Machine Learning in Demography

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Main contributions... so far....

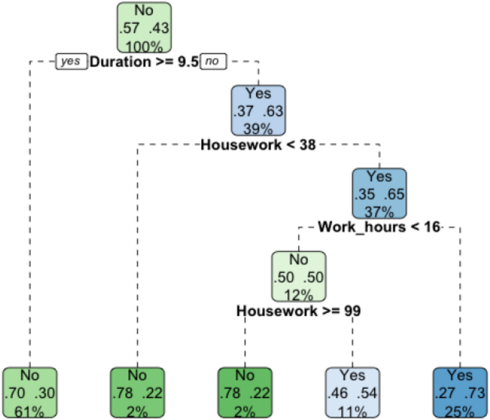
- Machine Learning techniques for family demography:An application of random forests to the analysis of divorce determinants in Germany.2018. (B.Arpino, M. Le Moglie,L. Mencarini)
- New methods for estimating detailed fertility schedules from abridged data. 2018. (Grigoriev, P., Michalski, A. I., Gorlischev, V. P., Jdanov, D. A., Shkolnikov, V. M.)
- A Neural Network Analyzer for Mortality Forecast. 2018. (D. Hainaut)
- Machine Learning Techniques for Mortality Modeling. 2017. (P. Deprez, P. V. Shevchenko, M. V. Wüthrich)

Demographic Applications

Machine Learning techniques for family demography:An application of random forests to the analysis of divorce determinants in Germany.2018. (B.Arpino, M. Le Moglie,L. Mencarini)

- they use longitudinal data from the German Socio-Economic Panel survey (SOEP)
- individuals aged up to 65 years and who started their relationship during the observation period (i.e., 1984- 2015). Followed until the union ends or until the last available observation
- The final sample consists of 18,613 observations (2,038 couples observed, on average, over 12.6 years).

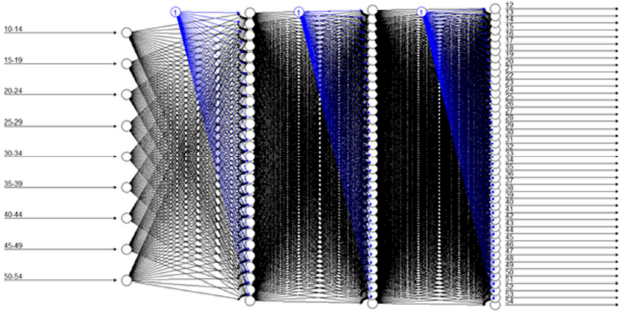
Demographic Applications



Demographic Applications

New methods for estimating detailed fertility schedules from abridged data. 2018. (Grigoriev, P., Michalski, A. I., Gorlischev, V. P., Jdanov, D. A., Shkolnikov, V. M.)

- main aim, split aggregated fertility data into a fine grid of ages by using NN



Demographic Applications

A Neural Network Analyzer for Mortality Forecast. 2018. (D. Hainaut)

- The author obtains the Lee Cater parameters by using an NN instead of the SVD

Demographic Applications

Machine Learning Techniques for Mortality Modeling. 2017. (P. Deprez, P. V. Shevchenko, M. V. Wüthrich)

- authors by using regression tree illustrate how machine learning techniques allow us to analyze the quality of mortality models.
- the feature space where the tree has been applied : $X = GxAxT$
- These techniques show the weaknesses of mortality models .

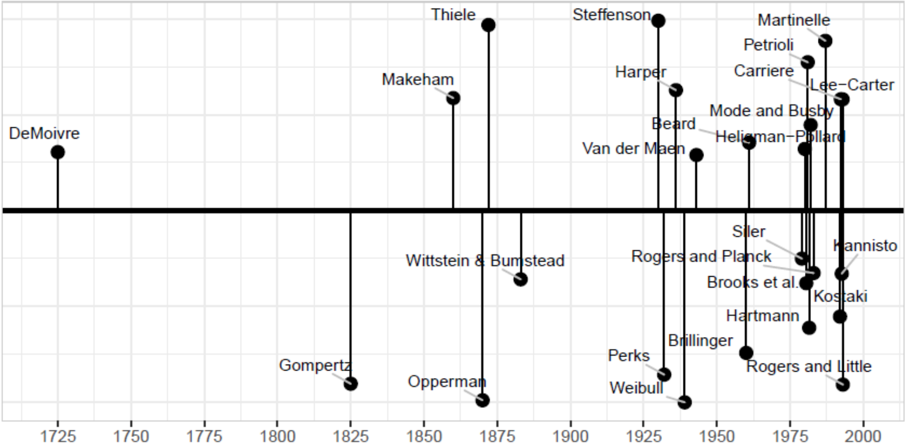
$$\Delta q^{\mathrm{LC}}(\boldsymbol{x}) = \frac{q^{\mathrm{tree}}(\boldsymbol{x}) - q^{\mathrm{LC}}(\boldsymbol{x})}{q^{\mathrm{LC}}(\boldsymbol{x})} = \hat{\mu}(\boldsymbol{x}) - 1, \qquad \text{for } \boldsymbol{x} \in \mathcal{X}.$$

Mortality Modelling. Crash Course

Mortality Modelling. Crash Course

- In the last century the increase in life expectancy, often at a faster rate than expected, raised a significant challenge for life insurers and public retirement systems.
- The desire to anticipate future mortality changes, lead to large efforts devoted to developing mathematical methods to predict the future.
- The first attempts lead to simple models until the statistical theory evolution, which made possible the so-called stochastic models.

Mortality Modelling. Crash Course



Mortality Modelling. Crash Course

... Stochastic Models

- Nowadays this latter approach represents the most widespread among scholars
- Thanks to its advantages just like the possibility to obtain a mortality surface as output
- One of the most used stochastic models is the Lee-Carter (1992)

Model:Lee-Carter

LC proposes a log-bilinear model for mortality rates incorporating both age and year effects:

$$ln(m_{ij}) = \alpha_i + \beta_i \kappa_j + \varepsilon_{ij} \tag{1}$$

α_i is the general shape of the log-mortality at age i
κ_j represents the time trend index of general mortality level
β_i indicates the sensitivity of the log-mortality at age i to variations in the time index
ε_{ij} is the residual term at age x and time t.

With constraints:

$$\sum_i {\beta_i}^2 = 1; \ \sum_j k_j = 0 \tag{2}$$

Lee-Carter model has been used and revised since 1992

- Booth and Tickle (2008), Booth et al. (2006), Li and Lee (2005), Renshaw and Haberman (2006)
- its canonical version is still broadly used as a benchmark. The scientific environment has been dominated by Lee Carter model approach

Mortality Modelling. Crash Course

Parallel Approaches

- Life Expectancy Forecast:
  - Oeppen and Vaupel (2002)
  - Torri and Vaupel (2012)
  - Lee (2006)
  - Raftery et al. (2013)
  - Pascariu et al. (2018)
- Age at Death distribution
  - Basellini and Camarda (2019)
  - Pascariu et al. (2018)

Mortality Modelling. Crash Course

Once a model has been developed and parameters have been estimated or calibrated, it is important to consider whether it is a good model or not. Guidelines by Cairns, Blake and Dowd (2008)

- The model should be consistent with historical data.
- Long-term dynamics under the model should be biologically reasonable.
- Parameter estimates should be robust relative to the period of data and range of ages employed.
- Model forecasts should be robust relative to the period of data and range of ages employed.
- The model should be relatively parsimonious.

Mortality Modelling. Crash Course

Unfortunately, many of the demographic models do not meet these requirements. So there is a need to improve classical approaches. Machine (and Deep) Learning can help us.

- **A Deep Learning Integrated Lee-Carter Model.**
  2019.(A. Nigri,S. Levantesi, M. Marino, S. Scognamiglio and F. Perla)
- **Application of Machine Learning to Mortality Modeling and Forecasting.**
  2019.(S. Levantesi and V. Pizzorusso)

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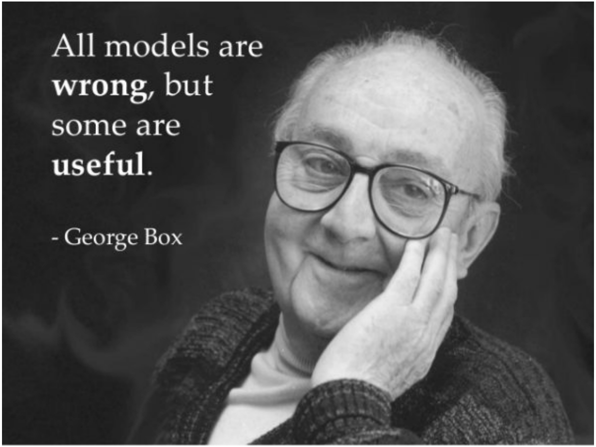
- parsimony criterion
- simple is better than complex



POLICY FORUM: DEMOGRAPHY

Broken Limits to Life Expectancy

Jim Oeppen and James W. Vaupel*

Is life expectancy approaching its limit? Many—including individuals planning their retirement and officials responsible for health and social policy—believe it is. The evidence suggests otherwise.

Consider first an astonishing fact. Female life expectancy in the record-holding country has risen for 160 years at a steady pace of almost 3 months per year [Fig. 1 and suppl. table 1 (*1*)]. In 1840 the record was held by Swedish women, who lived on average a little more than 45 years. Among na-

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in income, salubrity, nutrition, education, sanitation, and medicine, with the mix varying over age, period, cohort, place, and disease (*4*). Before 1950, most of the gain in life expectancy was due to large reductions in death rates at younger ages. In the second half of the 20th century, improvements in survival after age 65 propelled the rise in the length of people's lives. For Japanese females, remaining life expectancy at age 65 grew from 13 years in 1950 to 22 years today, and the chance of surviving from 65 to 100 soared from less than 1 in 1000 to 1 in 20 (*1*). The details are complicated but the resultant straight line of life-

output and in population size, including an explosion in the number of the elderly (*5*, *6*). Although students of mortality eventually recognized the reality of improvements in survival, they blindly clung to the ancient notion that under favorable conditions the typical human has a characteristic life-span. As the expectation of life rose higher and higher, experts were unable to imagine its rising much further. They envisioned various biological barriers and practical impediments. The notion of a fixed life-span evolved into a belief in a looming limit to life expectancy.

Ultimate Expectations of Life

In 1928, Louis Dublin quantified this consensus (*7*). Using U.S. life tables as a guide, he estimated the lowest level to which the death rate in each age group could possibly be reduced. His calculations were made "in the light of present knowledge and without intervention of radical innovations or fantastic evolutionary change in our physiological make-up

- Oeppen and Vaupel 2002 they show a remarkable linear trend in the female life expectancy (at birth, period basis), from 1840 to 2000.
- Over this entire 160-year period, the record life expectancy consistently increased by 0.24 years of life per calendar year of time.

Key Message:... rate of 24 years per century.