

Supplementary Methods and Materials: Negative Binomial Conditional Autoregressive Model

HPV vaccination rates for ZCTA i (y_i), are assumed to be distributed Poisson:

$$y_i \sim \text{Poisson}(N_i \theta_i),$$

$$\theta_i = g_i \exp(\beta_0 + \mathbf{x}_i' \boldsymbol{\beta} + u_i),$$

where N_i is the population of ZCTA i . The vaccination rate (θ_i) is a function of the ZCTA characteristics (\mathbf{x}) and two error terms. The non-spatial offset term, g_i , is the standard negative binomial dispersion term, distributed gamma with mean one:

$$g_i \sim \text{Gamma}(1/\alpha, \alpha).$$

The larger α is, the greater the over-dispersion. The Poisson model corresponds to $\alpha = 0$. The spatial error term, u_i , is distributed normally with a mean (conditional on the other ZCTAs) equal to the average error term among adjacent ZCTAs and a variance proportional to the number of adjacent ZCTAs:

$$u_i | u_{j, i \neq j} \sim N(\bar{\mu}_i, \sigma_i^2),$$

$$\bar{\mu}_i = \frac{1}{\sum_{j=1}^N w_{ij}} \sum_{j=1}^N w_{ij} u_j,$$

$$\sigma_i^2 = \frac{\sigma_u^2}{\sum_{j=1}^N w_{ij}},$$

with $w_{ij} = 1$ if ZCTAs are adjacent and 0 otherwise (i.e., contiguity neighbors).

We used prior distributions for the model parameters suggested by Neyens, Faes (1) that were uninformative: $\beta_0 \sim$ uniform over the real number line, $\boldsymbol{\beta} \sim N(0, 100000)$, $1/\alpha \sim \exp(1)$, $\tau = 1 / \sigma_i^2 \sim \text{Gamma}(0.5, 0.0005)$. In a sensitivity analysis, we also estimated a model using alternative priors for α and τ : $1/\alpha \sim \text{Gamma}(0.1, 1)$ (2) and $\tau \sim U(0, 10000)$ (3). The results were unchanged from those reported in the paper.

References

1. Neyens T, Faes C, Molenberghs G. A generalized Poisson-gamma model for spatially overdispersed data. *Spatial and Spatio-temporal Epidemiology*. 2012;3:185-94. doi: <http://dx.doi.org/10.1016/j.sste.2011.10.004>.

2. George EI, Makov UE, Smith AFM. Conjugate Likelihood Distributions. *Scand J Stat.* 1993;20:147-56. PubMed PMID: WOS:A1993LL60200004.
3. Gelman A. Prior distributions for variance parameters in hierarchical models(Comment on an Article by Browne and Draper). *Bayesian Anal.* 2006;1:515-33. PubMed PMID: WOS:000207447000014.