PAA 2011 Extended Abstract.

Gompertz analysis of pneumonia and influenza death rates by age, United States, 1959–2006*

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Abstract

Pneumonia and influenza incidence and death rates are often analyzed as time series. A variety of techniques are used therein, most notably Serfling regression to calculate excess mortality (or excess incidence) by establishing a baseline which is then subtracted from the observed data. In this paper we explore a different approach, which is designed to fit alongside Serfling regression, not to supplant it. Serfling regression and similar approaches are time domain techniques. We perform what might be called parametric age domain analysis, where we model he steepness of the increase, by age, in pneumonia and influenza death rates. Gompertz models fit an exponential curve to hazard rates (death rates) by age. By performing this analysis for the 47 years of available data, we get a picture of how the age profile of influenza mortality has changed in the United States over the last half-century, spanning the pre-vaccination era, the era of vaccine adoption, and the current era of reasonably high vaccination rates at old ages.

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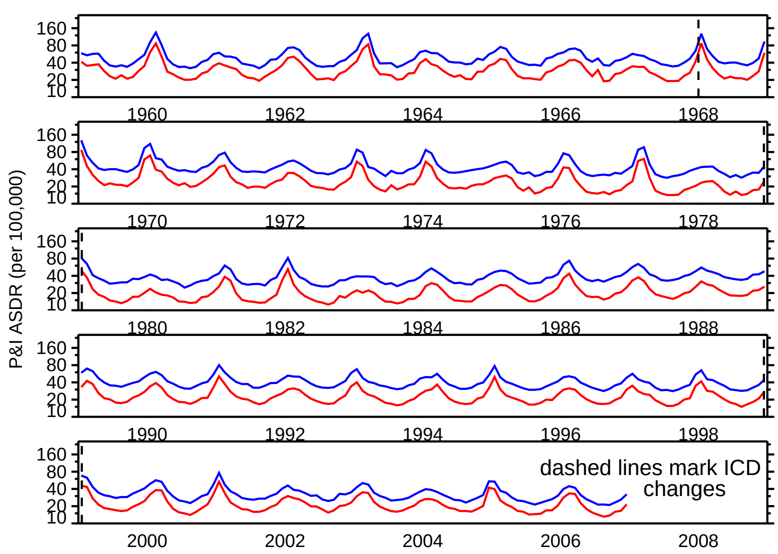
1 Background

- Pneumonia & Influenza ("P&I") death rates are often analyzed as time series
- Serfling regression is typically used to establish excess (i.e., above-baseline) mortality
- The time domain approach is just one possibility; the data are multi-dimensional (time, age) so time domain (or frequency domain) approaches may be supplemented by what we informally call age domain analysis
- We do a type of age domain analysis borrowed from demography, where there is a parametrization of the level (α) and slope (β) of P&I mortality by age

2 Pneumonia & Influenza Mortality

- Problem: time series at many age groups: $\{0\},\{1–4\},\{5–9\},\ldots,\{85+\}$
- The age-standardized death rate (ASDR) is a weighted average of death rates at all ages. Shown here are raw P&I ASDRs, not excess mortality:



Males are blue females are red.

- This compresses, not uses, information on age
- Doing separate time domain analysis for each age just swamps the analysis and is still not really an age analysis — it's a time analysis × many ages
- The demographic approach is to consider explicit variation by age

3 Gompertz Analysis

The Gompertz mortality model is:

$$h(x) = \alpha \exp(\beta x), \tag{1}$$

where $h(\cdot)$ is the mortality hazard, x is age, and α, β are parameters.

Logging both sides, this is equivalent to:

$$\log(h(x)) = \log(\alpha) + \beta x. \tag{2}$$

Thus, if a mortality regime is Gompertzian, it is simply a matter of regressing log hazards as y and age as x in an OLS regression, to get estimates of α and β. Death counts in each cell are used as weights, to avoid giving oldest ages with few deaths (historically, age 85+) undue influence.

- Gompertz mortality is monotonically increasing so only applies to old age
- We restrict to age>45
- Empirical death rates may be used instead of hazards (which would be calculated from a life table)

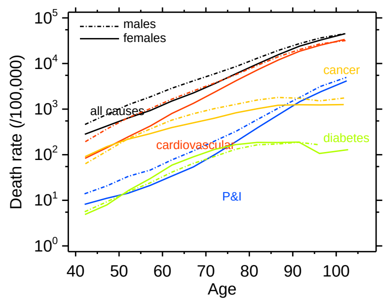
4 Materials and Methods

- Monthly death counts from US National Center for Health Statistics (`http://www.cdc.gov/nchs/`)
- Population counts (exposure) from the Human Morality Database (`http://www.mortality.org/`), interpolated to months
- Monthly P&I rates calculated (see above figure)

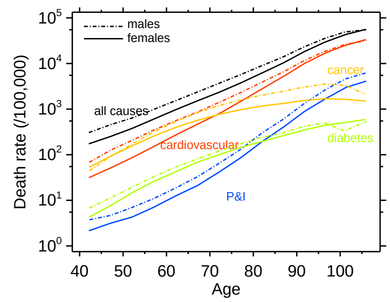
- Monthly data aggregated to "Summer" (May–October) and "Winter" (November–April) half-years
- ICD adjustment according to published conversion tables

5 "Age Domain" Plots — Comparison with Other Causes of Death

1960 (calendar year):



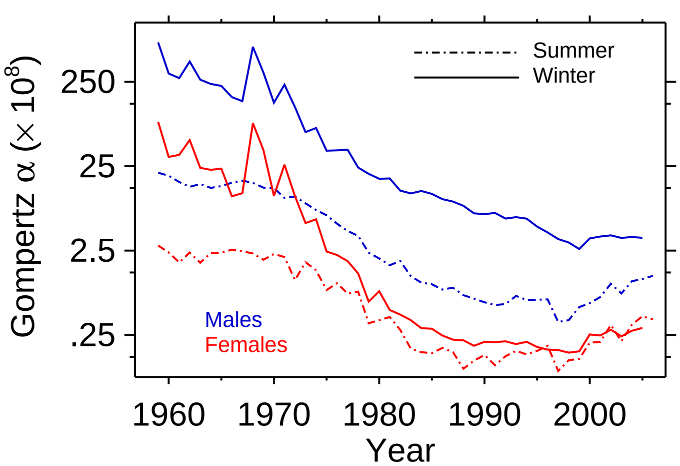
2000 (calendar year):



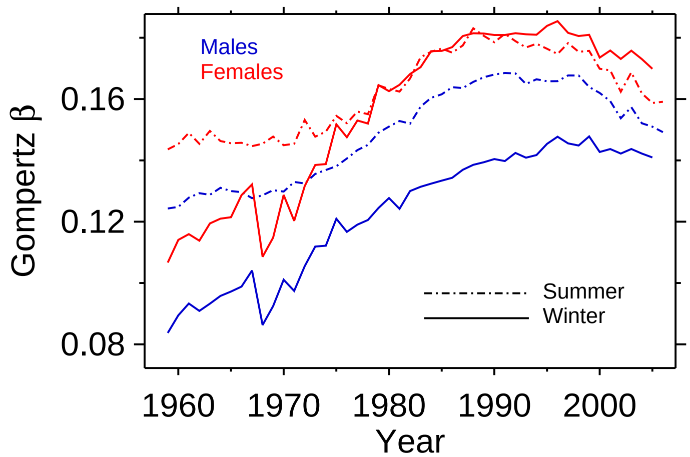
Note the linearity on log scale of P&I death rates

6 Gompertz Results

Level Parameter (α):



Slope Parameter (β):



Note the 1968–69 (H3N2) pandemic.

7 Conclusions

- The secular decline of P&I mortality is mostly about changes in level, not in slope, of Gompertzian mortality
- The steepness of the age profile of P&I mortality, as modeled by the Gompertz β, has increased in the past 50 years
- The leveling of β in the last $\sim$15 yr may be due to vaccination
  - Note, however, that α and β tend to move in compensatory ways, and during the period where β has leveled-off, α has increased or stopped declining
- The 1968–69 pandemic showed an increase in α and a compensatory decrease in β — $\max(\alpha)$ and $\min(\beta)$ correspond to the H3N2 pandemic, but the summer data are unaffected
- The summer:winter difference in the age structure of P&I mortality is greater for men than for women, but only since about 1980
  - To be more precise, female patterns across the two half-year periods have converged over the last 50 years, whereas for males

the patterns move in parallel. Whenever possible, P&I mortality analysis should be conducted separately by sex

8 Key Literature

- An example of the Serfling approach for elderly (large literature here): A. T. Newall, C. Viboud, C. and J. G. Wood. 2010. Influenza-attributable mortality in Australians aged more than 50 years: A comparison of different modelling approaches. *Epidemiology and Infection*, 138(6):836–842

- Age distribution using the Serfling approach: Lone Simonsen *et al.* 1998. Pandemic versus epidemic influenza mortality: A pattern of changing age distribution. *Journal of Infectious Diseases*, 178(1):53-60

- Similar approach to ours: Shiro Horiuchi and John R. Wilmoth. 1997. Age patterns of the life table aging rate for major causes of death in Japan, 1951–1990. *Journal of Gerontology: Biological Sciences*, 52A(1):B67–B77