

# **New Trend in the U.S. Mortality: Gompertzialization of Mortality Trajectory**

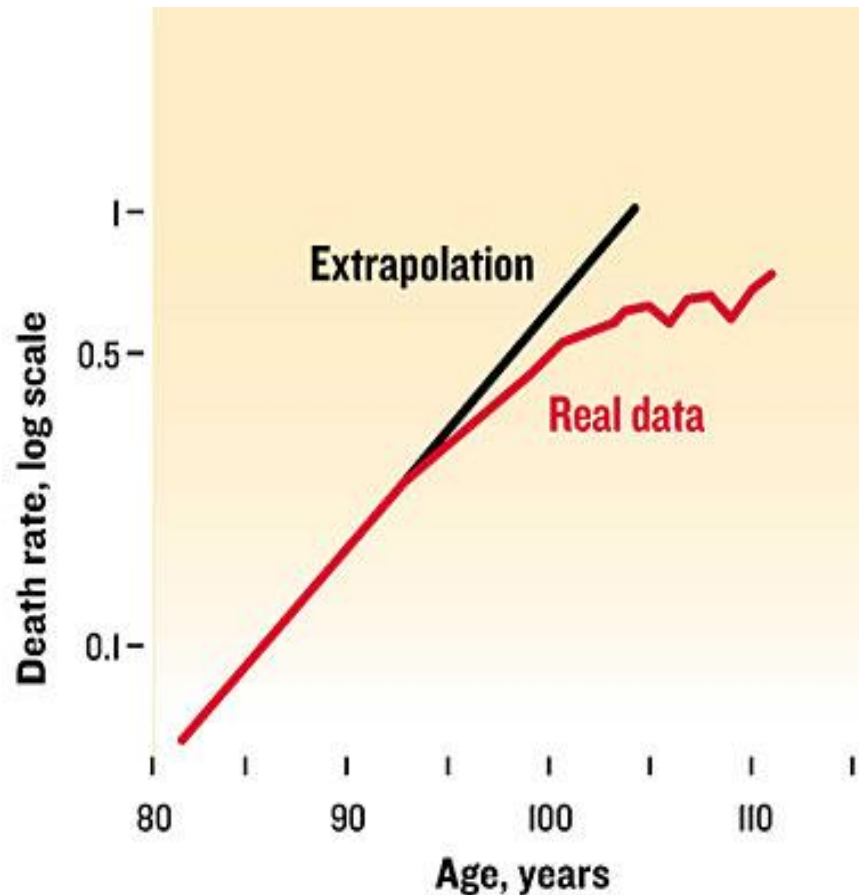
Dr. Natalia S. Gavrilova, Ph.D.

Dr. Leonid A. Gavrilov, Ph.D.

**Center on Aging  
NORC at The University of Chicago  
Chicago, Illinois, USA**

**Earlier studies** (*Greenwood and Irwin, 1939; Gavrilov and Gavrilova, 1991; Wilmoth, 1995; Horiuchi and Wilmoth, 1998; Thatcher, 1999*) suggested that the exponential growth of mortality with age (Gompertz law) is followed by a period of deceleration, with slower rates of mortality increase.

# Mortality deceleration at advanced ages



After age 95, the observed risk of death [red line] deviates from the values predicted by the Gompertz law [black line].

Mortality of Swedish women for the period of 1990-2000 from the Kannisto-Thatcher Database on Old Age Mortality

Source: Gavrilov, Gavrilova, "Why we fall apart. Engineering's reliability theory explains human aging". *IEEE Spectrum*. 2004.

# **Study of the Social Security Administration Death Master File**

## **MORTALITY MEASUREMENT AT ADVANCED AGES: A STUDY OF THE SOCIAL SECURITY ADMINISTRATION DEATH MASTER FILE**

Leonid A. Gavrilov\* and Natalia S. Gavrilova†

---

### **ABSTRACT**

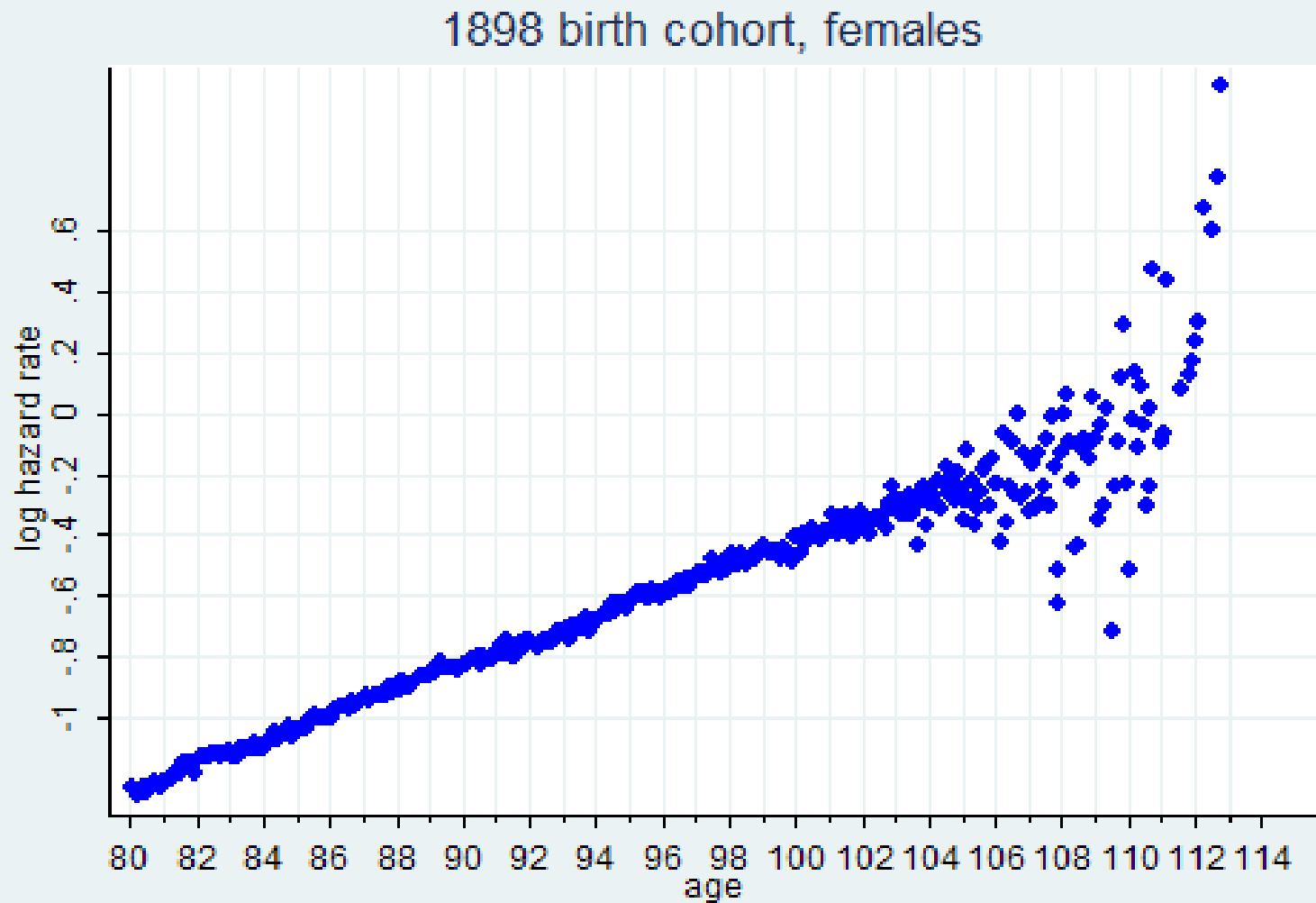
Accurate estimates of mortality at advanced ages are essential to improving forecasts of mortality and the population size of the oldest old age group. However, estimation of hazard rates at extremely old ages poses serious challenges to researchers: (1) The observed mortality deceleration

---

**NORTH AMERICAN ACTUARIAL JOURNAL, VOLUME 15, NUMBER 3**

***North American Actuarial Journal, 2011,  
15(3):432-447***

# U.S. 1898 birth cohort mortality



Data Source: Social Security Administration Death Master File  
Nelson-Aalen monthly estimates of hazard rates using Stata 11

# The second studied dataset: U.S. cohort death rates taken from the Human Mortality Database

*Journals of Gerontology: BIOLOGICAL SCIENCES*  
Cite journal as: *J Gerontol A Biol Sci Med Sci*  
doi:10.1093/gerona/глу009

© The Author 2014. Published by Oxford University Press on behalf of The Gerontological Society of America.  
All rights reserved. For permissions, please e-mail: [journals.permissions@oup.com](mailto:journals.permissions@oup.com).

## Biodemography of Old-Age Mortality in Humans and Rodents

Natalia S. Gavrilova and Leonid A. Gavrilov

Center on Aging, NORC at the University of Chicago, Chicago, Illinois.

Address correspondence to Natalia S. Gavrilova, PhD, Center on Aging, NORC at the University of Chicago, 1155 East 60th Street, Chicago, IL 60637.  
Email: [gavrilova@longevity-science.org](mailto:gavrilova@longevity-science.org)

The growing number of persons living beyond age 80 underscores the need for accurate measurement of mortality at advanced ages and understanding the old-age mortality trajectories. It is believed that exponential growth of mortality

**What is the reason  
for this controversy  
between old and  
new findings?**

# **Is Mortality Deceleration Caused by Age Misreporting?**

**It was demonstrated that age misstatement biases mortality estimates downwards at the oldest ages, which contributes to mortality deceleration (Preston et al., 1999).**

**If this hypothesis is correct then mortality deceleration should be more prevalent among historically older birth cohorts when data were less reliable.**



# Study of historical evolution of old-age mortality trajectories

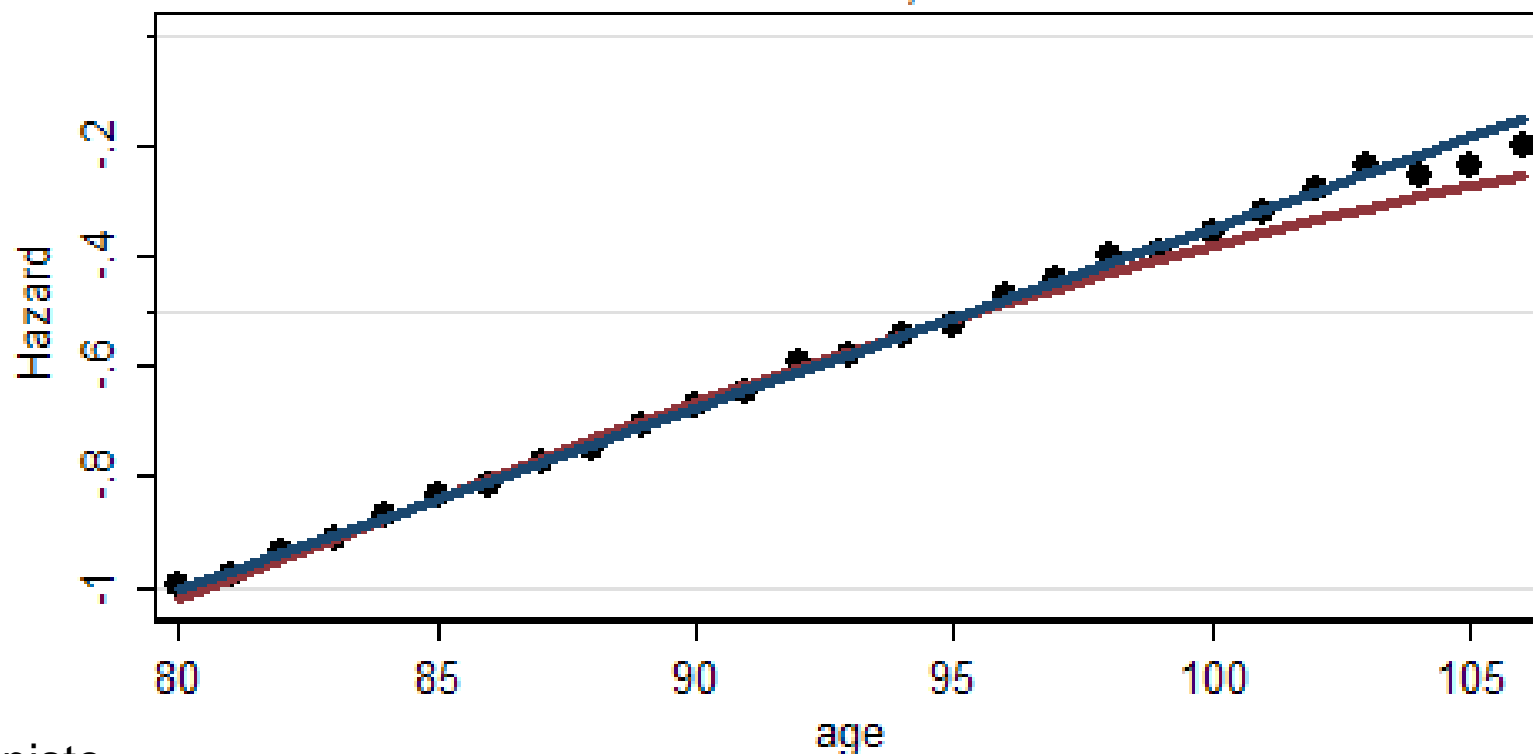
**Data:** Age-specific cohort death rates for 1880-1899 single-year birth cohorts for the United States and Canada (from the Human Mortality Database)

**Analysis:** Weighted non-linear regression with Gompertz and Kannisto models for mortality in the age interval 60-105 year

**Accuracy of fit** was estimated using Bayesian information criterion (BIC)

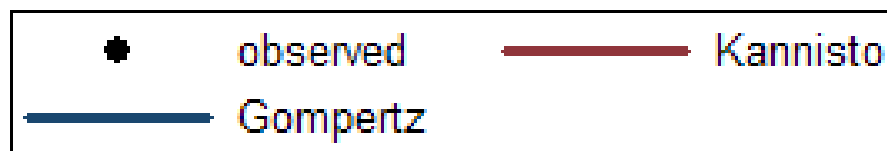
# Fitting mortality with Kannisto and Gompertz models, HMD U.S. data

1895 cohort, Males



Kannisto model

$$\mu_x = \frac{ae^{bx}}{1 + ae^{bx}}$$



Gompertz model

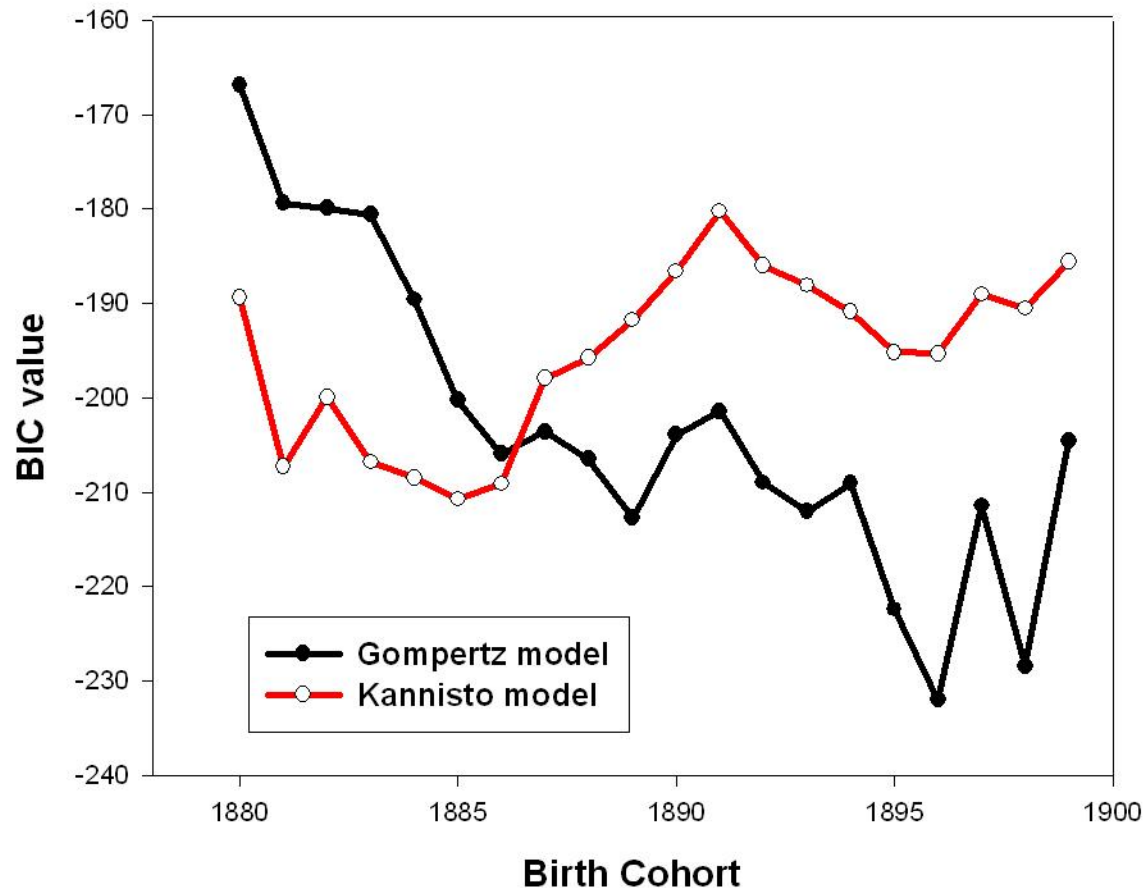
$$\mu_x = ae^{bx}$$

# Historical Evolution of Mortality Trajectories

## 1880-1899 single-year U.S. birth cohorts. Men

### BIC values for fitting Gompertz and Kannisto models

Lower BIC values = better fit

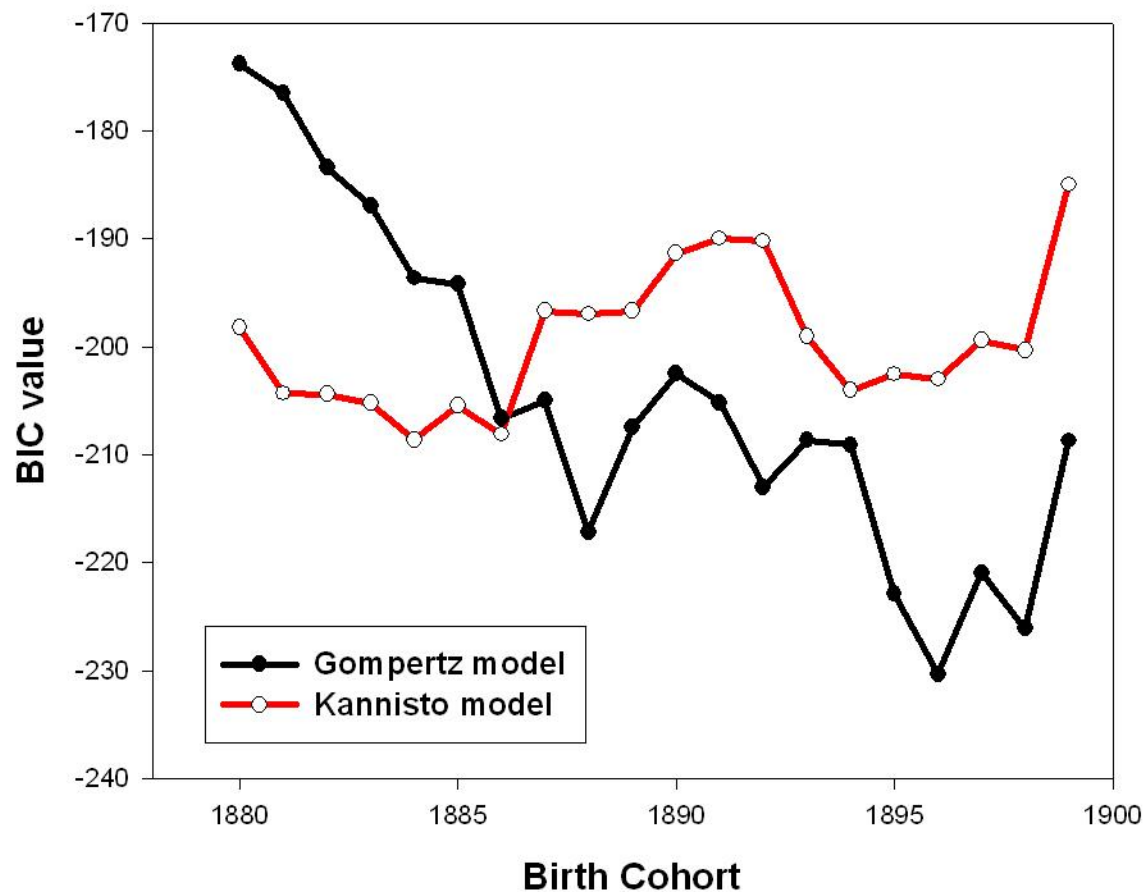


Fitting age-specific cohort death rates taken from the Human Mortality Database

# 1880-1899 single-year U.S. birth cohorts. Women

## BIC values for fitting Gompertz and Kannisto models

Lower BIC values = better fit



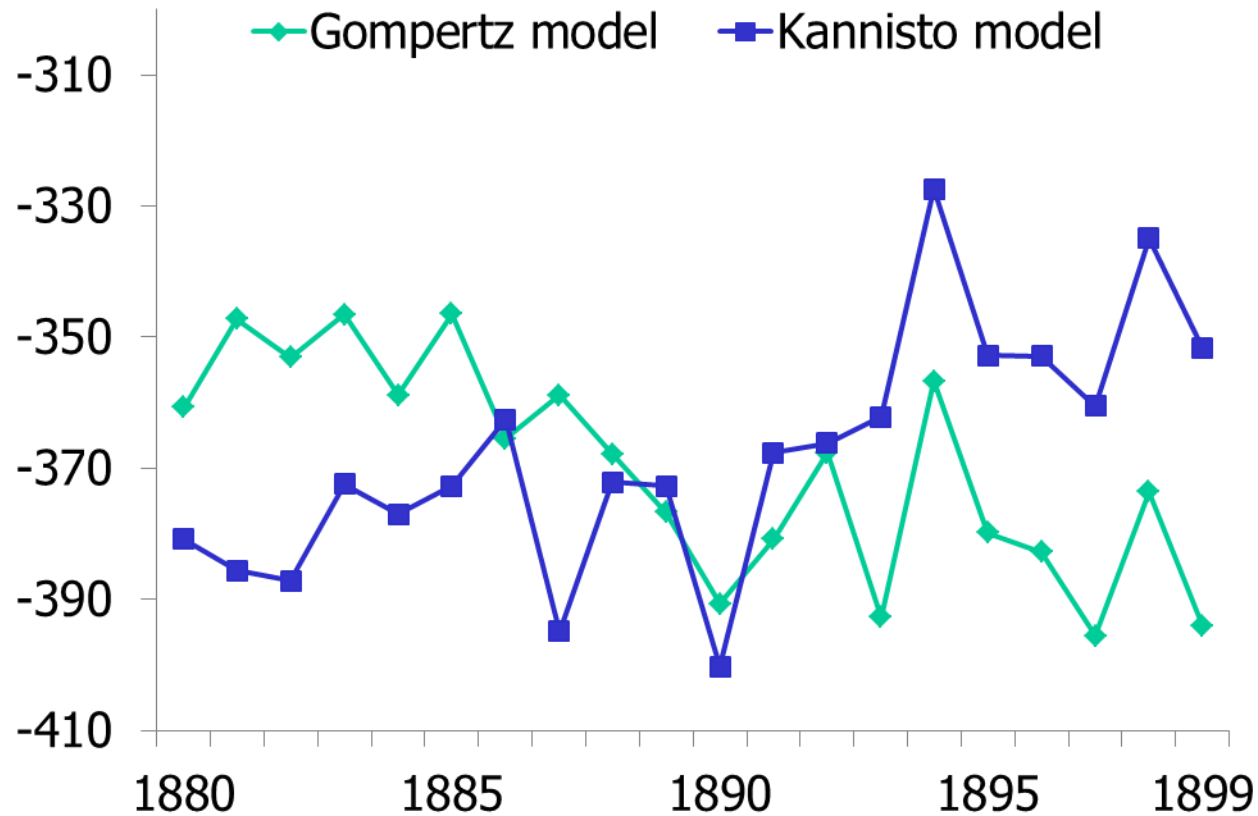
Fitting age-specific cohort death rates taken from the Human Mortality Database

# Historical Evolution of Mortality Trajectories

## 1880-1899 Canadian birth cohorts. Men

### BIC values for fitting Gompertz and Kannisto models

Lower BIC values = better fit



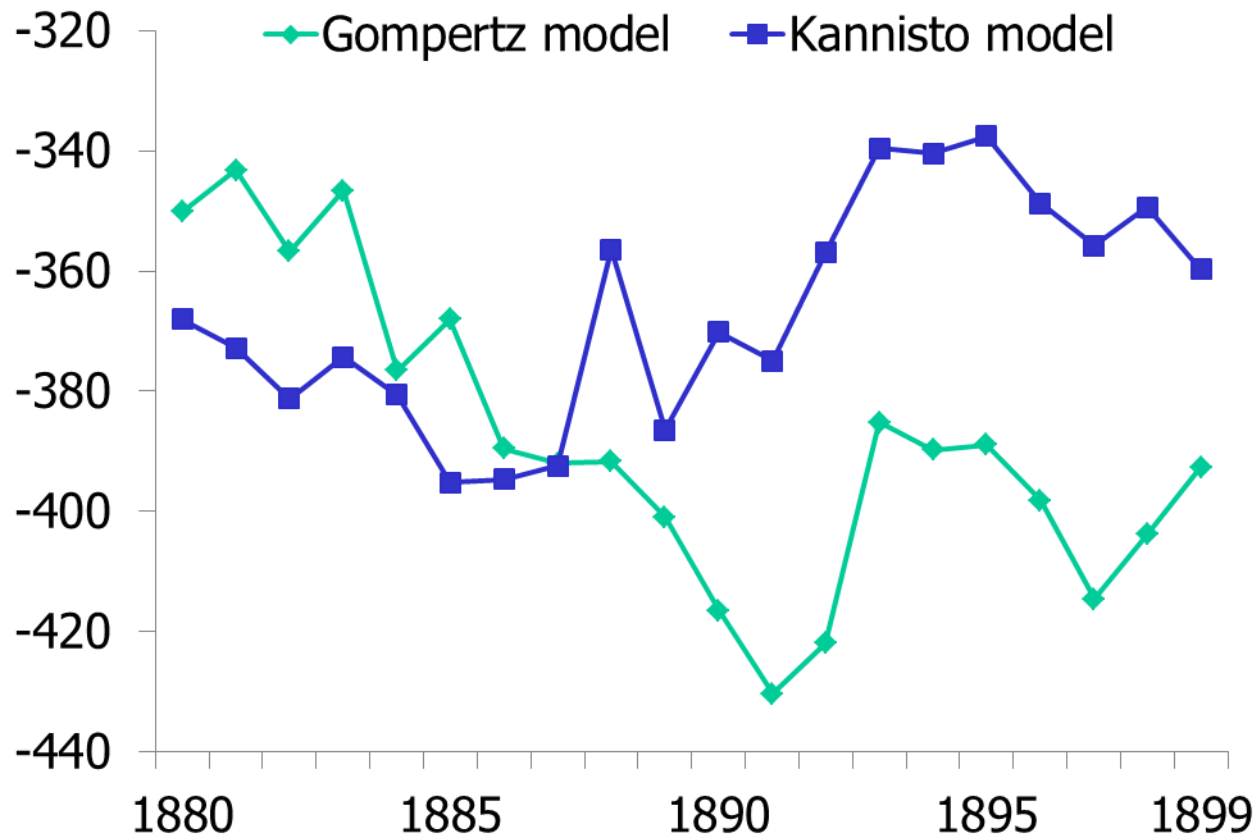
Fitting age-specific cohort death rates taken from the Human Mortality Database

# Historical Evolution of Mortality Trajectories

## 1880-1899 Canadian birth cohorts. Women

### BIC values for fitting Gompertz and Kannisto models

Lower BIC values = better fit



Fitting age-specific cohort death rates taken from the Human Mortality Database

# Conclusion

**Mortality deceleration is more prevalent in historically older birth cohorts when age reporting was less accurate**

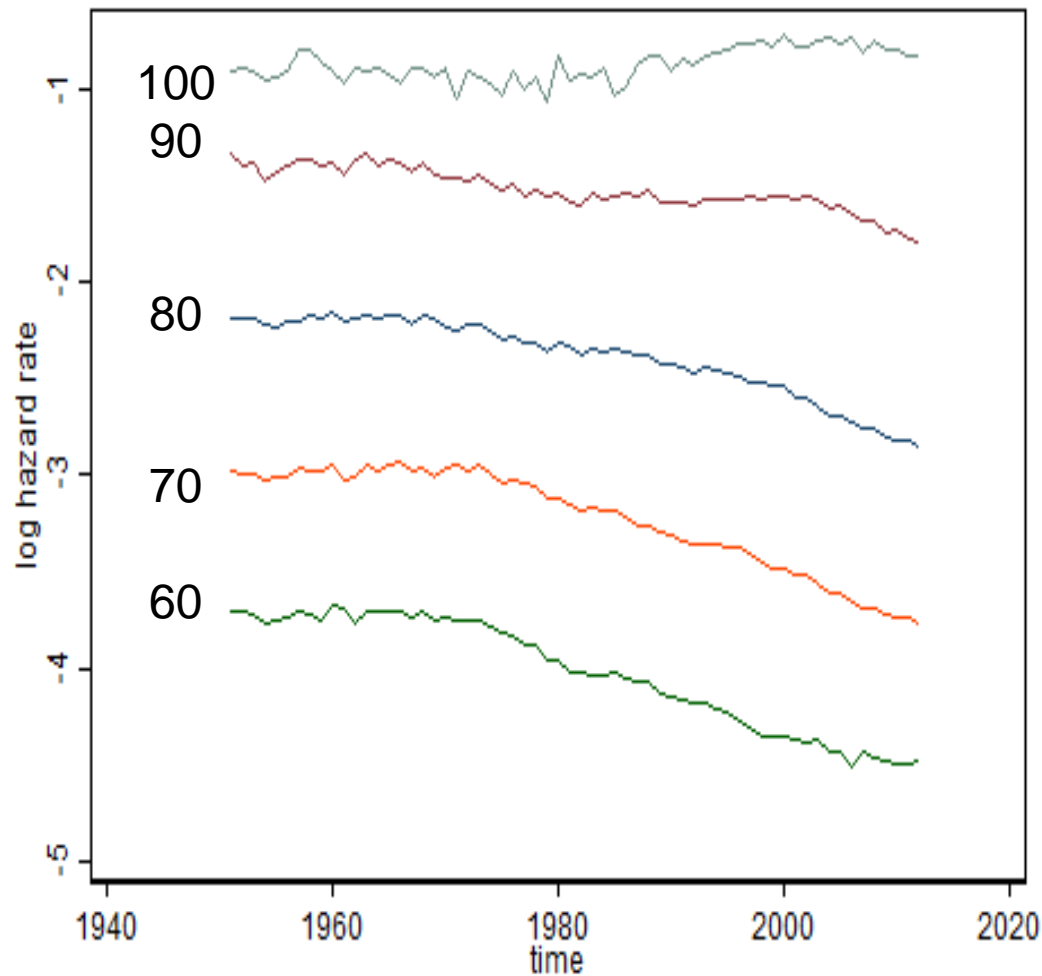
# **What can explain this observation?**

- **Improvement of age reporting**
- **No improvement for mortality of centenarians**

**Found for Swedish, Danish and UK centenarians**



# Mortality of Male Centenarians Does Not Decline Over Time

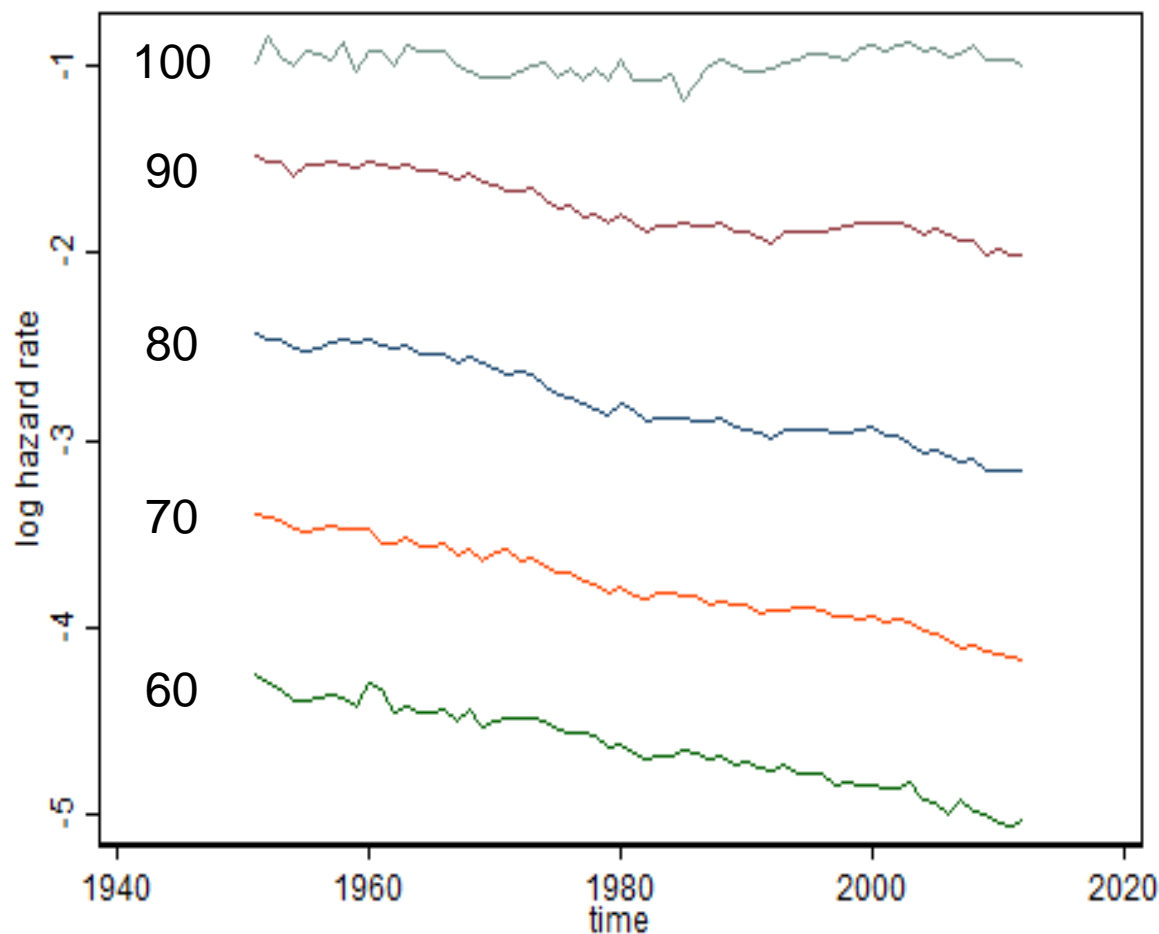


**Mortality of U.S.  
Men at 60, 70, 80,  
90 and 100 years**

Based on data from  
the Human Mortality  
Database

Source: Gavrilov et  
al., Gerontology, 2017

# Mortality of Female Centenarians Does Not Decline Over Time



**Mortality of U.S. Women at 60, 70, 80, 90 and 100 years**

Based on data from the Human Mortality Database

Source: Gavrilov et al., Gerontology, 2017

# Conclusions

**Gompertzialization of old-age mortality trajectories over time.**

**Mortality stagnation over time for centenarians.**

**These two trends may potentially lead to accelerating pattern of mortality increase with age in the future**

**As a result, the number of centenarians in the future may be lower than expected**

# Acknowledgments

This study was made possible thanks to:

generous support from the  
National Institute on Aging (R21AG054849)

Stimulating working environment at the  
Center on Aging, NORC/University of Chicago

**For More Information and Updates  
Please Visit Our  
Scientific and Educational Website  
on Human Longevity:**

**<http://longevity-science.org>**