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Computational Methods for Modelling Mortality and Fertility Projections: Application to Spanish Demography

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Abstract

Spain faces a demographic future with low birth rates. In addition, it is one of the countries with a higher life expectancy, therefore, for economic, social and politics purposes is important to project and forecast such mortality and fertility rates. Mortality and fertility rates are simulated for this country using GAPC stochastic models for mortality forecasting and a Bayesian projection model for fertility projections.

Structure and Methodology

First section points out the worldwide demographical transition and the expected rates for longevity and fertility phenomena for next years. Second and third sections are devoted to fit and simulate mortality and fertility rates for Spain using models and computational methods with **R**. Finally, main conclusions are addressed and most relevant references are provided.

The Demographic Phenomena

The world is getting older. And it does so because it is undergoing a demographic transformation. Human beings live longer and whereas life expectancy has increased, fertility rates are decreasing. Thus:

- I) The projected global life expectancy at birth is expected to reach 83 years in 2095 and
- II) the projected fertility rate will decrease to two births per woman by the same year.

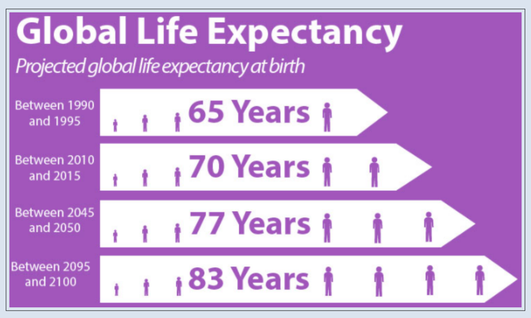

Figure 1: Source: *World Population Prospects: 2017 Revision.*

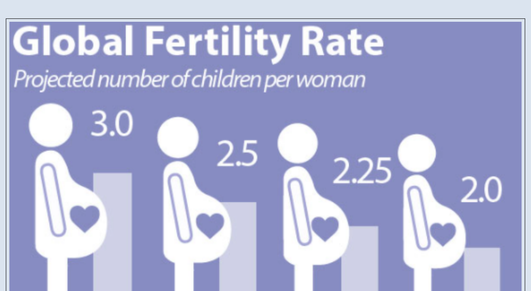

Figure 2: Source: *World Population Prospects: 2017 Revision.* United Nations Department of Economic and Social Affairs, Population Division.

The evolution of the age structure of the population allows a better understanding of aging:

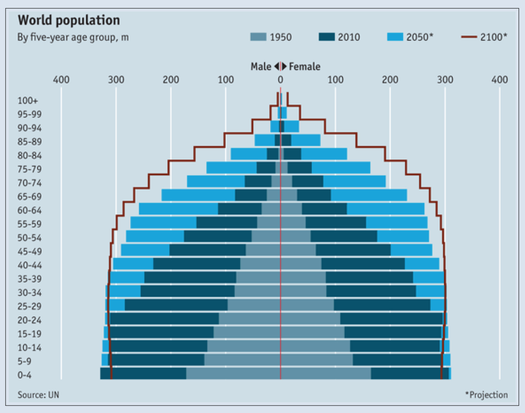

Figure 3: Worldwide population structure. Source: *ONU.*

A 47% increasing in worldwide population is expected for the next 80 years.

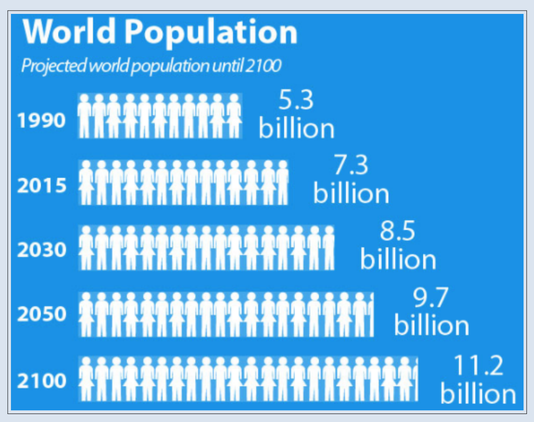

Figure 4: Source: *World Population Prospects: 2017 Revision.* United Nations Department of Economic and Social Affairs, Population Division.

Stochastic Mortality Modelling for Spanish Population with StMoMo

The R package StMoMo (Villegas et. al., 2017) is used to project the mortality rate according to age, sex and time for the spanish population.

Models Comparison

Based on two criteria:

1. Quantitative Criteria:
   - ⇒ Bayes Information Criteria (BIC).
   - ⇒ Incomplete. Doesn't provide all the information.
2. Qualitative Criteria:
   - ⇒ Transparency and reasonable forecasting.
   - ⇒ Age and period robustness.
   - ⇒ Biologically reasonable.

Most Important Models

Lee-Carter, (1992); *Renshaw-Haberman*, (2006); *Age-Period-Cohort* (APC); *Cairns-Blake-Dowd*, (2006); *Cairns et. al.*, (2007a y 2007b),...

The Need of Mortality Models

- With reliable data, the underlying process is driven by a stochastic process.
- Mortality evolution uncertainty.
- Better **longevity risk management**.
- Risk reserve setting.
- Design of *insurance-life contracts with integrated options.*
- Pricing and hedging of assets linked to mortality.
- Improving strategies for pension funds and policymakers.

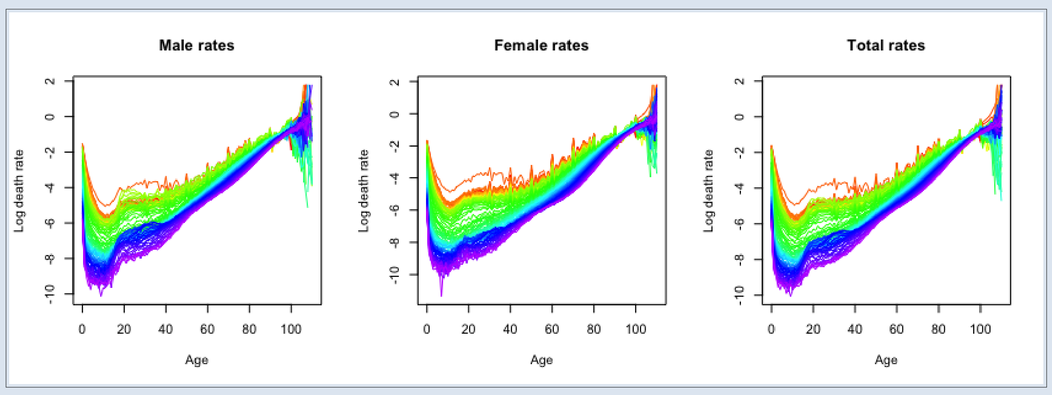

Figure 5: Logarithm pattern of mortality rates according to age and time for the Spanish population. Several behaviors are shown, respectively, for men, women, and total population. For the Lee-Carter model (without the logarithmic transformation) the **R** function *"lca"* can be used, also being applied separately between men, women and the total population and considering a maximum age of 100 years.

European Fertility Rates

Fertility rates in Europe are decreasing at all levels: by country and region. The spanish case is particularly severe.

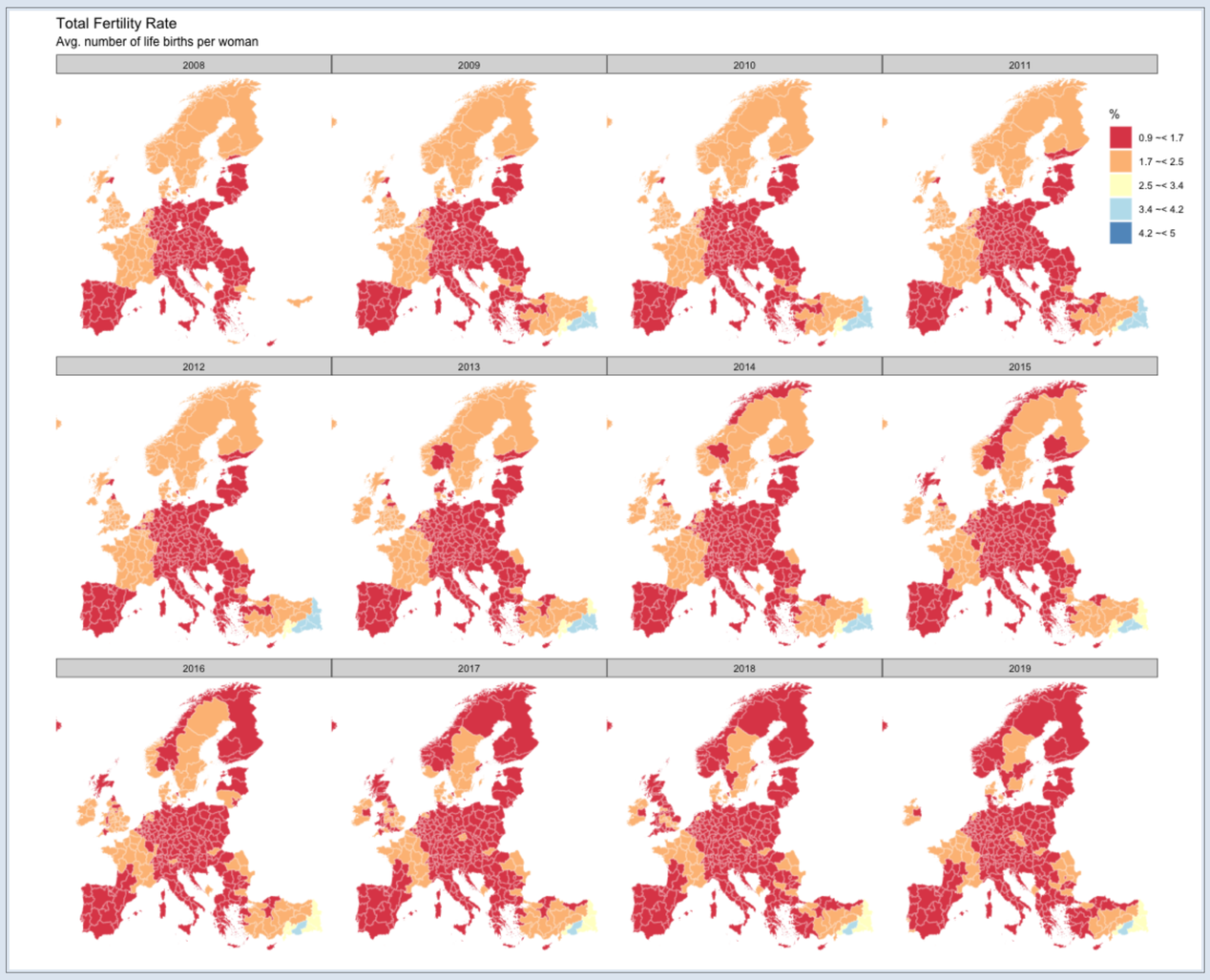

Figure 6: Total Fertilty Rate (average number of births per woman NUTS-3 level. *Source: EUROSTAT.*

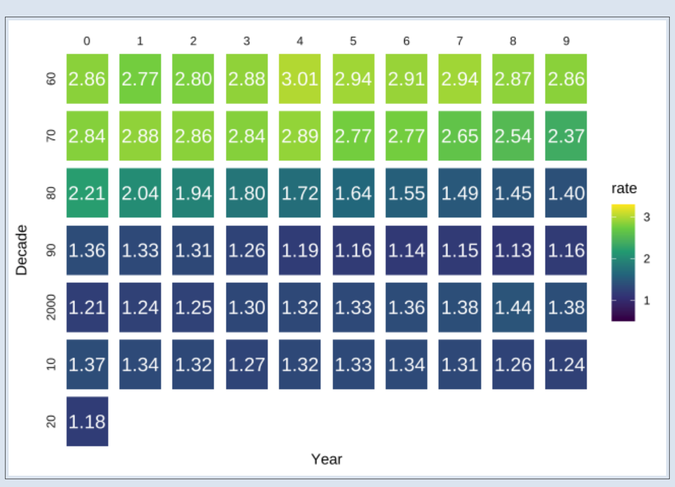

Figure 7: Spanish Fertility Rate Evolution 1960-2020. *Source: Eurostat*

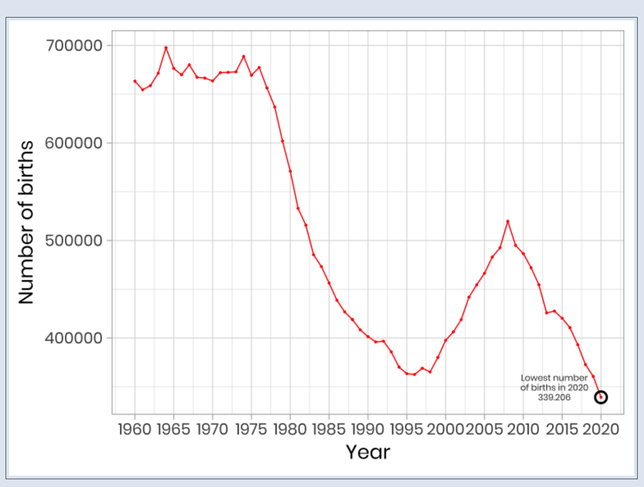

Figure 8: Number of births is Spain 1960-2020. *Source: INE*

Fitting and Projection of the 'bayesTFR' Model for the Spanish Population

The model proposed by Ševčíková et al. (2011) uses 5-year estimates of the TFR (Total Fertility Rate) from several periods and based on the observation that the evolution of TFR includes three broad phases: Phase I: a pre-transitional high fertility phase; Phase II: the transition to fertility in which the TFR decreases from high fertility levels to or below the replacement fertility level and Phase III, where after the low fertility transition, which includes recovery of fertility below replacement towards replacement fertility and oscillations around fertility at that same level.

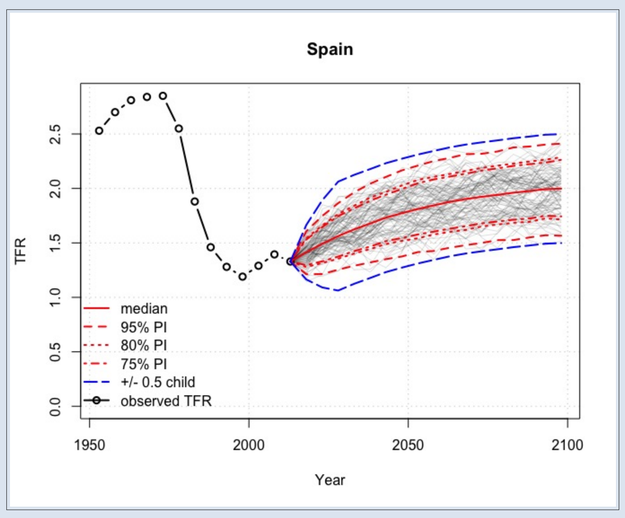

Figure 9: Spanish Fertility Rate Projections.

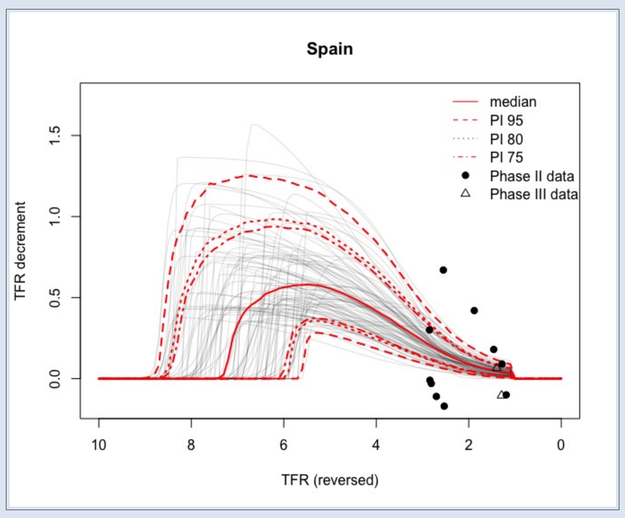

Figure 10: Spain (hierarchical) mean of the decline curve.

Conclusions

A three-parameter model can capture most of the variation in the fertility and mortality patterns observed. Models with more parameters, for most of the purposes, they are not necessary, and they may experience difficulties adapting such models to a small number of data.

Extract of Most Relevant References

1. Villegas, A., Kaishev, V., Milosovich, P. (2017): **StMoMo: An R Package for Stochastic Mortality Modeling**.
2. Ševčíková, H., Alkema, L. and Raftery, A. E. (2011): **bayesTFR: An R Package for Probabilistic Projections of the Total Fertility Rate**, Journal of Statistical Software, 43, 1, 1-29 https://www.jstatsoft.org/v43/i01/

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