# Results of the spatial BYM model with our implementation

## 1 Implementation of the BYM model.

```
data {
  int<lower=0> N;
  int<lower=0> N_edges;
  int<lower=1, upper=N> node1[N_edges];  // node1[i] adjacent to node2[i]
  int<lower=1, upper=N> node2[N_edges];  // and node1[i] < node2[i]

  int<lower=0> y[N];              // count outcomes
//  vector[N] x;                    // predictor
  vector<lower=0>[N] E;           // exposure
}
transformed data {
  vector[N] log_E = log(E);
}
parameters {
  real beta0;                // intercept
//  real beta1;                // slope

  real<lower=0> sigma_theta;   // sd of heterogeneous effects
  real<lower=0> sigma_phi;     // sd of spatial effects

  vector[N] theta_std;       // standardized heterogeneous effects
  vector[N - 1] phi_std_raw; // raw, standardized spatial effects
}
transformed parameters {
//  real<lower=0> sigma_theta = inv(sqrt(tau_theta));  // convert precision to sigma
  vector[N] theta = theta_std * sigma_theta;         // non-centered parameterization

//  real<lower=0> sigma_phi = inv(sqrt(tau_phi));      // convert precision to sigma
//  vector[N] phi_std;
  vector[N] phi;
  phi[1:(N - 1)] = phi_std_raw;
  phi[N] = -sum(phi_std_raw);

  // vector[N] phi;
  // phi = phi * sigma_phi;    // non-centered parameterization
}
model {
//  y ~ poisson_log(log_E + beta0 + beta1 * x + theta + phi);

  y ~ poisson_log(log_E + beta0 + theta + sigma_phi * phi);

  target += -0.5 * dot_self(phi[node1] - phi[node2]);

//  beta0 ~ normal(0, 5);
//  beta1 ~ normal(0, 5);
```

```
  theta_std ~ normal(0, 1);
//  tau_theta ~ gamma(3.2761, 1.81);  // Carlin WinBUGS priors
//  tau_phi ~ gamma(1, 1);            // Carlin WinBUGS priors
}
generated quantities {
//  vector[N] mu = exp(log_E + beta0 + beta1 * x + phi + theta);
  vector[N] mu = exp(log_E + beta0 + sigma_phi * phi + theta);
  vector[N] SMR = exp(beta0 + sigma_phi * phi + theta);
//  real psi = sd(phi) / (sd(theta) + sd(phi));  // proportion spatial variation
}
```

## 2 Fitting the model to Spain's mortality data.

```
library(rstan)
library(spdep)
# options(mc.cores = parallel::detectCores())
options(mc.cores = 3)

source("mungeCARdata4stan.R")
load("../../Mortalidad nacional/DatosSinTemporal.Rdata")
Veci <- nb2WB(CartoMuniSinIslas.nb)
nbs = mungeCARdata4stan(Veci$adj, Veci$num)
N = nbs$N
node1 = nbs$node1
node2 = nbs$node2
N_edges = nbs$N_edges

tcomp02 <- system.time(mod.BYM <- stan_model("BYM_Mitzi_NoPriors3.stan"))
# Compilation in 61 seconds

save(mod.BYM, file = "mod.Stan.BYM.NoPriors3.Rdata")
# load('mod.Stan.BYM.NoPriors3.Rdata')

Ejecuta.BYM.Stan <- function(Sexo, Causa) {
    y <- MorTabu[Sexo, Causa, ]
    E <- Esperados[Sexo, Causa, ]

    datos <- list(N, N_edges, node1, node2, y, E)
    param <- c("SMR", "mu", "beta0", "sigma_phi", "sigma_theta")
    Res.t <- system.time(Res <- sampling(object = mod.BYM, data = datos, chains = 3,
        iter = 4400, warmup = 400, thin = max(1, floor(3 * (4400 - 400)/1000)),
        cores = 3, pars = param))

    Res.BYM[[Sexo]][[Causa]] <<- list()
    Res.BYM[[Sexo]][[Causa]]$tiempo <<- Res.t
    Res.BYM[[Sexo]][[Causa]]$summary <<- Res
    Res.BYM[[Sexo]][[Causa]]$RR <<- summary(Res)$summary[1:7907, 1]
    Res.BYM[[Sexo]][[Causa]]$P.RR <<- apply(extract(Res, pars = "SMR")$SMR,
        2, function(x) {
            mean(x > 1)
        })
}
```

```
Res.BYM <- list(Hombres = list(), Mujeres = list())

for (i in c(9:18, 22, 28, 30, 31, 33, 35:37, 41)) {
    Ejecuta.BYM.Stan(1, i)
    save(Res.BYM, file = "Res.BYM-StanMitzi.NoPriors3.Rdata")
}
```

# 3 Descriptive principals.

| Cause | Time | sigma_phi | sigma_theta | max.Rhat | min.n_eff |
|---|---|---|---|---|---|
| (9) Mouth and pharynx | 5419.7 | 2.564 [0.3077,4.6264] | 0.2847 [0.0526,0.5988] | NaN | 1.50 |
| (10) Esophagus | 9303.7 | 0.5841 [0.2653,1.1523] | 0.1401 [0.0034,0.3351] | 81.75 | 1.50 |
| (11) Stomach | 4824.7 | 0.6545 [0.301,1.3293] | 0.1178 [0.0015,0.2997] | 129.02 | 1.50 |
| (12) Colon | 9353.5 | 0.2406 [0.2141,0.2671] | 0.1009 [0.0826,0.1177] | 1.01 | 544.47 |
| (13) Rectum | 9282.1 | 0.2036 [0.1617,0.245] | 0.1209 [0.0934,0.1448] | 1.01 | 202.03 |
| (14) Liver | 4937.7 | 0.3117 [0.2773,0.349] | 0.146 [0.1212,0.1696] | 1.01 | 431.36 |
| (15) Pancreas | 4927.4 | 0.2141 [0.1835,0.2441] | 0.061 [0.0203,0.0907] | 1.02 | 298.88 |
| (16) Other digestives | 5218.0 | 0.2037 [0.1572,0.2527] | 0.0478 [0.0025,0.1023] | 1.02 | 303.97 |
| (17) Larynx | 5479.5 | 0.35 [0.305,0.3914] | 0.0797 [0.0161,0.1277] | 1.02 | 246.02 |
| (18) Lung | 5157.0 | 0.3601 [0.3371,0.383] | 0.0837 [0.0631,0.1018] | 1.01 | 350.67 |
| (22) Other skin | 4926.5 | 0.2387 [0.1816,0.2969] | 0.0465 [0.0024,0.1152] | 1.02 | 169.74 |
| (28) Prostate | 4782.3 | 1.2679 [0.1728,3.425] | 1.3599 [0.0252,3.9608] | 6073.42 | 1.50 |
| (30) Kidney | 4734.1 | 0.9631 [0.2474,2.3225] | 2.1043 [0.0039,6.2195] | 32487.04 | 1.50 |
| (31) Bladder | 4695.2 | 0.3179 [0.2753,0.3806] | 0.4226 [0.0462,1.1115] | 156.29 | 1.50 |
| (33) Brain | 9016.7 | 0.1486 [0.1102,0.1915] | 0.087 [0.051,0.1176] | 1.04 | 116.98 |
| (35) Poorly defined | 4820.0 | 0.2242 [0.1979,0.2519] | 0.0978 [0.0758,0.1179] | 1.02 | 382.89 |
| (36) Other lymphatics | 4928.4 | 0.1763 [0.1416,0.2098] | 0.0748 [0.0458,0.0987] | 1.01 | 350.81 |
| (37) Leukemias | 4961.9 | 0.1445 [0.1099,0.1833] | 0.0683 [0.024,0.1024] | 1.02 | 241.48 |
| (41) Other tumors | 4925.3 | 0.3019 [0.2581,0.3421] | 0.0461 [0.0027,0.0941] | 1.02 | 416.76 |
| Median | 4937.7 | 0.3 | 0.1 | NA | 241.48 |