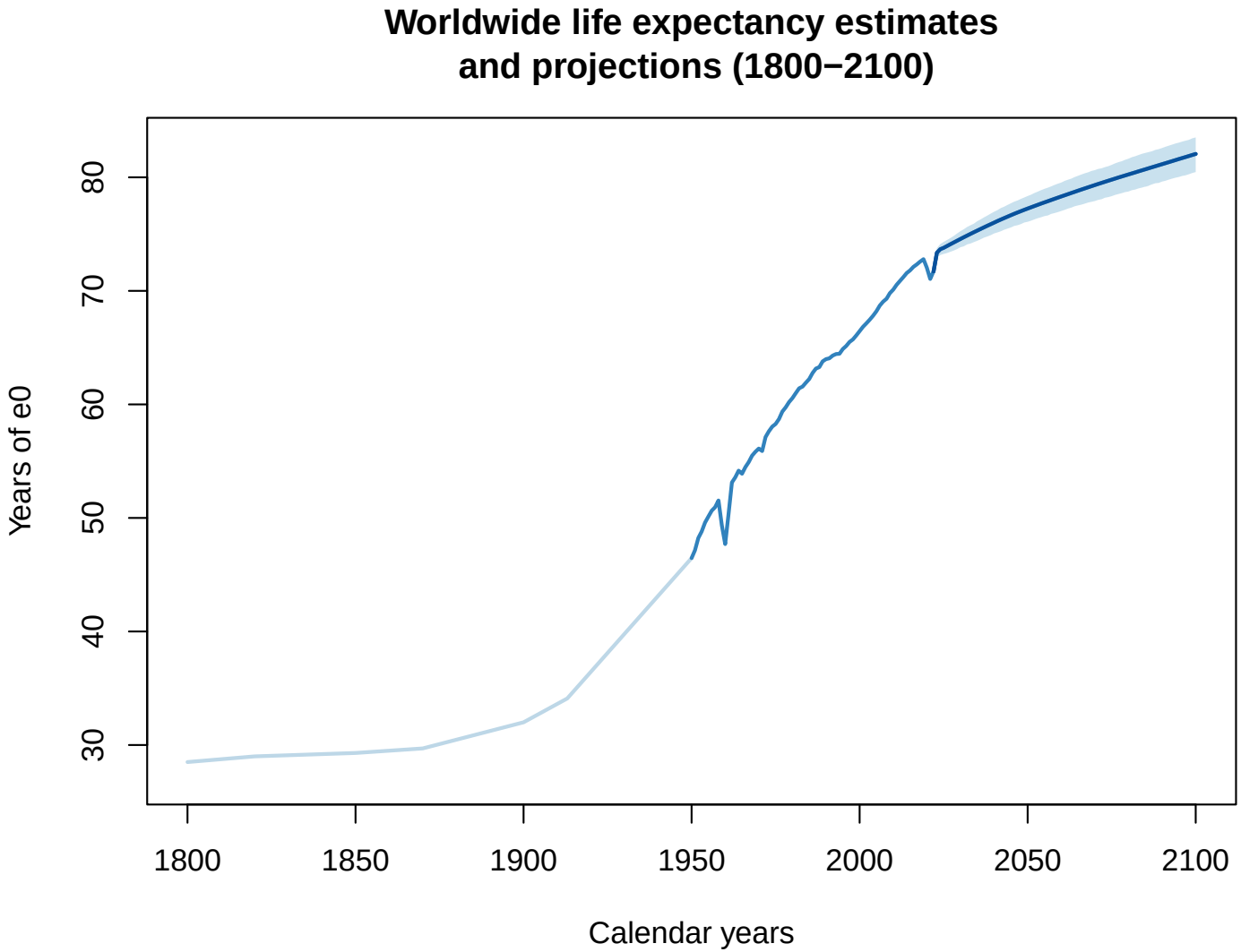
Future trends in mortality : can we still count on progress and convergence ?

Bruno Masquelier

UCLouvain, Belgium

Global Demography Expert Survey on Drivers and Consequences of Demographic Change

Long-term trends in life expectancy and projections



Sc : Riley (2005) for the period 1800-1950, United Nations (2022) for the period 1950-2100

Alternative projections of life expectancy

JRC and IIASA (Lutz et al., 2018) :

Sc : Wittgenstein Centre Human Capital Data Explorer and United Nations (2022)

Alternative projections of life expectancy

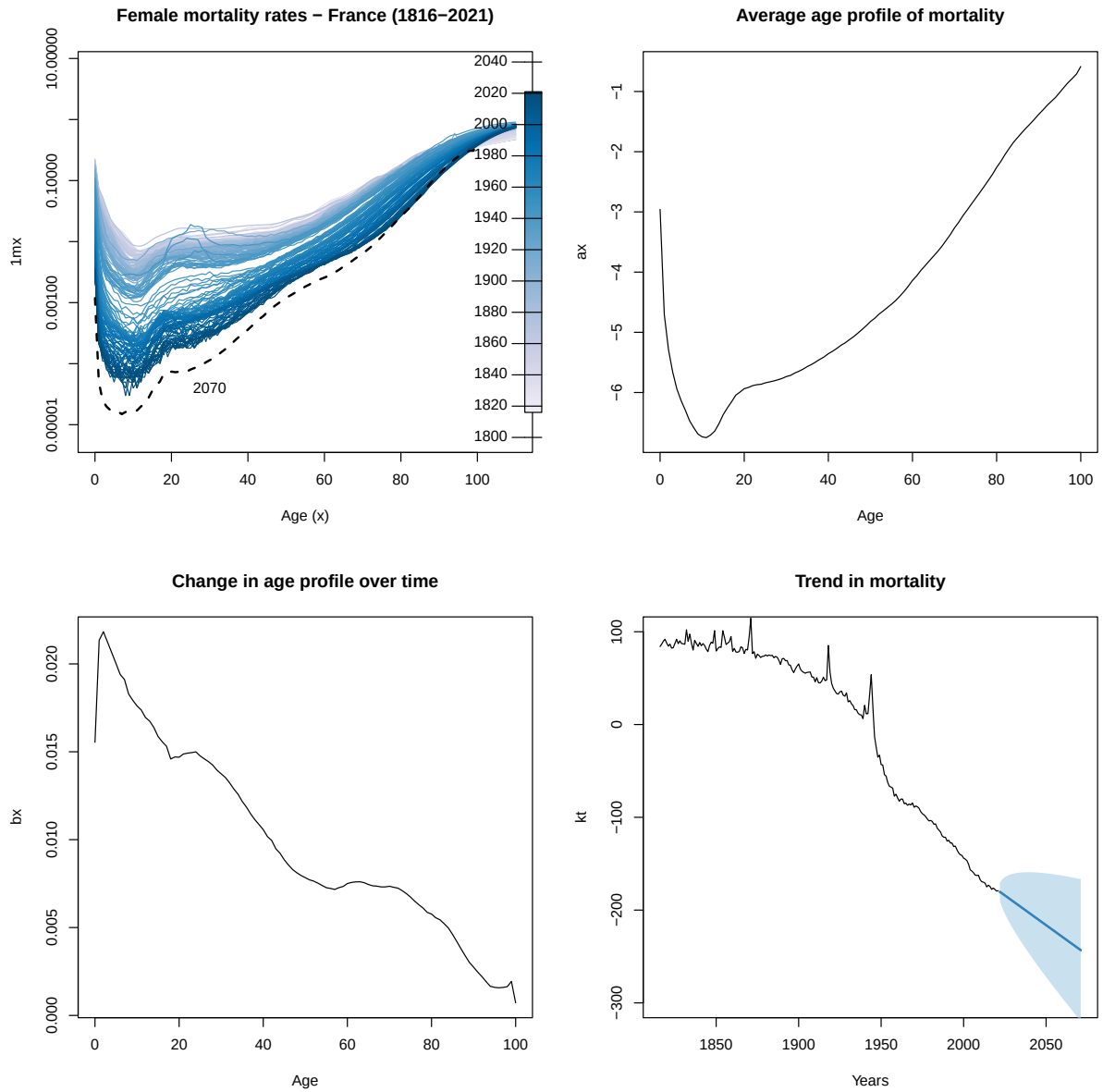
IHME (Vollset et al., 2020) :

Sc : IHME Global Health Data Exchange and United Nations (2022).

How do demographers project mortality ?

1. Extrapolation based on past trends
   - Separate extrapolation of age-specific mortality rates.
   - Extrapolation of summary indices from the life table : life expectancy, under-five mortality, etc.
   - Mortality surfaces (Lee-Carter model)
   - Age-Period-Cohort methods, etc.
2. Interpolation towards mortality targets.
3. Disaggregation by causes of death.
   - Projection of mortality for major causes of death (Foreman et al., 2018).
   - Projections with and without specific causes (e.g., HIV-AIDS, COVID-19).

$$ln(m_{xt}) = a_x + b_x * k_t + \epsilon_{x,t}$$



Sc : Application of the Lee and Carter (1992) model to data from the Human mortality database with the `demography` package (Hyndman and Ullah, 2007)

The pressing need for better mortality statistics

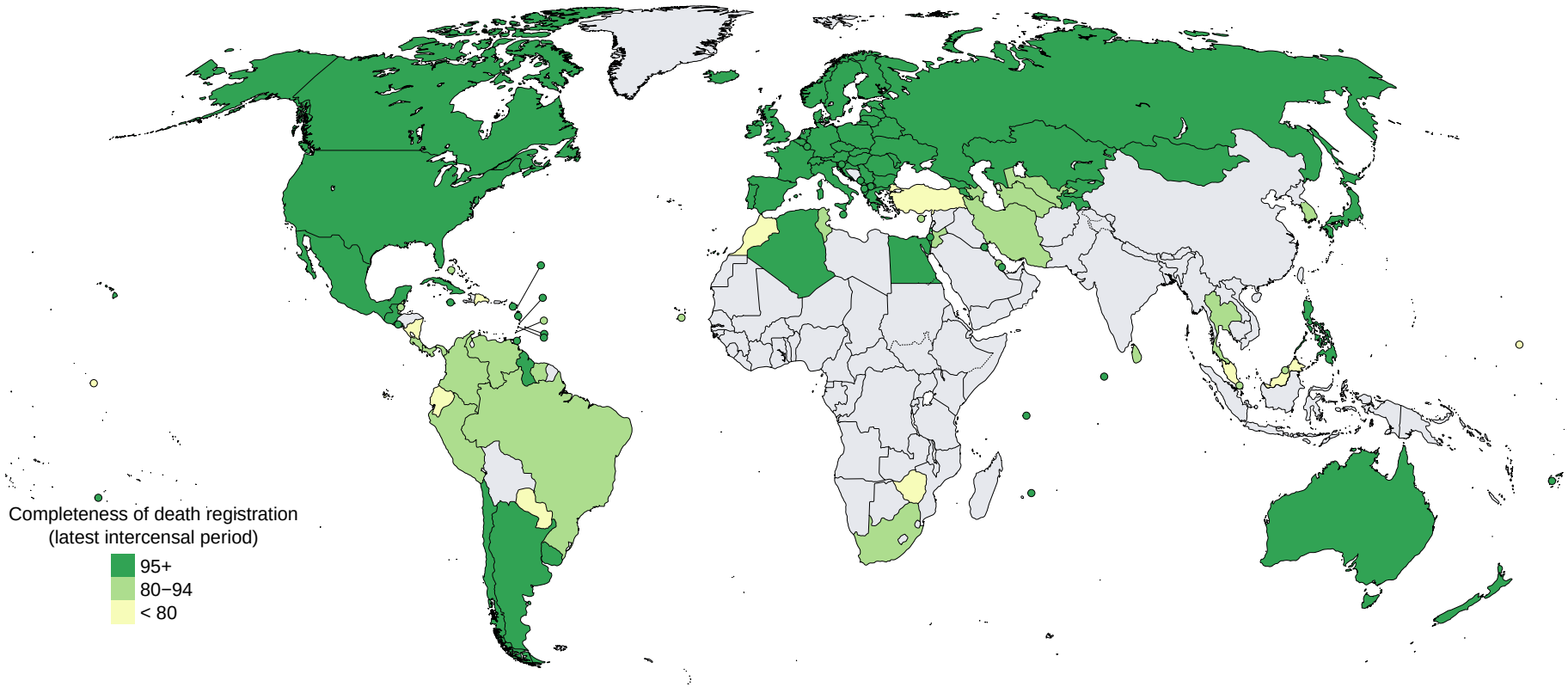
In an ideal world :

- Age and sex-disaggregated mortality rates would be available for all countries.
- These rates would be generated from comprehensive systems of civil registration and vital statistics (**CRVS**).
- Causes of death would be **certified** by physicians and **coded** according to a standard classification (currently ICD-11).

In reality,

- CRVS systems require a strong and decentralized administration and involve numerous stakeholders.
- Only 38% of deaths were registered in 2015 (Mikkelsen et al., 2015).
- Information about the cause of death can be of poor quality ("garbage codes").
- CRVS systems are often disrupted during crises or conflicts.

Estimated completeness of death registration (based on the WHO Mortality Database) (Masquelier et al., 2021) :



+ Sample Registration System in India, Disease Surveillance Points in China.

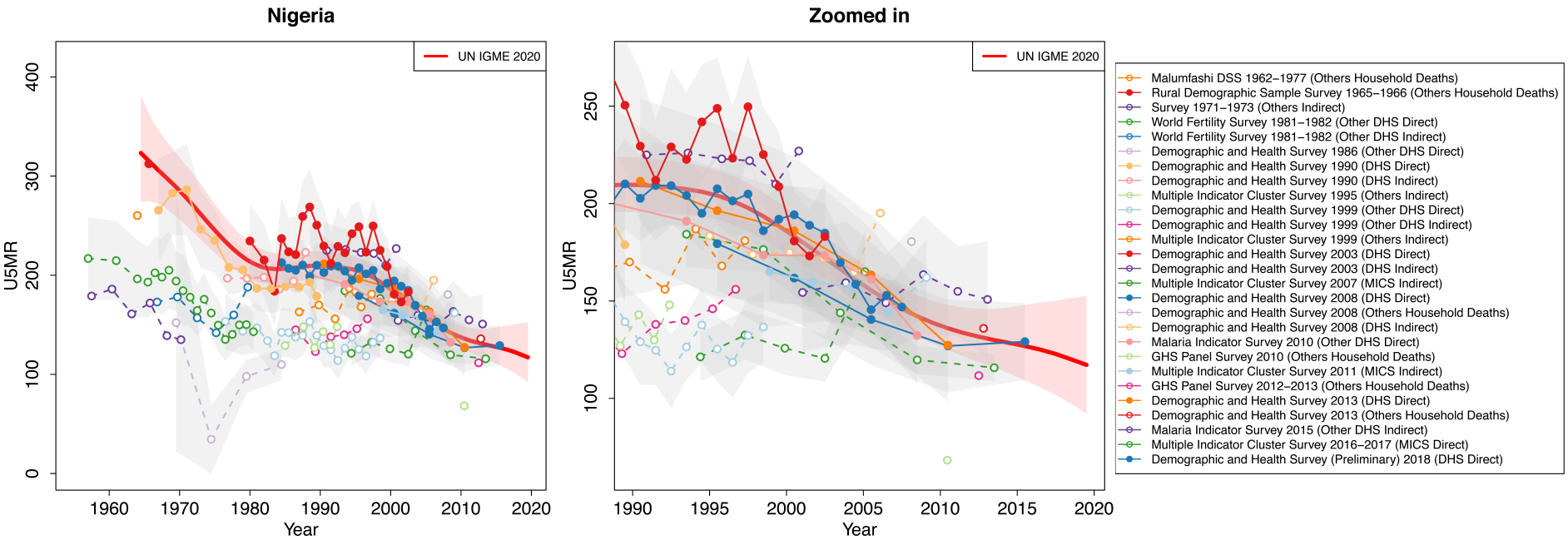
Demographic surveys and censuses

Diversity of approaches to measure mortality in LMICs :

- Birth histories of women aged 15-49 for child mortality (DHS, MICS)
- Survival of adult siblings for mortality between 15 and 60 years (DHS).
- Survival of parents (surveys and censuses)
- Deaths in the last twelve months in households

No approach is fully satisfactory (selection biases, misreporting, sampling errors).
The situation is particularly critical for older adults (and yet 74% of deaths occurred over the age of 50 in LMICs in 2022).

Example of the reconstruction of under-5 mortality trends (UN IGME estimates) :



Source : `childmortality.org` - Sharrow et al. (2022)

What assumptions for the future ?

1. How far can mortality decline ?
   - Spread of health-conscious behaviours : reduction in smoking, etc.
   - Advances in medicine : treatments for cardiovascular diseases, cancers, etc.
   - Secular trend towards a steady increase in life expectancy.
2. What are the risks of trend reversals ?
   - Economic crises, conflicts, climate change, etc.
   - Adoption of unhealthy lifestyles (lack of exercise, high-fat and sugary diets, drug use, etc.)
   - New or resurgent diseases : COVID-19, etc.
   - New risks : resistance to antimalarials, antibiotics, etc.
3. Are countries converging towards low mortality levels ?

The secular trend

Jim Oeppen and James W.Vaupel, "Broken Limits to Life Expectancy", *Science*, Vol. 296, No. 5570 (May 10, 2002)

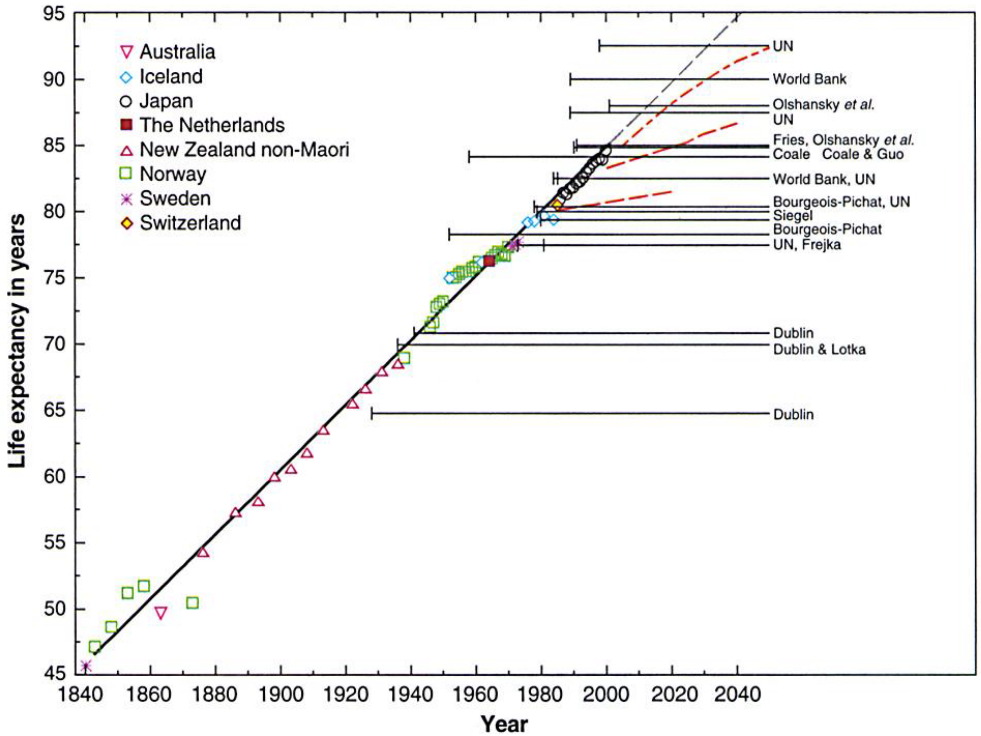


Fig. 1. Record female life expectancy from 1840 to the present [suppl. table 2 (*1*)]. The linear-regression trend is depicted by a bold black line (slope = 0.243) and the extrapolated trend by a dashed gray line. The horizontal black lines show asserted ceilings on life expectancy, with a short vertical line indicating the year of publication (suppl. table 1). The dashed red lines denote projections of female life expectancy in Japan published by the United Nations in 1986, 1999, and 2001

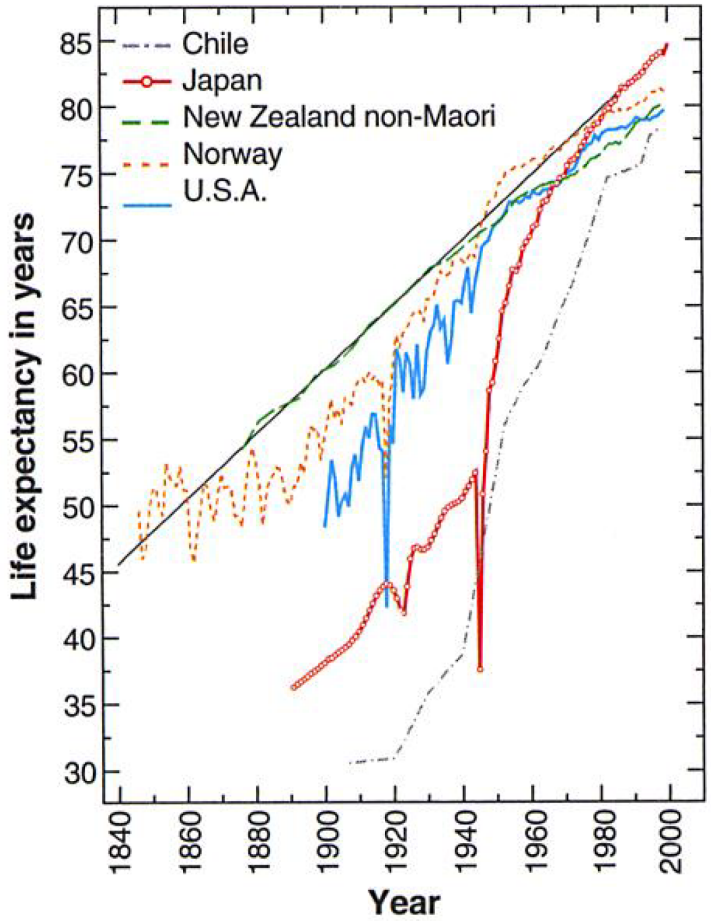
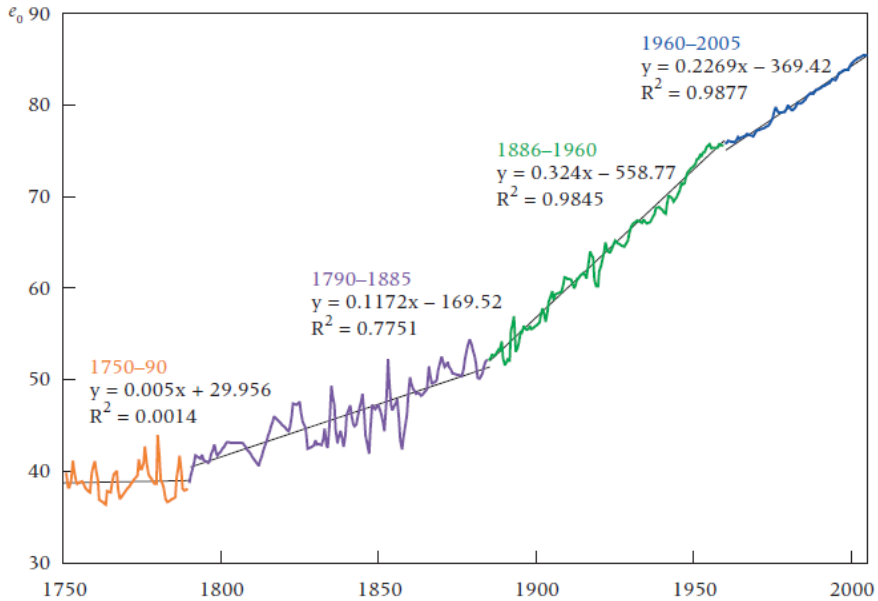


Fig. 2. Female life expectancy in Chile, Japan, New Zealand (non-Maori), Norway, and the United States compared with the trend in record life expectancy.

Will life expectancy increase indefinitely by three months every year ?

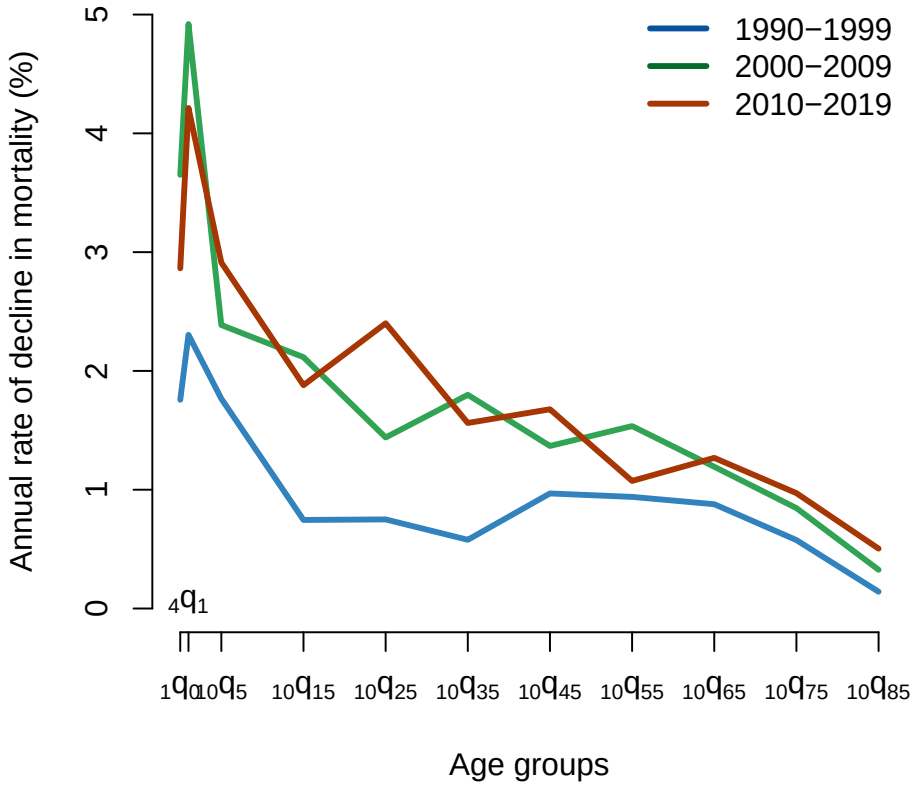
Critique by Vallin and Meslé (2009) :

FIGURE 9 Maximum female life expectancy at birth after removal of Norway (until 1866) and New Zealand from our dataset and linear approximation of the trend in four time periods, 1750–2005



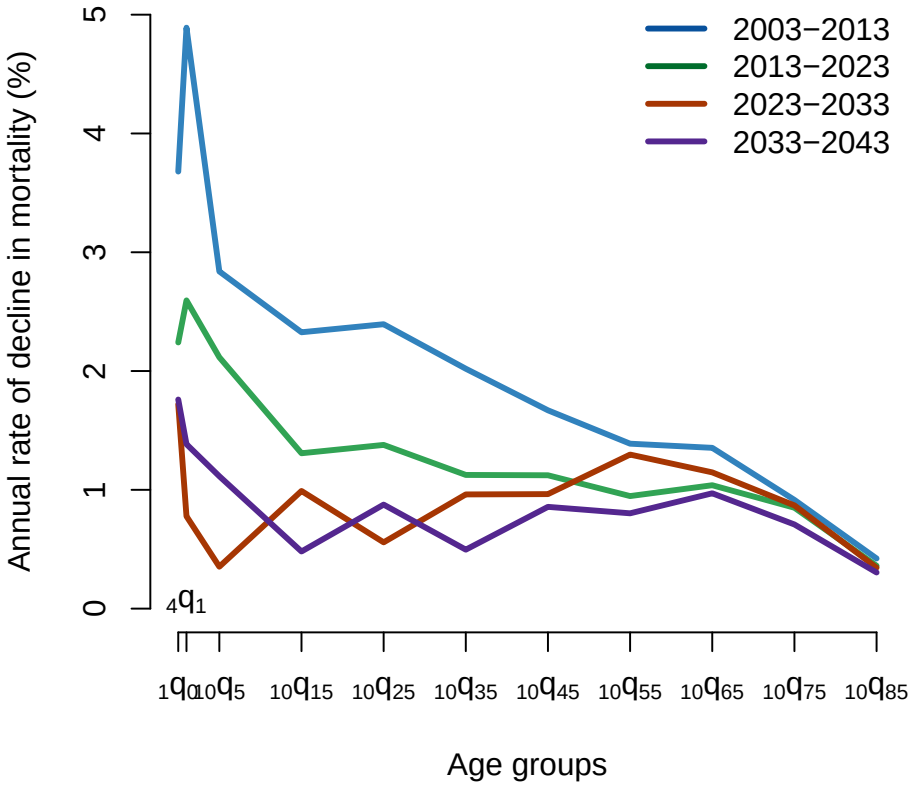
- There are different periods that correspond to medical advances (Jenner, Pasteur, cardiovascular revolution).
- Progress is likely to slow down as the reduction in mortality affects individuals at increasingly older ages.

A slowdown in the progress against mortality ?



Sc : own calculations from United Nations (2022)

- For all age groups, the annual rate of decline in mortality was much faster in 2000-2009 than in 1990-1990.
- But in 2010-2019, the pace of decline has not accelerated further.
- The annual rate of decline in U5MR doubled from 1990-1999 (1.9%) to 2000-2009 (4.0%) before slowing in 2010-2019 (3.4%) (IGME, 2020).



Sc : own calculations from United Nations (2022)

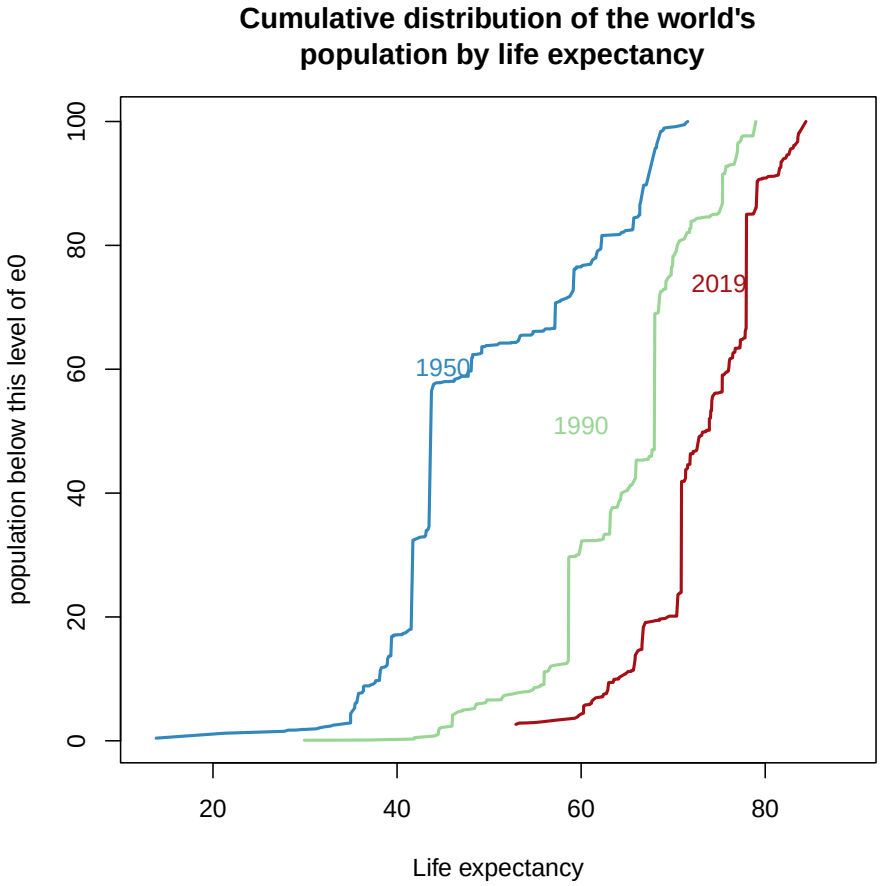
- This slowdown is also predicted by the United Nations (2022), when considering rates of decline for age-specific risks of dying.

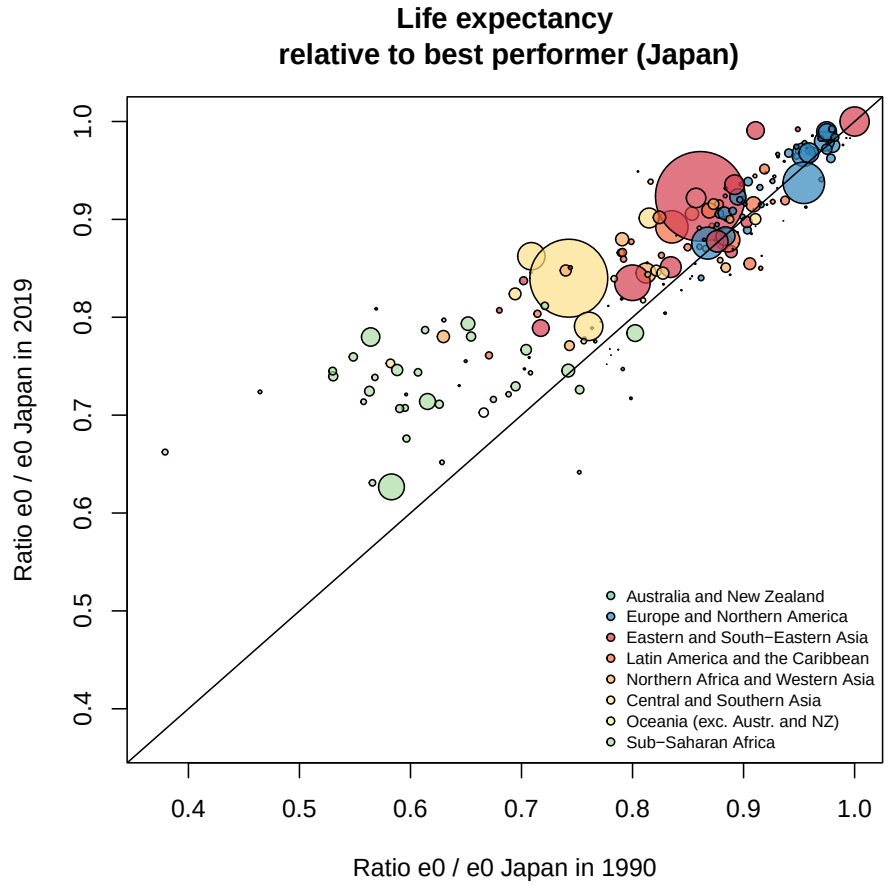
What about convergence ?

> *As countries complete the demographic transition and reach historically low levels of mortality, further reductions in death rates become more difficult to achieve and the rise in life expectancy slows down, prompting a trend towards convergence between countries and regions over the long-term (United Nations, 2022)*

> *Economic growth in many low-income and middle-income countries and the increasing availability of high-impact health technologies make a grand convergence in health achievable by 2035 (Jamison et al., 2013)*

But how should we measure convergence ?

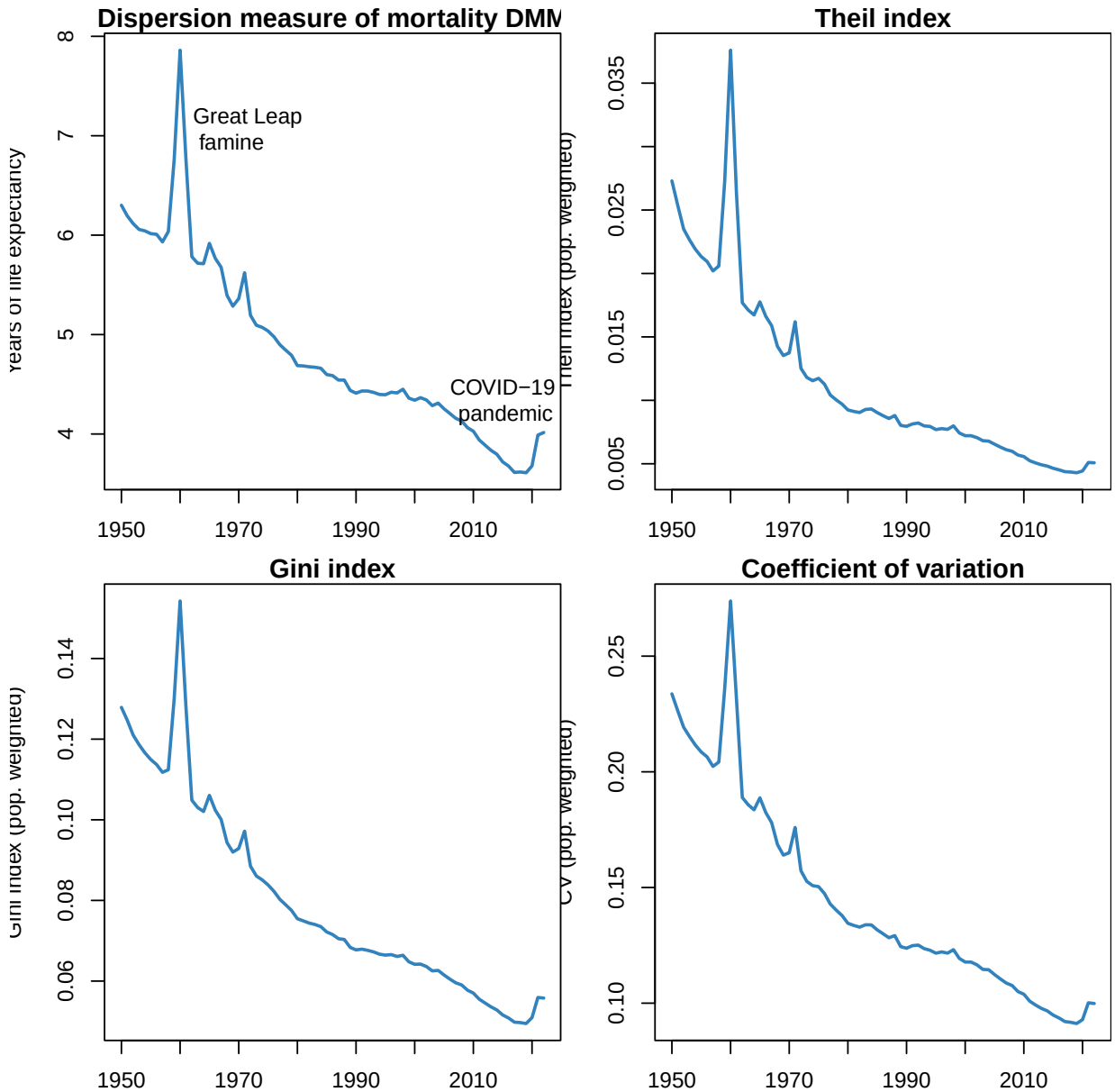




Source : estimates from United Nations (2022).

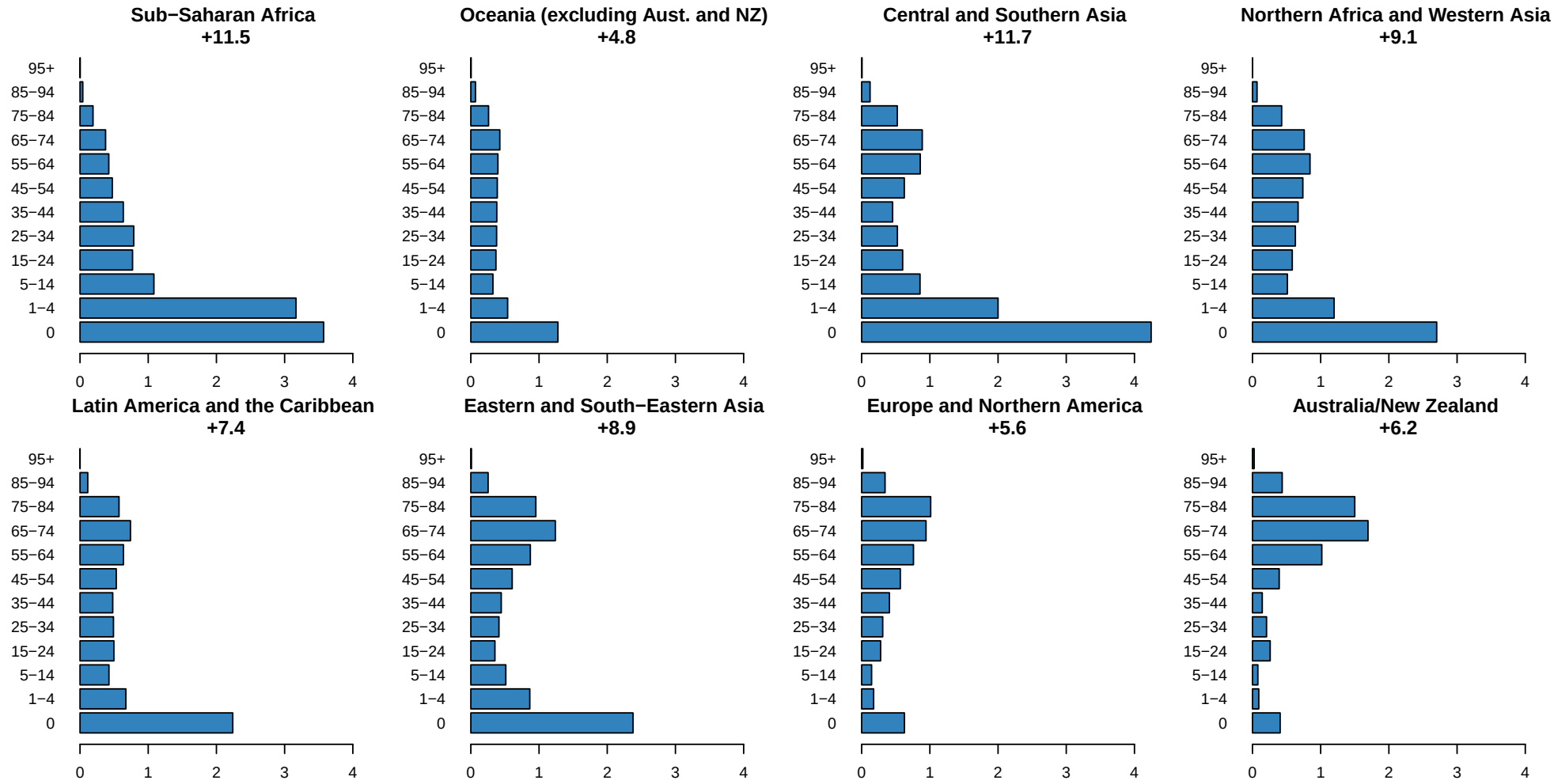
Year	Median	Top(10%)-bottom(10%)
1950	44	29
1990	68	19
2019	74	15

When considering life expectancy, it is undeniable that there has been convergence over the last few decades. But convergence is somehow "built-in" in this metric.



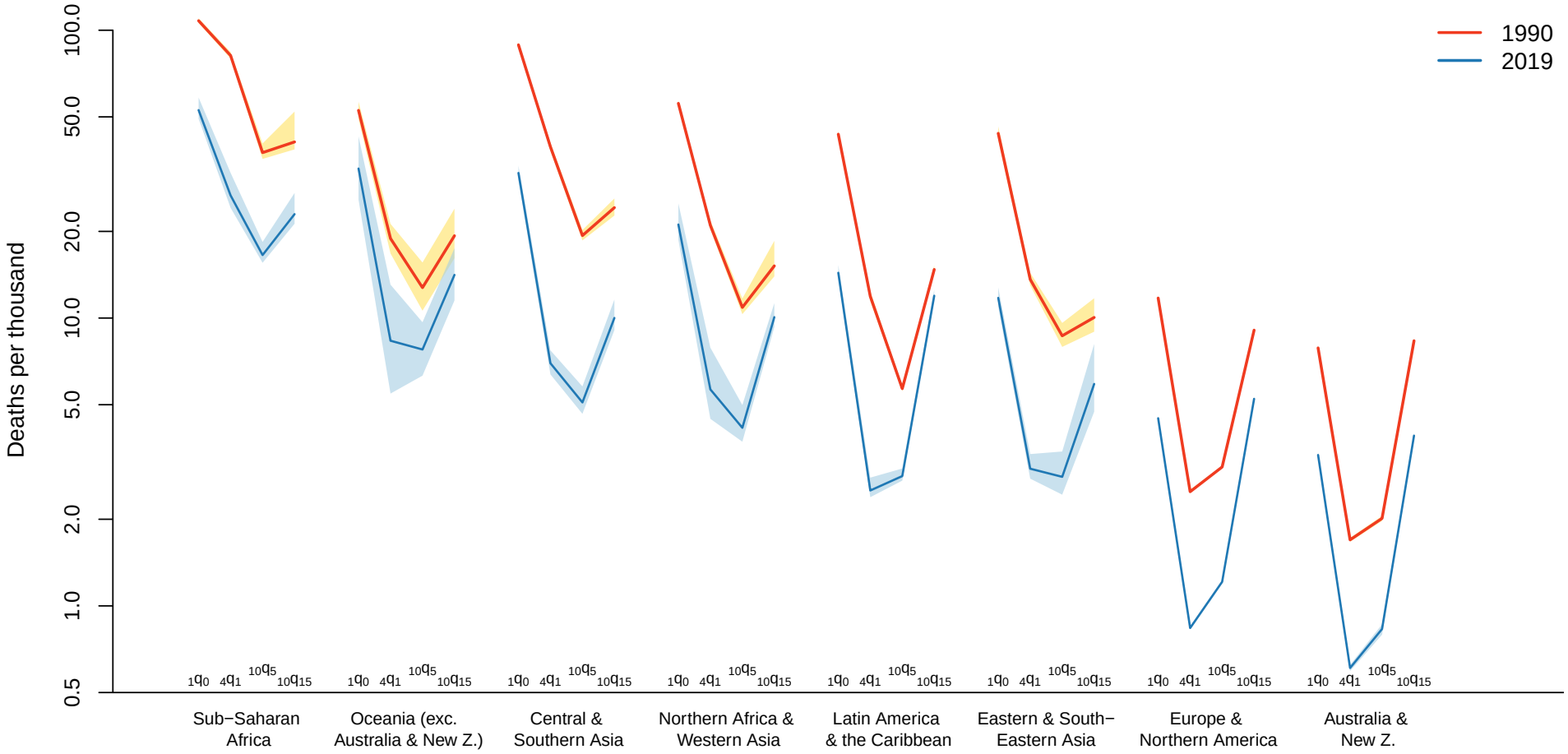
Source : estimates from United Nations (2022), own calculations - the DMM metric is based on Moser et al. (2005).

Age-specific contributions to gains in life expectancy at birth (1990-2019)



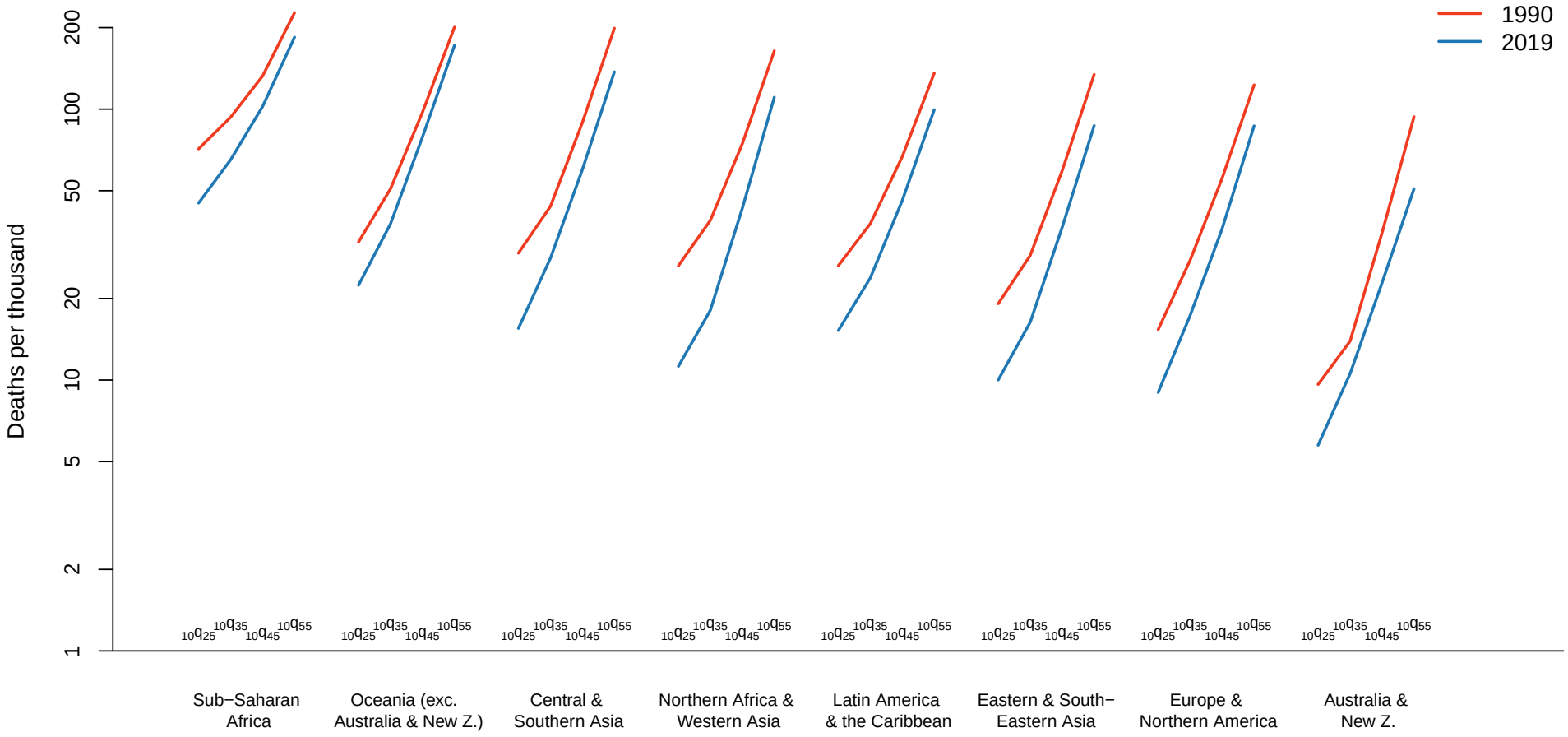
Source : estimates from United Nations (2022), own calculations based on Arriaga (1984).

Trends in mortality before age 25



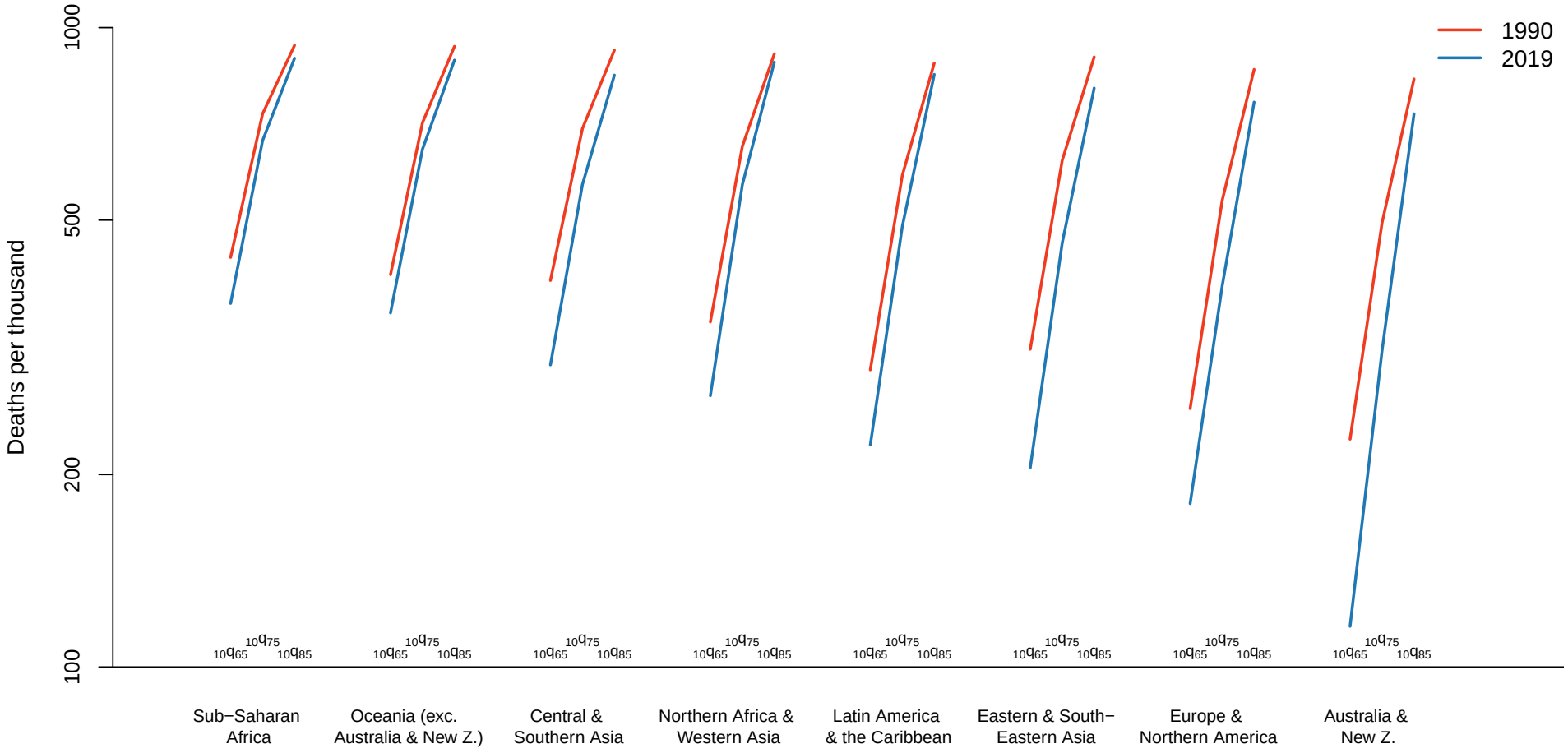
Source : estimates from UN IGME - Masquelier et al. (2021)

Trends in mortality from age 25 to 65



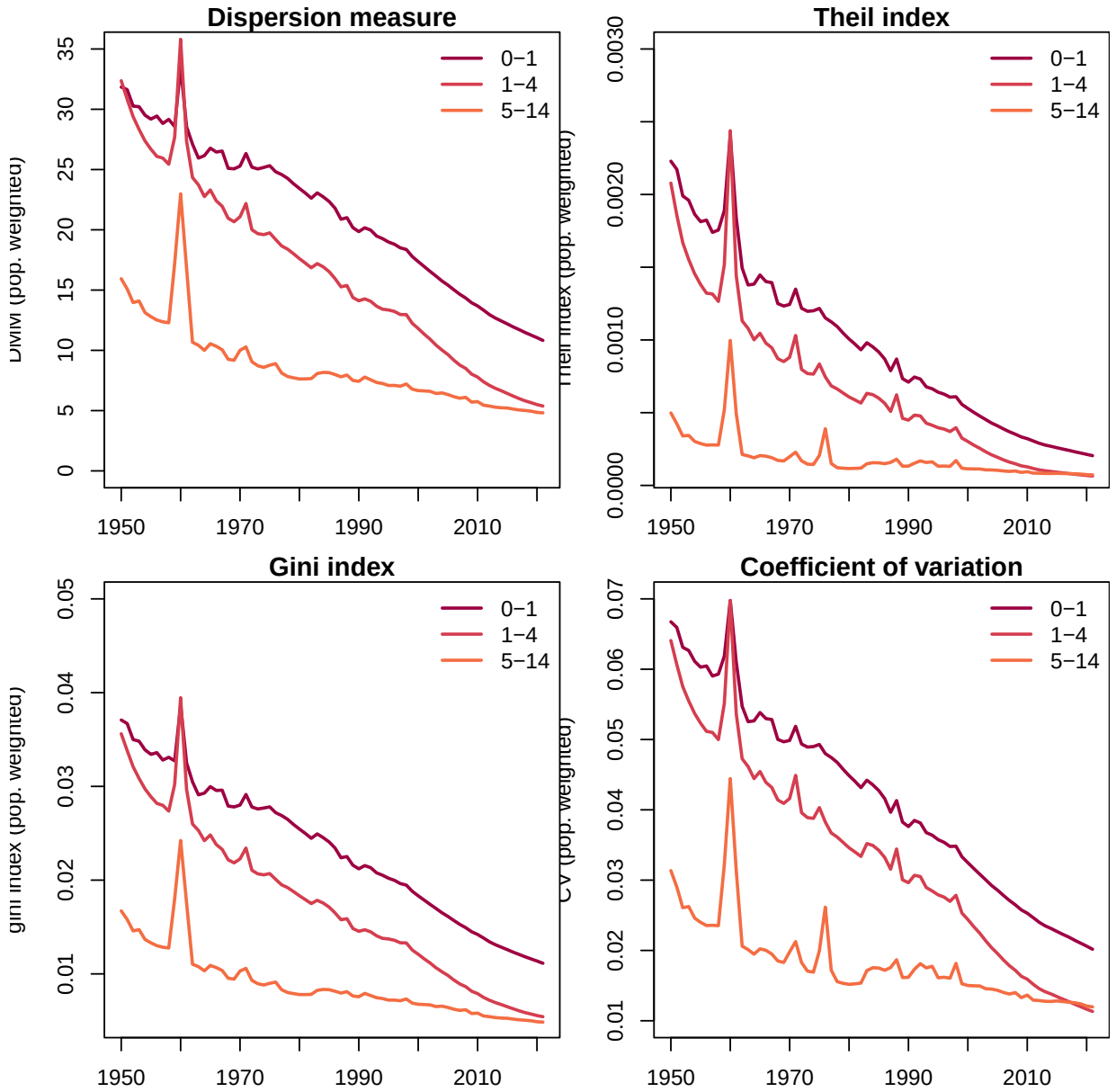
Source : estimates from United Nations (2022).

Trends in mortality from age 65 to 95



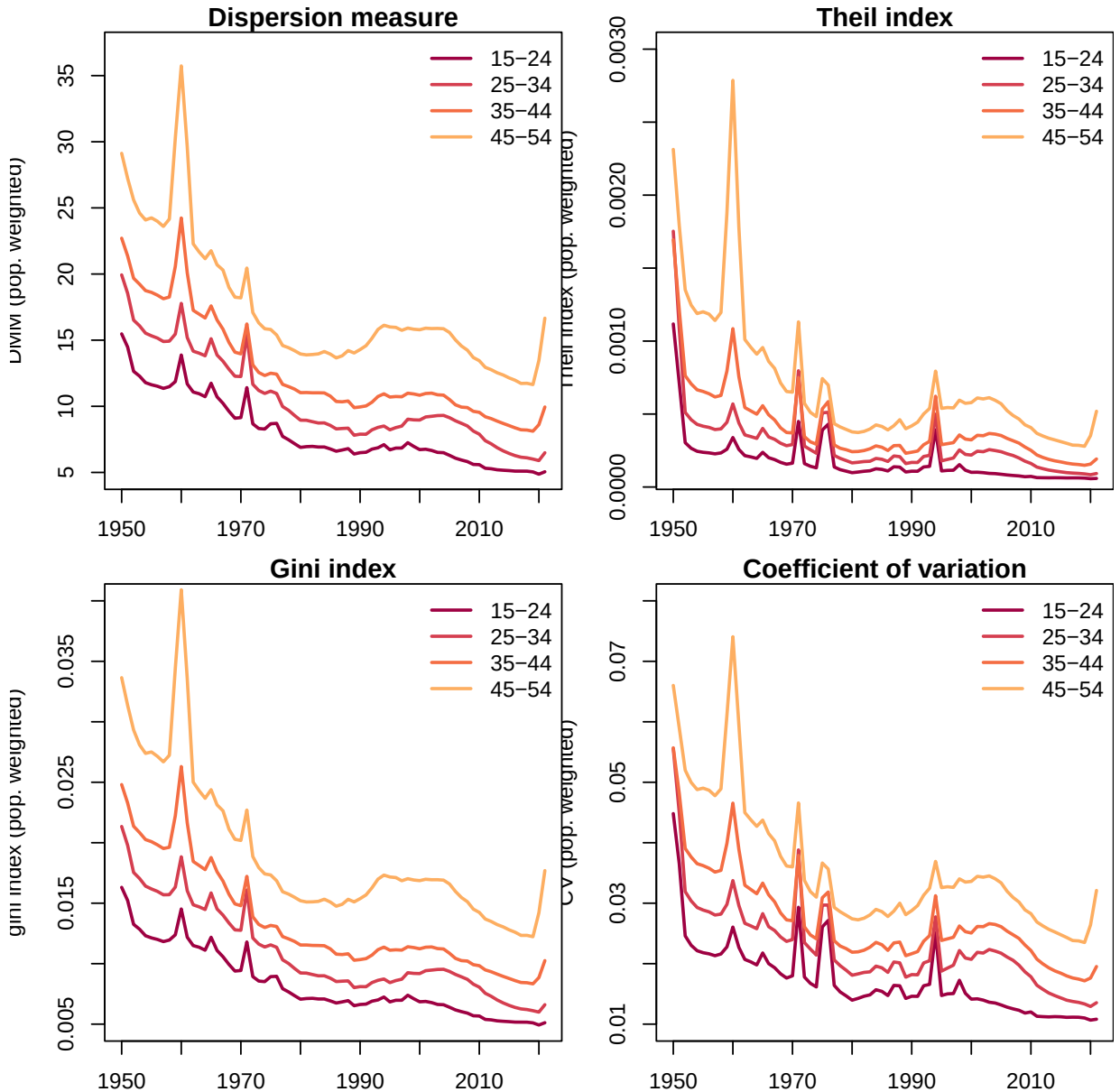
Source : estimates from United Nations (2022).

Convergence in age-specific mortality rates : 0-14



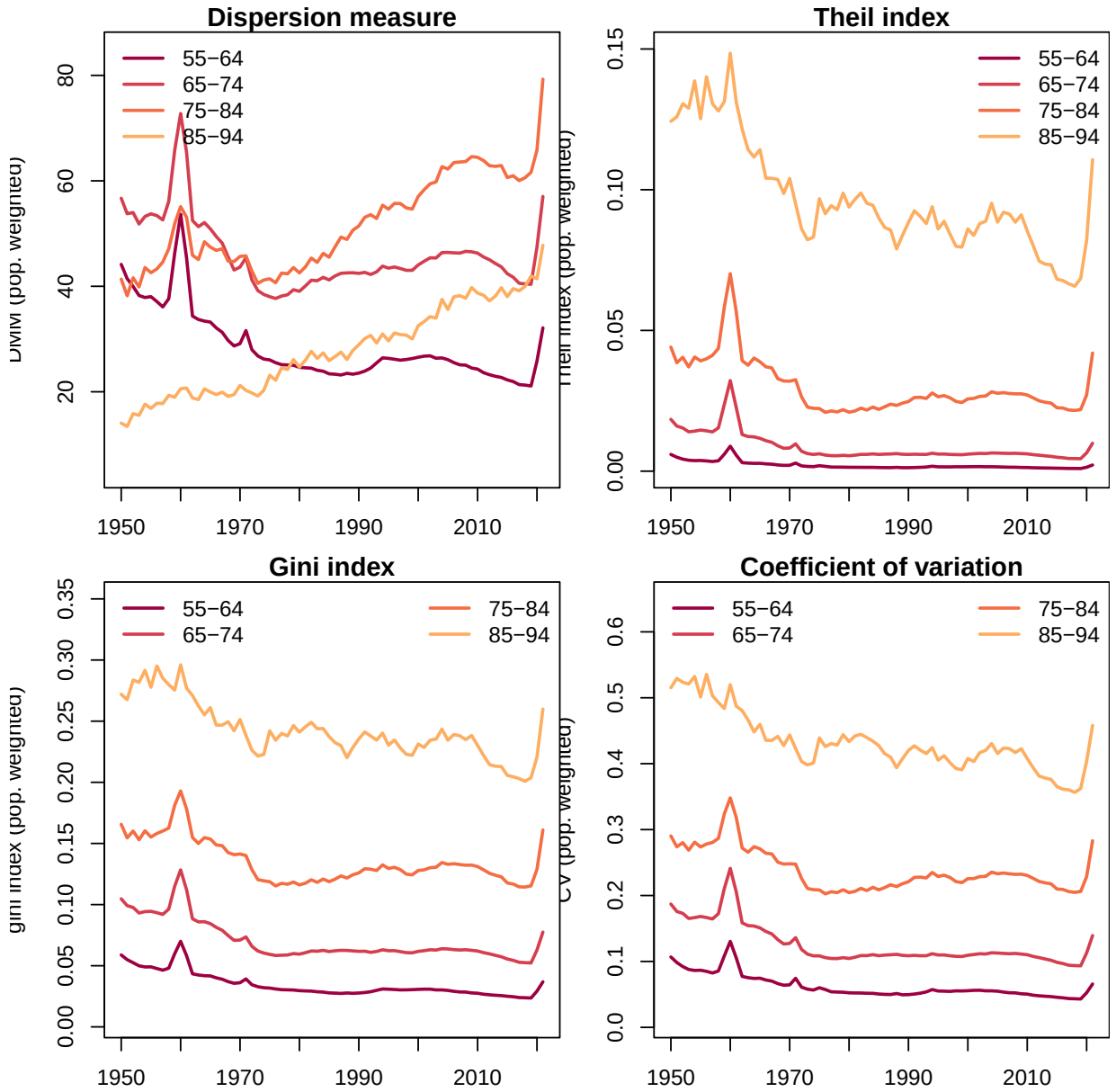
Source : estimates from United Nations (2022), own calculations - the DMM metric is based on Moser et al. (2005).

Convergence in age-specific mortality rates : 15-54



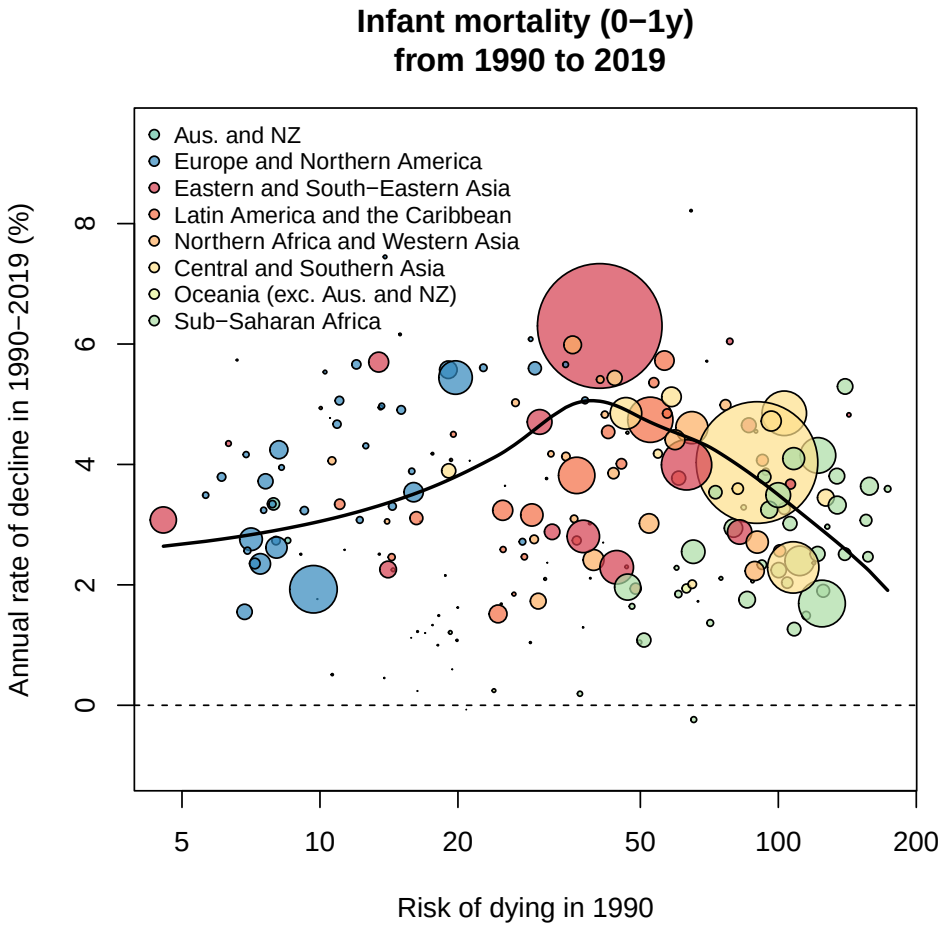
Source : estimates from United Nations (2022), own calculations - the DMM metric is based on Moser et al. (2005).

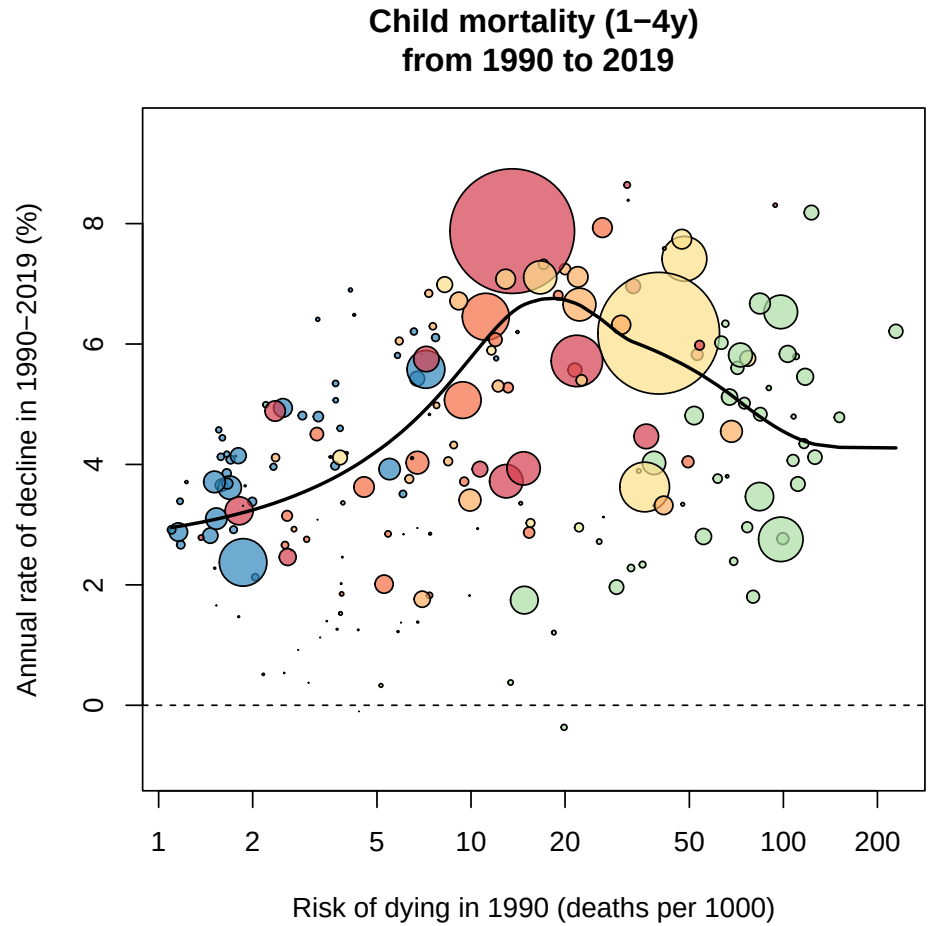
Convergence in age-specific mortality rates : 55-94



Source : estimates from United Nations (2022), own calculations - the DMM metric is based on Moser et al. (2005).

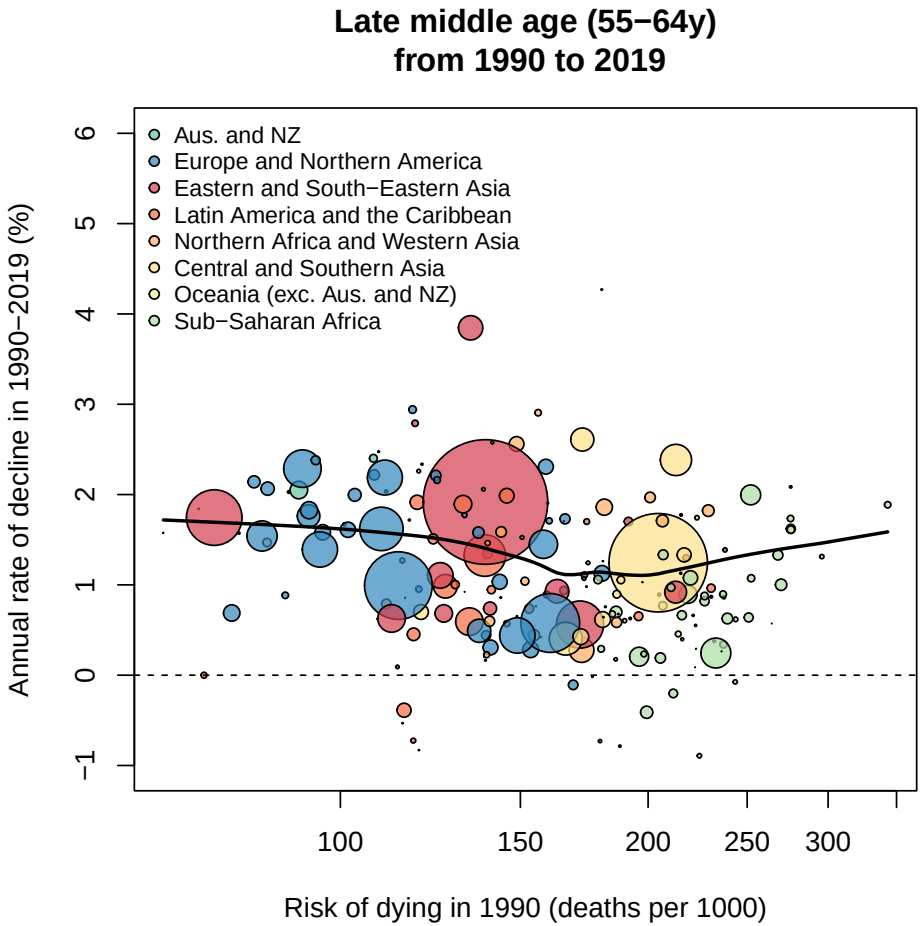
Country-specific trends : 0-4

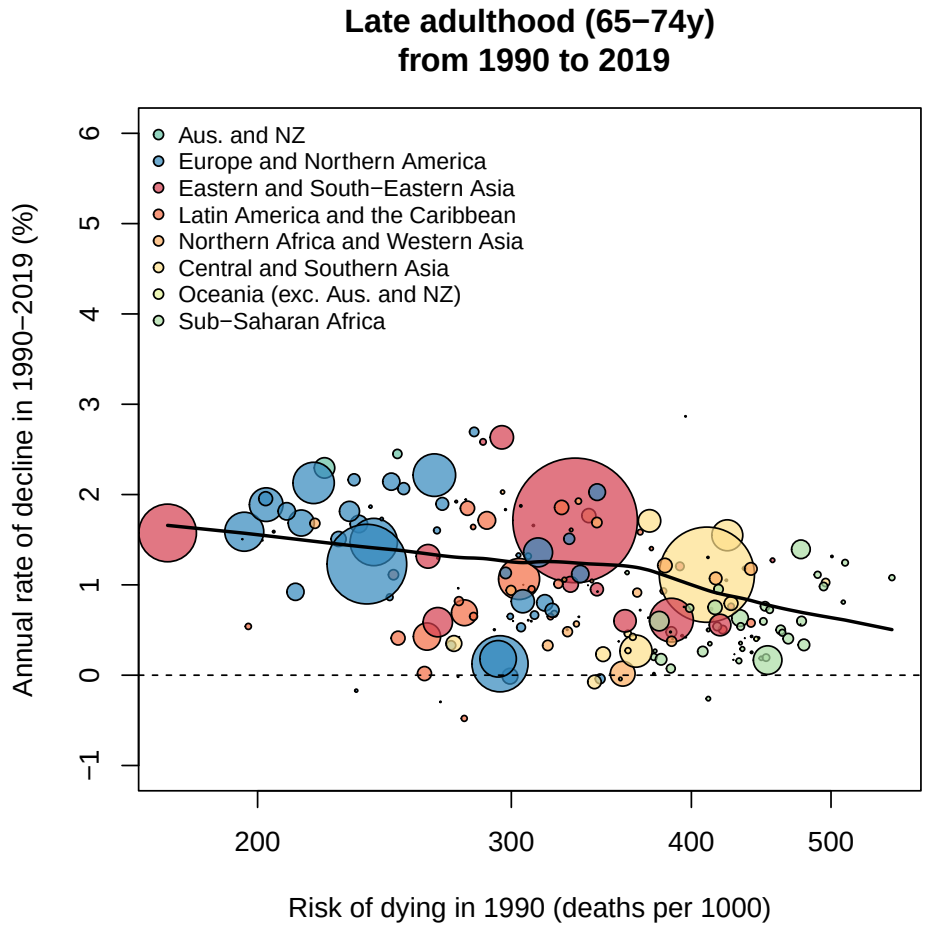




Sc : Estimates and projections from United Nations (2022), the size of each bubble represents the population aged 0-1 in 1990 (left-hand plot) or aged 1-4 in 1990 (right-hand plot).

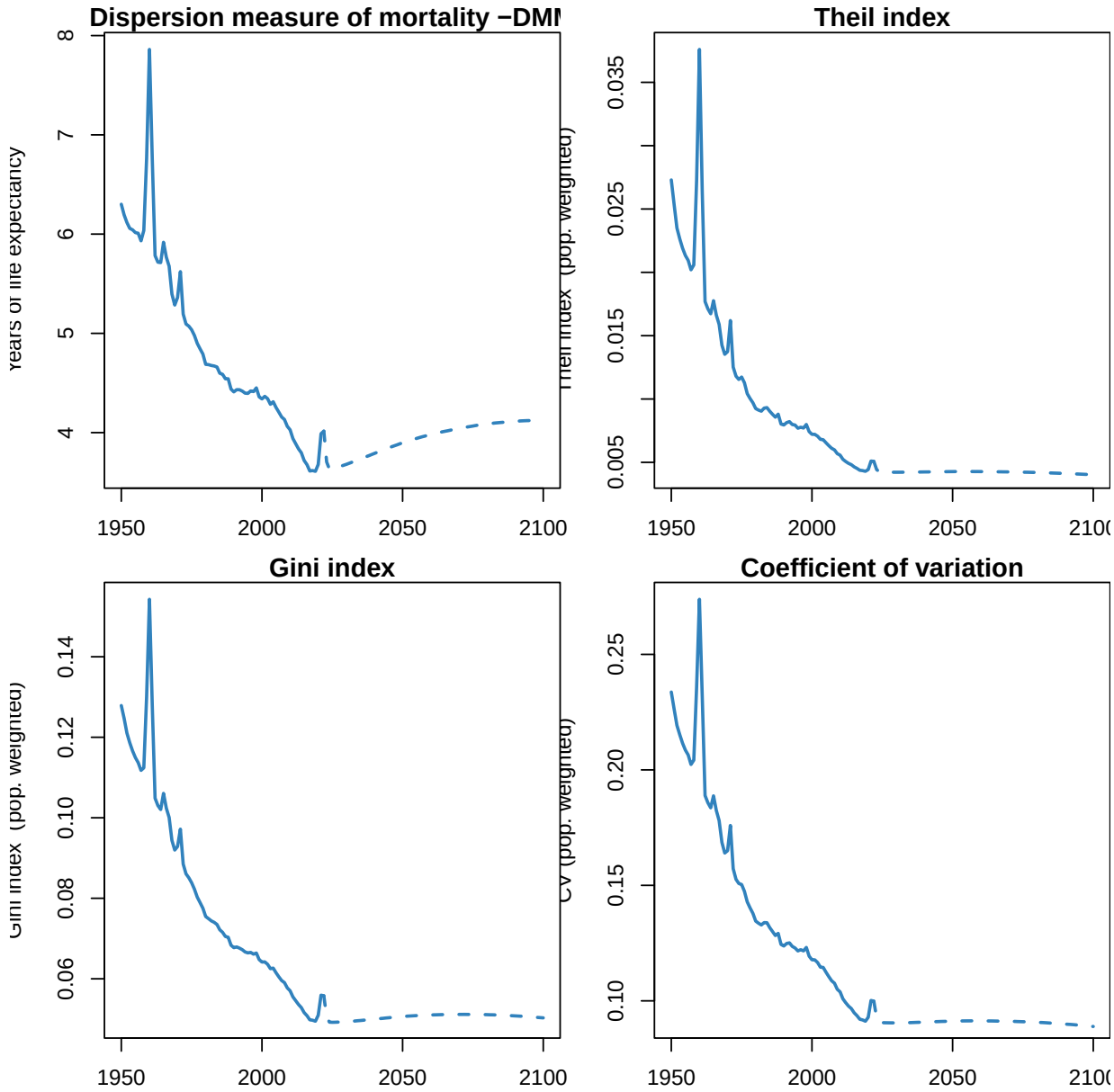
Country-specific trends : 55-74



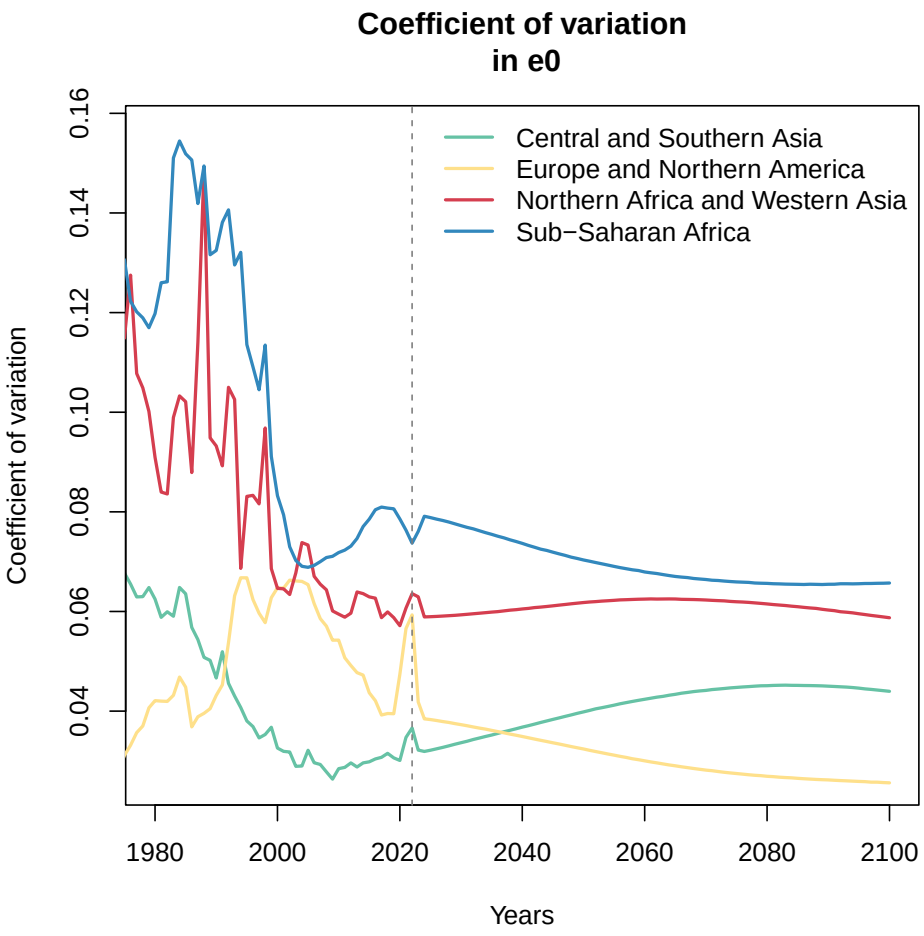


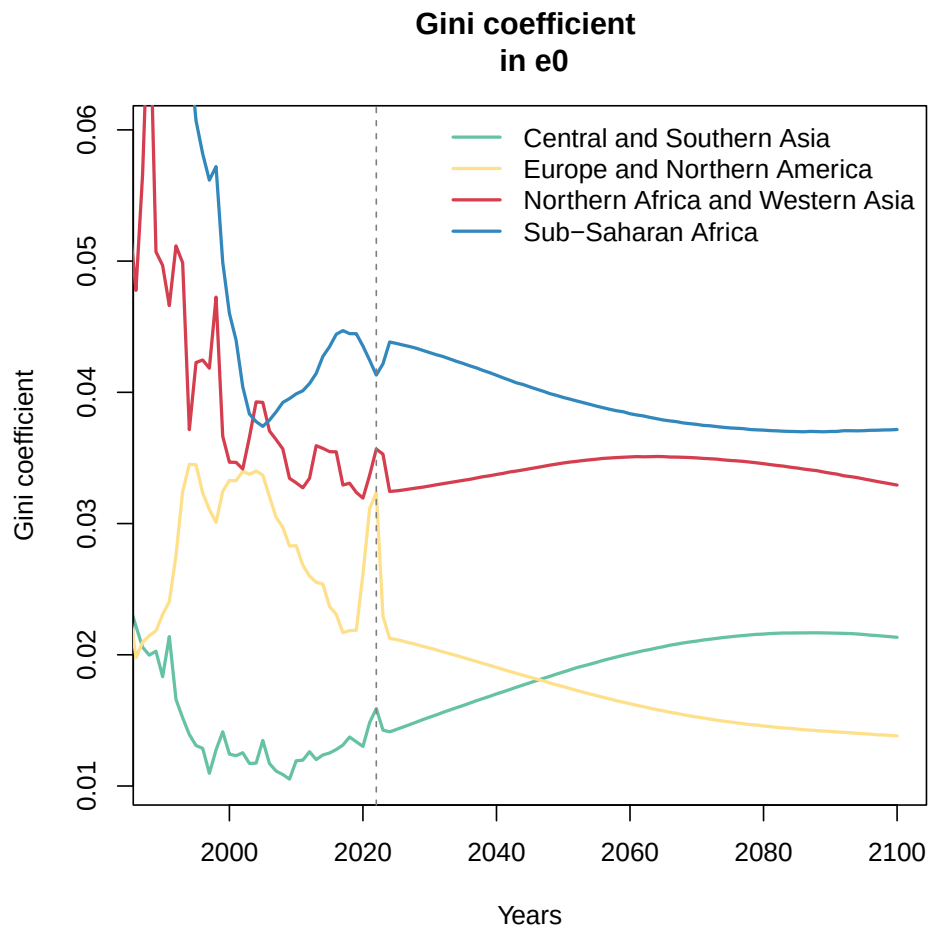
Sc : Estimates and projections from United Nations (2022), the size of each bubble represents the population aged 55-64 in 1990 (left-hand plot) or aged 65-74 in 1990 (right-hand plot).

Convergence in life expectancy might stall soon.



Source : estimates from United Nations (2022), own calculations - the DMM metric is based on Moser et al. (2005).





Source : estimates from United Nations (2022), own calculations - the DMM metric is based on Moser et al. (2005).

Conclusion

Although in one sense the world has become a better place as mortality declines, in another way it has become worse as the distribution of life expectancy at birth worldwide has started to diverge (Moser et al., 2005).

- We need assumptions to project mortality forward.
- There has been a lot of debate around convergence in mortality (Wilson, 2001; Moser et al., 2005; Oeppen and Vaupel, 2002).
- Focusing on life expectancy might have blurred our perspective, we should focus on age-specific mortality rates.
- Age-specific mortality rates have converged since 1950, but not in the older age groups.
- Convergence in mortality could stall in the coming years as the burden of mortality shifts to older ages.

References I

E. E. Arriaga. Measuring and explaining the change in life expectancies. *Demography*, 21(1) :83–96, Feb 1984.

Kyle J Foreman et al. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death : reference and alternative scenarios for 2016–40 for 195 countries and territories. *The Lancet*, 392(10159) :2052–2090, November 2018.

R. Hyndman and Sh. Ullah. Robust forecasting of mortality and fertility rates : A functional data approach. *Computational Statistics & Data Analysis*, 51(10) :4942 – 4956, 2007. ISSN 0167-9473.

IGME. *Levels and Trends in Child Mortality : 2020 Report*. 2020.

Dean T Jamison, Lawrence H Summers, George Alleyne, Kenneth J Arrow, Seth Berkley, Agnes Binagwaho, Flavia Bustreo, David Evans, Richard G A Feachem, Julio Frenk, Gargee Ghosh, Sue J Goldie, Yan Guo, Sanjeev Gupta, Richard Horton, Margaret E Kruk, Adel Mahmoud, Linah K Mohohlo, Mthuli Ncube, Ariel Pablos-Mendez, K Srinath Reddy, Helen Saxenian, Agnes Soucat, Karen H Ulltveit-Moe, and Gavin Yamey. Global health 2035 : a world converging within a generation. *The Lancet*, 382(9908) :1898–1955, December 2013. doi : 10.1016/s0140-6736(13)62105-4. URL `https://doi.org/10.1016/s0140-6736(13)62105-4`.

R. Lee and L. Carter. Modeling and Forecasting U.S. Mortality. *Journal of the American Statistical Association*, 87 (419) :659–671, 1992.

W. Lutz, A. Goujon, S. Kc, M. Stonawski, and Stilianakis. *Demographic and human capital scenarios for the 21st century : 2018 assessment for 201 countries.* Publications Office, 2018. doi : 10.2760/835878. URL `https://data.europa.eu/doi/10.2760/835878`.

References II

B. Masquelier, L. Hug, D. Sharrow, D. You, C. Mathers, P. Gerland, and L. Alkema. Global, regional, and national mortality trends in youth aged 15–24 years between 1990 and 2019 : a systematic analysis. *The Lancet Global Health*, 9(4) :e409–e417, April 2021.

L. Mikkelsen, D. E. Phillips, C. AbouZahr, P. W. Setel, D. de Savigny, R. Lozano, and A. D. Lopez. A global assessment of civil registration and vital statistics systems : monitoring data quality and progress. *Lancet*, May 2015.

K. Moser, V. Shkolnikov, and D. Leon. World mortality 1950-2000 : divergence replaces convergence from the late 1980s. *Bulletin of the World Health Organization*, 83(3) :202–209, 2005.

J. Oeppen and J. Vaupel. Broken limits to life expectancy. *Science*, 296 (5570) :1029–1031, 2002.

James C. Riley. The timing and pace of health transitions around the world. *Population and Development Review*, 31(4) :741–764, 2005. ISSN 1728-4457. doi : 10.1111/j.1728-4457.2005.00096.x. URL `http://dx.doi.org/10.1111/j.1728-4457.2005.00096.x`.

David Sharrow, Lucia Hug, Danzhen You, Leontine Alkema, Robert Black, Simon Cousens, Trevor Croft, Victor Gaigbe-Togbe, Patrick Gerland, Michel Guillot, Kenneth Hill, Bruno Masquelier, Colin Mathers, Jon Pedersen, Kathleen L Strong, Emi Suzuki, Jon Wakefield, and Neff Walker. Global, regional, and national trends in under-5 mortality between 1990 and 2019 with scenario-based projections until 2030 : a systematic analysis by the UN inter-agency group for child mortality estimation. *The Lancet Global Health*, 10(2) :e195–e206, February 2022.

United Nations. *World Population Prospects : The 2022 Revision*. United Nations, 2022. URL `https://esa.un.org/unpd/wpp/`.

References III

Stein Emil Vollset, Emily Goren, Chun-Wei Yuan, Jackie Cao, Amanda E Smith, Thomas Hsiao, Catherine Bisignano, Gulrez S Azhar, Emma Castro, Julian Chalek, Andrew J Dolgert, Tahvi Frank, Kai Fukutaki, Simon I Hay, Rafael Lozano, Ali H Mokdad, Vishnu Nandakumar, Maxwell Pierce, Martin Pletcher, Toshana Robalik, Krista M Steuben, Han Yong Wunrow, Bianca S Zlavog, and Christopher J L Murray. Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100 : a forecasting analysis for the global burden of disease study. *The Lancet*, 396(10258) : 1285–1306, October 2020. doi : 10.1016/s0140-6736(20)30677-2. URL `https://doi.org/10.1016/s0140-6736(20)30677-2`.

C. Wilson. On the scale of global demographic convergence, 1950-2000. *Population and Development Review*, 27(1) :155–171, 2001.