Spatial and Spatial-temporal models for Small Area Data

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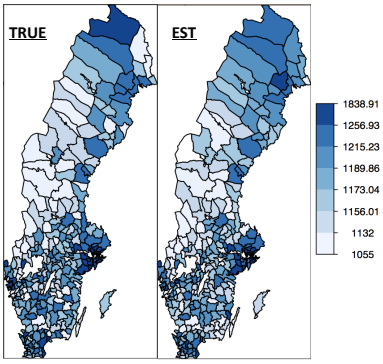
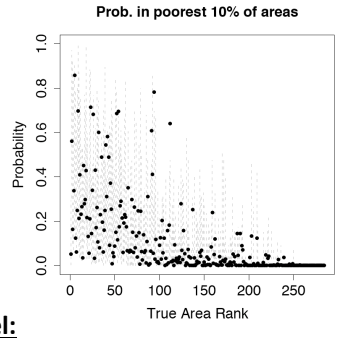
Bayesian spatial models for small area estimation (SAE) (collaboration with ONS)

- National statistical agencies are often required to produce estimates of population characteristics, such as unemployment rates or mean income, for various administrative small areas.
- Model-based estimates that combine survey information on a sample of the population in each area and census characteristics of the whole population, are widely used



Map on the left (TRUE) shows the mean income obtained from a population register in Sweden. Map on the right (EST) is reconstructed using our Bayesian spatial model with only a 1% sample from the population data.

- BIAS researchers have developed and implemented methods for small area estimation from sparse samples based on Bayesian hierarchical models, in which several types of spatial random effects are introduced to improve estimation.



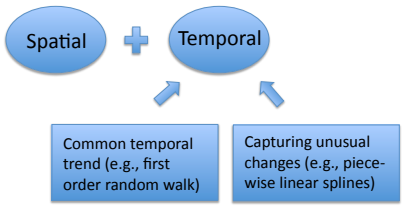
Key features of this model:

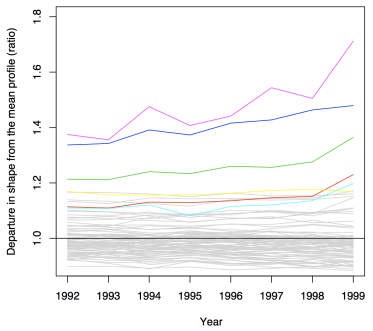
- estimates can readily be produced for areas with no survey data by taking account of spatial dependence between areas;
- classification of areas (e.g., ranking, probability of being below a threshold value or percentile) can be produced together with uncertainty measure.

There is often considerable uncertainty in rankings!

Bayesian spatial-temporal models for predictions and detection of unusual trends (collaboration with ONS)

- We have generalized the spatial SAE models to incorporate temporal data.
- A novel mixture model has been proposed, which can flexibly accommodate different temporal patterns.
- The mixture model in general reduces estimation errors by 15%, compared to analyzing data at each time-point individually.
- In the Swedish income application, for example, the mixture model can not only reveal the national mean time trend but also capture area-specific changes deviating from the national.
- Furthermore, one can classify areas as "*normal*" (those following the national trend) and as "*unusual*" (those with abrupt/unexpected changes over time).





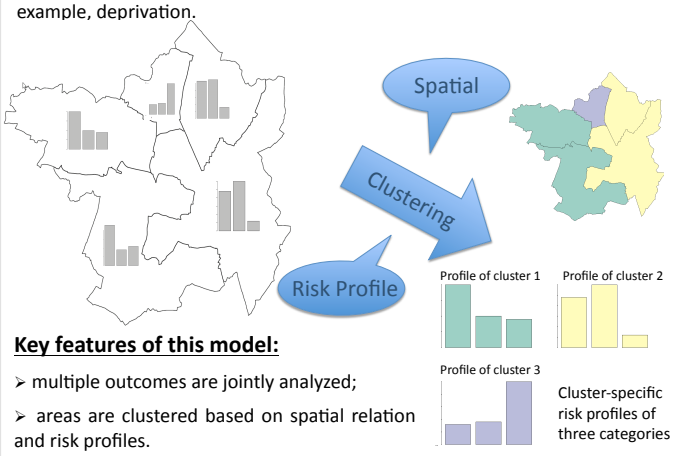
Ratios of the area-specific profiles to the mean time profile, showing the classification of normal (grey lines) and "unusual" (colored lines) trends by the mixture model. A normal trend will display more or less a horizontal line while an "unusual" trend will display a ratio line deviating from the black line, which corresponds to the mean profile.

Key features of this model:

- improves small area estimations by borrowing information from observations of previous time-points;
- detects "unusual" changes in time;
- provides a tool to evaluate impact of policies.

Crime-type profiling (collaboration with Department of Geography, University of Cambridge)

- While estimating and mapping crime rates are two of the important issues in criminology, characterization of profiles according to crime categories (e.g., burglary, drug offences, fraud) at some administrative area level may help to allocate police resources efficiently.
- BIAS researchers are developing a Bayesian model where counts of crimes in various categories are jointly analyzed through an algorithm that probabilistically assigns areas to clusters based on their rate distributions by category and their geographical relations (e.g., whether two areas are adjacent to each other)
- We will apply this model to analyze data sets on crime in Cambridgeshire, which comprises 2350 Census Output Areas. There are 10 crime categories, according to the Home Office classification.
- The research questions we would like to address are, for example, whether crime profiles differ between urban and rural areas and differ between Cambridge and Peterborough and whether crime profiles are related to, for example, deprivation.



Key features of this model:

- multiple outcomes are jointly analyzed;
- areas are clustered based on spatial relation and risk profiles.

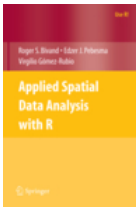
Training materials and software

Software

- R package SAE for small area estimation
- WinBUGS code for implementing various Bayesian spatial models for SAE

Book

- R.S. Bivand, E.J. Pebesma and V. Gómez-Rubio. *Applied Spatial Data Analysis with R. Springer (2008).*



Training events

- Short course on Applied Bayesian Modelling and Small Area Estimation using WinBUGS, given to ONS staff at Titchfield
- Short course on Applied spatial data analysis with R
- Short course on Small Area Estimation using R
- Short course on Gaussian Markov Random Fields
- Short course on Introduction to Bayesian analysis using WinBUGS