), 141–159.

Goldstein, J. R., & Lee, R. D. (2024). Life Expectancy Reversals in Low-Mortality Populations. *Population and Development Review*, *50*(2), 437–459. https://doi.org/10.1111/padr.12619

Keyfitz, N. (2013). *Applied Mathematical Demography*. Springer Science & Business Media.

Kitagawa, E. M., & Hauser, P. M. (1973). *Differential Mortality in the United States: A Study in Socioeconomic Epidemiology*. Harvard University Press.

Murphy, M., & Grundy, E. (2022). Slowdown in Mortality Improvement in the Past Decade: A US/UK Comparison. *The Journals of Gerontology: Series B*, *77*(Supplement_2), S138–S147. https://doi.org/10.1093/geronb/gbab220

OECD & The King's Fund. (2020). *Is Cardiovascular Disease Slowing Improvements in Life Expectancy?: OECD and The King's Fund Workshop Proceedings*. OECD Publishing. https://doi.org/10.1787/47a04a11-en

Raleigh, V. S. (2019). *Trends in life expectancy in EU and other OECD countries: Why are improvements slowing?* (OECD Health Working Papers N. 108; OECD Health Working Papers, V. 108). https://doi.org/10.1787/223159ab-en

Schoen, R. (1970). The geometric mean of the age-specific death rates as a summary index of mortality. *Demography*, *7*(3), 317–324. https://doi.org/10.2307/2060150

Vaupel, J. W., & Canudas-Romo, V. (2002). Decomposing demographic change into direct vs. Compositional components. *Demographic Research*, *7*, 1–14. https://doi.org/10.4054/DemRes.2002.7.1