Spatiotemporal analysis of infant mortality rates in Argentina using mixed Poisson models

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Abstract

Infant mortality is considered one of the more important indicators for planning and programming activities in health. Their study contributes to the assessment of one of the Millennium Development Goals (MDGs) proposed by the United Nations (and adopted by Argentina) whose deadline is scheduled for 2015. The fourth of these objectives has the overall goal of reducing by two thirds (between 1990 and 2015) mortality in children. In addition, Argentina has the commitment of reducing by 10% provincial inequalities. This work aims to analyze the fulfillment of these objectives by analyzing infant mortality rates that have been estimated using spatio-temporal mixed Poisson models. The methodology used allows a comprehensive analysis of the differences between regions and periods. From this analysis we conclude that even though Argentina does not have met the MDGs targets yet, there is a slight tendency toward compliance.

Keywords: Infant Mortality Rate, Poisson models, CAR models, Spatiotemporal distribution.

1. Introduction

The infant mortality rate (IMR) is considered one of the more important indicators for planning and programming activities in health. It is also a widely used measure (both nationally and internationally) to assess the health status of a population. This is because infant mortality rate is very vulnerable to the effect of economic, social and cultural conditions. It is also a good measure to evaluate the efficiency of curative and preventive services. Therefore, it is an indicator of the degree of development of a community. Furthermore, their study contributes to the assessment of one of the Millennium Development Goals proposed by the United Nations (and adopted by Argentina) whose deadline is scheduled for 2015. The fourth of these objectives is to reduce by two thirds (between 1990 and 2015) mortality in children. Argentina has also the compromise of reducing by 10% provincial inequalities.
The methodology used by the Ministry of Health of Argentina for the evaluation of the Millennium Development Goals (in terms of infant mortality) is limited to the study of crude rates and the evolution of the Gini coefficient. Although computing mortality rates in a certain period permits to evaluate the evolution of the geographical pattern over time, crude rates may be unstable if the event is rare or if there are areas with low population. This may distort the actual disease pattern when plotted on a map. A procedure used to stabilize crude rates, i.e. to achieve less variability, is to adjust them

by using statistical models (see for example Ugarte et al., 2006) that are able to borrow strength among neighboring areas and/or across time. These models are in fact Poisson regression models that incorporate spatial and temporal random effects. The spatial correlation appears because nearby regions shared common environmental factors and other social and cultural features that make neighboring regions to have similar mortality rates. It is also sensible to include temporal random effects (random walks or conditional autoregressive models) as we do not expect abrupt changes from one year to the next.
In this work we estimate infant mortality rates in the provinces of Argentina during the period 1990-2013 using a mixed Poisson model that includes spatio-temporal interaction.

2. Mixed Poisson model description

Suppose that the study area is divided into n contiguous regions ($i=1\cdots n$) and data are available for T periods of time ($t=1\cdots T$), O_{it} is the number of observed cases (mortality counts) and n_{it} is the population at risk in the i-area and t-period. The interest relies on smoothing rates obtained as $r_{it} = O_{it} / n_{it}$. In our context, annual Infant Mortality Rate (IMR) is defined as the number of children dying at less than 1 year of age (O_{it}), divided by the number of live births (n_{it}) for each area and period.
Assuming $O_{it} \sim \text{Poisson}(\mu_{it}=n_{it}r_{it})$, $\log(O_{it})=\log(n_{it})+\log(r_{it})$.
The specification of $\log(r_{it})$ gives rise to alternative disease mapping models. Here, $u_{it}=\log(r_{it})=\beta+\phi_i+\gamma_t+\delta_{it}$, where β is an overall risk level, ϕ_i represents spatial effects, γ_t represents temporal effects and δ_{it} are space-time interaction effects. For a complete description of the model see for instance, Ugarte et al. (2014) and the references therein.

The model, that is in fact a generalized linear mixed model (McCulloch and Searle, 2001), will be fitted using penalized quasi-likelihood (PQL) (Breslow and Clayton, 1993; Dean et al., 2004). This is an approximate fitting technique which uses a Laplace approximation to the integrated mixed model likelihood. It is much easier to implement than usual maximum likelihood estimation. The main features of PQL are that it provides adequate point estimates, it is computationally simple, and it has few convergence problems.

3. Analysis of Infant Mortality in Argentina (1990-2013)

Infant mortality counts are available for the 24 regions of Argentina (23 provinces and the city of Buenos Aires, CABA) during the period 1990-2013 (data from 2014 and 2015 are not available yet). Analysis of these data aims to assess the following priority objectives proposed in the Millennium Development Goals:

1) Reducing child mortality by two thirds between 1990 and 2015
2) Reducing by 10% provincial inequalities

To assess both objectives, infant mortality rates were estimated using the Poisson model explained in the previous section. Figure 1 shows the evolution of the geographical pattern of infant mortality. It can be observed that mortality rates decline in magnitude from north to south. We can clearly observe how they were decreasing over time, although the decline was not similar in all provinces (see Figure 2).
To evaluate the reduction in infant mortality we computed the percentage of variation (in estimated IMR) between 1990 and 2013. The provinces that had a greater decrease in IMR were Chaco (66%), Misiones (66%), Jujuy (65%) and Catamarca (65%). While the ones that had smaller decreases were: CABA (44%), Rio Negro (47%) and Formosa (47%). The overall decrease was 57%. This means that only two provinces reached the proposed objective, and three others were close to reach it. The rest of the provinces did not meet the target yet but show a tendency to achieve it. As a measure of provincial inequalities (objective 2), we estimate the range of IMR estimated for each year. These figures indicate that this goal was achieved from 2005 (see Figure 1).
With regard to model fitting, it can be considered that over-dispersion was captured by the model (Deviance / df = 1.3). By the other hand, it is important to note that the model was able to capture full spatial variability. An approximate Wald test indicated the need to retain the spatio-temporal interaction term in the model.

4. Conclusions

The study of the geographical evolution of mortality rates provides valuable information for epidemiologists and public health authorities facilitating decision-making and health interventions. However, it is important to realize that the use of crude rates could be misleading and it is necessary to use models that are able to smooth the rates making them more stable. In this paper a mixed Poisson model that incorporate spatial, temporal and spatio-temporal interaction has been considered to stabilize crude infant mortality rates in Argentina. The methodology has allowed evaluating the goals set by the Ministry of Health of Argentina with regard to the Millennium Development Goals. The results show that the Argentinian objectives have not been completely achieved yet, although a tendency towards its fulfillment has been observed.

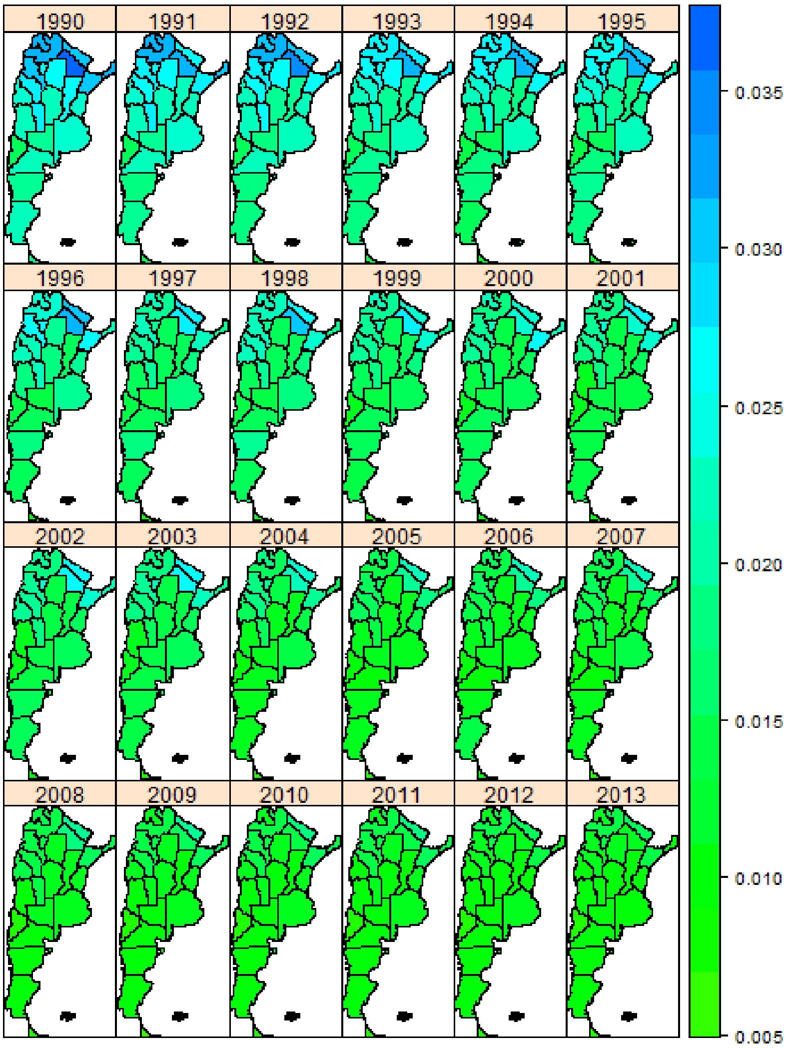

Figure 1. Estimated Infant Mortality Rates in provinces of Argentina during the 1990 to 2013

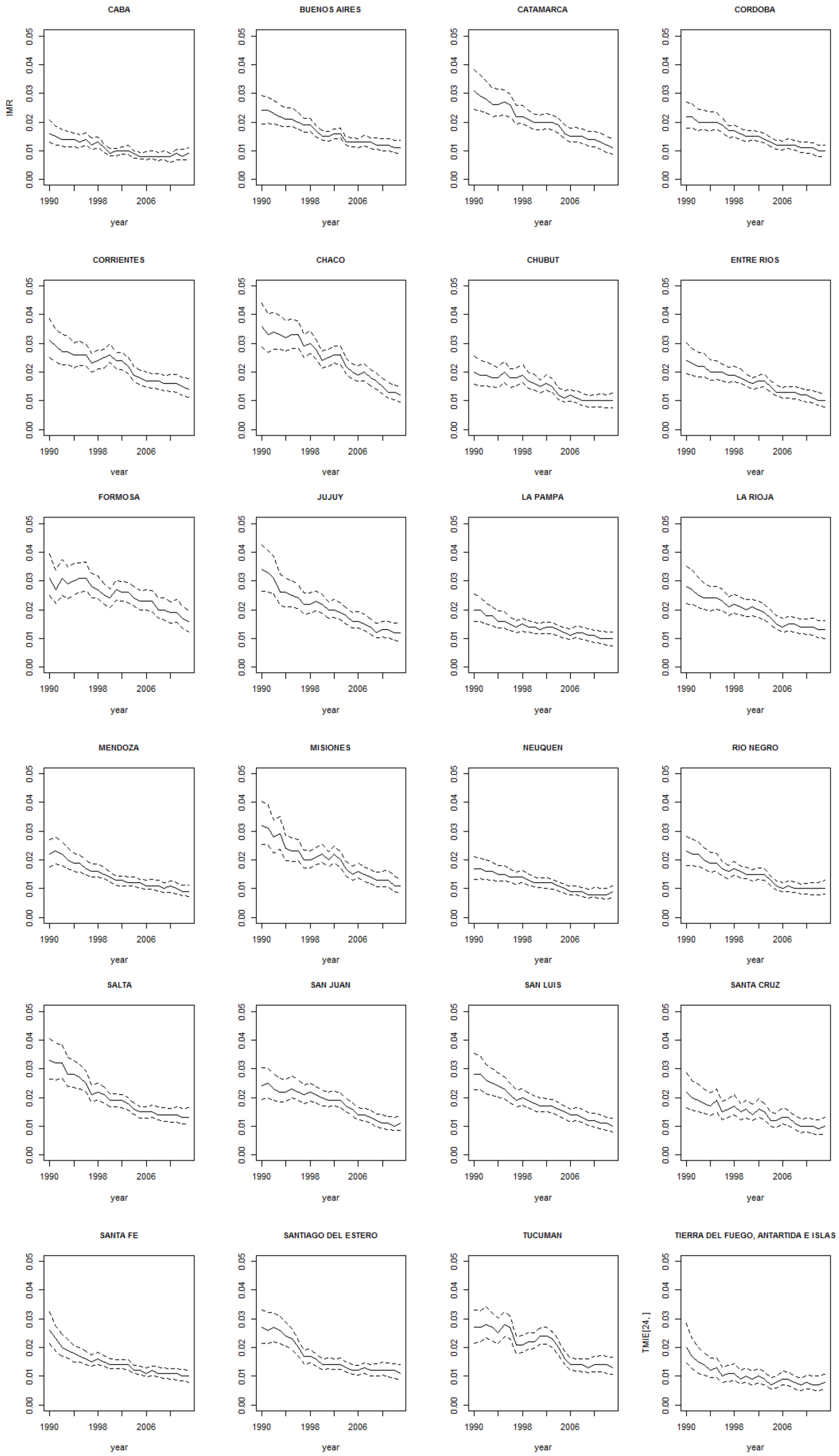

Figure 2. Evolution of the estimated infant mortality rates by province

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Data source

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