Bayesian cohort component population projections: An exploration of different model specifications

Peter W.F. Smith and James Raymer

ESRC Research Centre for Population Change

University of Southampton

25 April 2012

Abstract

In this paper, we explore the use of Bayesian methods for cohort component population projections. The rationale for considering a Bayesian approach is that it offers a more natural framework than traditional probabilistic methods to project future populations with uncertainty measures. We focus on only a small part of the picture, that is, to explore the consequences of choosing different specifications of age-specific fertility and mortality in a closed cohort projection model in terms of its forecasted populations and measures of uncertainty. For illustration, we use a historical time series of fertility and mortality from England and Wales. The data consist of age-specific rates for single years of age going back in time to 1841 for mortality and 1974 for fertility. Finally, we present and compare the projected populations, with associated measures of uncertainty, and evaluate the merits of the various specifications for including fertility and mortality.

Extended abstract

In this paper, we explore the use of Bayesian methods for cohort component population projections. The main motivation is the need to incorporate uncertainty into population

estimates and projections. Since the 1990s, there has been an increasing need to move away from deterministic and variant-style projections to probabilistic projections. Probabilistic projections have the advantage over variant style projections in that they specify the likelihood that a particular future population value will occur (Ahlburg and Land 1992; Lee and Tuljapurkar 1994; Lutz 1996; Bongaarts and Bulatao 2000). With variant projections, on the other hand, the user has no idea how likely they are, only that they are plausible scenarios representing the "most likely" and the "extreme" high and low possibilities. Despite the advantages of probabilistic projections, they have yet to be widely adopted by statistical agencies for several reasons (Lutz and Goldstein 2004). First, there are many types of uncertainties to consider, and including them in projections is not always straightforward, and it can be misleading to include them incorrectly. Second, national statistical offices do not always have the necessary expertise to develop probabilistic models or to extend their current models to include probabilities. Finally, while much has been done, there is still a lot of work needed to produce probabilistic models that are usable at a detailed demographic level, and that are capable of incorporating expert knowledge of demographic experts.

In this paper, we focus on only a small part of the picture, that is, to explore the consequences of choosing different specifications of age-specific fertility and mortality in a closed cohort projection model in terms of its forecasted populations and measures of uncertainty. For illustration, we use a historical time series of fertility and mortality from England and Wales. The data consist of age-specific rates for single years of age going back in time to 1841 for mortality and 1974 for fertility.

The rationale for considering a Bayesian approach is that it offers a more natural framework than traditional probabilistic methods to project future populations with uncertainty measures. First, variability in the data and uncertainties in the parameters and model choice can be explicitly included using probability distributions. Second, the approach

allows the inclusion of expert judgements, including their uncertainty, into the model framework. Third, the predictive distributions follow directly from the probabilistic model applied. As a result, probabilistic population forecasts, with more reliable and coherent estimates of predictive distributions, can be obtained for a particular projection model. Demographic events, such as fertility, mortality and migration, tend to exhibit strong regularities in their age patterns. Modelling these age patterns over time permits a relatively concise representation of the history of demographic patterns. These time series can be utilised to allow past trends to be extended to project future patterns. Within the Bayesian paradigm, we investigate various ways age-specific fertility and mortality can be specified. Strategies for incorporating these models into the growth matrix of the cohort component projection model are also explored. Finally, the projected populations, with associated measures of uncertainty, are presented and compared, and the merits of the various specifications for including fertility and mortality are evaluated.

References

Ahlburg DA and Land KC, eds. (1992) Population forecasting: Guest Editors' introduction. *International Journal of Forecasting* 8:289-299.

Bongaarts J and Bulatao RA, eds. (2000) *Beyond six billion: Forecasting the world's population*. National Academy Press, Washington DC.

Lee RD and Tuljapurkar S (1994) Stochastic population projections for the United States: Beyond high, medium and low. *Journal of the American Statistical Association* 89(428):1175-1189.

Lutz W, ed. (1996) *The future population of the world: What can we assume today?* Earthscan, London.

Lutz W and Goldstein JR (2004) Introduction: How to deal with uncertainty in population forecasting? *International Statistical Review* 72(1):1-4.