

Modello gerarchico

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Hierarchical model for 3 italian regions

```
regions <- unique(data_it$region)
hier_data <- get_hier_data(data_it, regions, initial_date = as.Date('2020-07-30'))

p_delay <- get_delay_distribution()

stan_data_hier <- list(J = length(regions),
                       N = nrow(hier_data$exposures),
                       N_nonzero = length(hier_data$nonzero_days),
                       nonzero_days = hier_data$nonzero_days,
                       conv_gt = get_gt_convolution(nrow(hier_data$exposures)),
                       length_delay = length(p_delay),
                       p_delay = p_delay,
                       exposures = hier_data$exposures,
                       nonzero_positives = hier_data$positives[hier_data$nonzero_days ,])
)

compiled_hier <- stan_model('hier_rt_model.stan')

## Trying to compile a simple C file
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## clang -mmacosx-version-min=10.13 -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/include StanHeaders.h
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include RcppEigen.h
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include RcppEigen.h
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
## ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/include StanHeaders.h
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include RcppEigen.h
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: f
## #include <complex>
## ^
## 3 errors generated.
```

```

## make: *** [foo.o] Error 1
fit_hier <- sampling(compiled_hier, data = stan_data_hier, iter= 2000, cores=getOption("mc.cores", 1L))

##
## SAMPLING FOR MODEL 'hier_rt_model' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.040489 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 404.89 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 1: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 1: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 1: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 1: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 1: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 1: Iteration: 1001 / 2000 [ 50%] (Sampling)
## Chain 1: Iteration: 1200 / 2000 [ 60%] (Sampling)
## Chain 1: Iteration: 1400 / 2000 [ 70%] (Sampling)
## Chain 1: Iteration: 1600 / 2000 [ 80%] (Sampling)
## Chain 1: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 1: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 1:
## Chain 1: Elapsed Time: 4005.48 seconds (Warm-up)
## Chain 1: 2317.02 seconds (Sampling)
## Chain 1: 6322.5 seconds (Total)
## Chain 1:
## 
## SAMPLING FOR MODEL 'hier_rt_model' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 0.020408 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 204.08 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 2: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 2: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 2: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 2: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 2: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 2: Iteration: 1001 / 2000 [ 50%] (Sampling)
## Chain 2: Iteration: 1200 / 2000 [ 60%] (Sampling)
## Chain 2: Iteration: 1400 / 2000 [ 70%] (Sampling)
## Chain 2: Iteration: 1600 / 2000 [ 80%] (Sampling)
## Chain 2: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 2:
## Chain 2: Elapsed Time: 3874.1 seconds (Warm-up)
## Chain 2: 2190.66 seconds (Sampling)
## Chain 2: 6064.77 seconds (Total)
## Chain 2:
## 
```

```

## SAMPLING FOR MODEL 'hier_rt_model' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 0.020603 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 206.03 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 3: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 3: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 3: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 3: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%] (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%] (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%] (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%] (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 3:
## Chain 3: Elapsed Time: 3936.85 seconds (Warm-up)
## Chain 3: 2192.28 seconds (Sampling)
## Chain 3: 6129.13 seconds (Total)
## Chain 3:
## 
## SAMPLING FOR MODEL 'hier_rt_model' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 0.021492 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 214.92 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 4: Exception: Exception: poisson_rng: Rate parameter is 0, but must be > 0! (in 'modelad77c23f3c1_hier_rt_model' at line 147)
## 
## Chain 4: Exception: Exception: poisson_rng: Rate parameter is 0, but must be > 0! (in 'modelad77c23f3c1_hier_rt_model' at line 147)
## 
## Chain 4: Exception: Exception: poisson_rng: Rate parameter is 0, but must be > 0! (in 'modelad77c23f3c1_hier_rt_model' at line 147)
## 
## Chain 4: Exception: Exception: poisson_rng: Rate parameter is 0, but must be > 0! (in 'modelad77c23f3c1_hier_rt_model' at line 147)
## 
## Chain 4: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 4: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 4: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 4: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%] (Sampling)

```

```

## Chain 4: Iteration: 1200 / 2000 [ 60%]  (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%]  (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%]  (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%]  (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%]  (Sampling)
## Chain 4:
## Chain 4:   Elapsed Time: 3779.66 seconds (Warm-up)
## Chain 4:           2163.66 seconds (Sampling)
## Chain 4:           5943.32 seconds (Total)
## Chain 4:

## Warning in validityMethod(object): The following variables have undefined
## values: y_rep[1,1],The following variables have undefined values: y_rep[2,1],The
## following variables have undefined values: y_rep[3,1],The following variables
## have undefined values: y_rep[4,1],The following variables have undefined
## values: y_rep[5,1],The following variables have undefined values: y_rep[6,1],The
## following variables have undefined values: y_rep[7,1],The following variables
## have undefined values: y_rep[8,1],The following variables have undefined values:
## y_rep[9,1],The following variables have undefined values: y_rep[10,1],The
## following variables have undefined values: y_rep[11,1],The following
## variables have undefined values: y_rep[12,1],The following variables have
## undefined values: y_rep[13,1],The following variables have undefined values:
## y_rep[14,1],The following variables have undefined values: y_rep[15,1],The
## following variables have undefined values: y_rep[16,1],The following
## variables have undefined values: y_rep[17,1],The following variables have
## undefined values: y_rep[18,1],The following variables have undefined values:
## y_rep[19,1],The following variables have undefined values: y_rep[20,1],The
## following variables have undefined values: y_rep[21,1],The following
## variables have undefined values: y_rep[22,1],The following variables have
## undefined values: y_rep[23,1],The following variables have undefined values:
## y_rep[24,1],The following variables have undefined values: y_rep[25,1],The
## following variables have undefined values: y_rep[26,1],The following
## variables have undefined values: y_rep[27,1],The following variables have
## undefined values: y_rep[28,1],The following variables have undefined values:
## y_rep[29,1],The following variables have undefined values: y_rep[30,1],The
## following variables have undefined values: y_rep[31,1],The following
## variables have undefined values: y_rep[32,1],The following variables have
## undefined values: y_rep[33,1],The following variables have undefined values:
## y_rep[34,1],The following variables have undefined values: y_rep[35,1],The
## following variables have undefined values: y_rep[36,1],The following
## variables have undefined values: y_rep[37,1],The following variables have
## undefined values: y_rep[38,1],The following variables have undefined values:
## y_rep[39,1],The following variables have undefined values: y_rep[40,1],The
## following variables have undefined values: y_rep[41,1],The following
## variables have undefined values: y_rep[42,1],The following variables have
## undefined values: y_rep[43,1],The following variables have undefined values:
## y_rep[44,1],The following variables have undefined values: y_rep[45,1],The
## following variables have undefined values: y_rep[46,1],The following
## variables have undefined values: y_rep[47,1],The following variables have
## undefined values: y_rep[48,1],The following variables have undefined values:
## y_rep[49,1],The following variables have undefined values: y_rep[50,1],The
## following variables have undefined values: y_rep[51,1],The following
## variables have undefined values: y_rep[52,1],The following variables have
## undefined values: y_rep[53,1],The following variables have undefined values:

```



```

## y_rep[39,2],The following variables have undefined values: y_rep[40,2],The
## following variables have undefined values: y_rep[41,2],The following
## variables have undefined values: y_rep[42,2],The following variables have
## undefined values: y_rep[43,2],The following variables have undefined values:
## y_rep[44,2],The following variables have undefined values: y_rep[45,2],The
## following variables have undefined values: y_rep[46,2],The following
## variables have undefined values: y_rep[47,2],The following variables have
## undefined values: y_rep[48,2],The following variables have undefined values:
## y_rep[49,2],The following variables have undefined values: y_rep[50,2],The
## following variables have undefined values: y_rep[51,2],The following variables
## have undefined values: y_rep[52,2],The following variables have undefined
## values: y_rep[53,2],The following variables have undefined values:

## Warning: Bulk Effective Samples Size (ESS) is too low, indicating posterior means and medians may be
## Running the chains for more iterations may help. See
## http://mc-stan.org/misc/warnings.html#bulk-ess

```

Trace plots

```

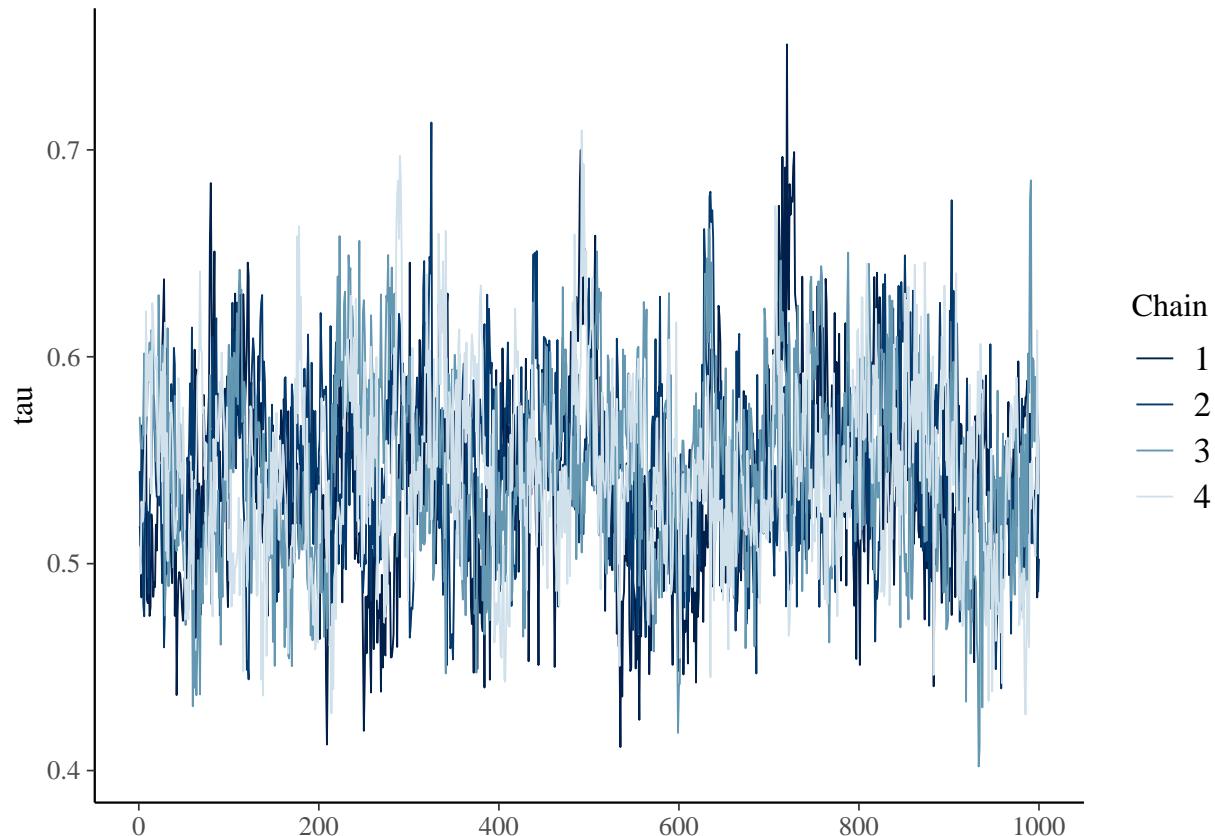
mcmc_trace(as.array(fit_hier, pars = c('tau')),
            np = nuts_params(fit_hier)
)

```

```

## No divergences to plot.

```

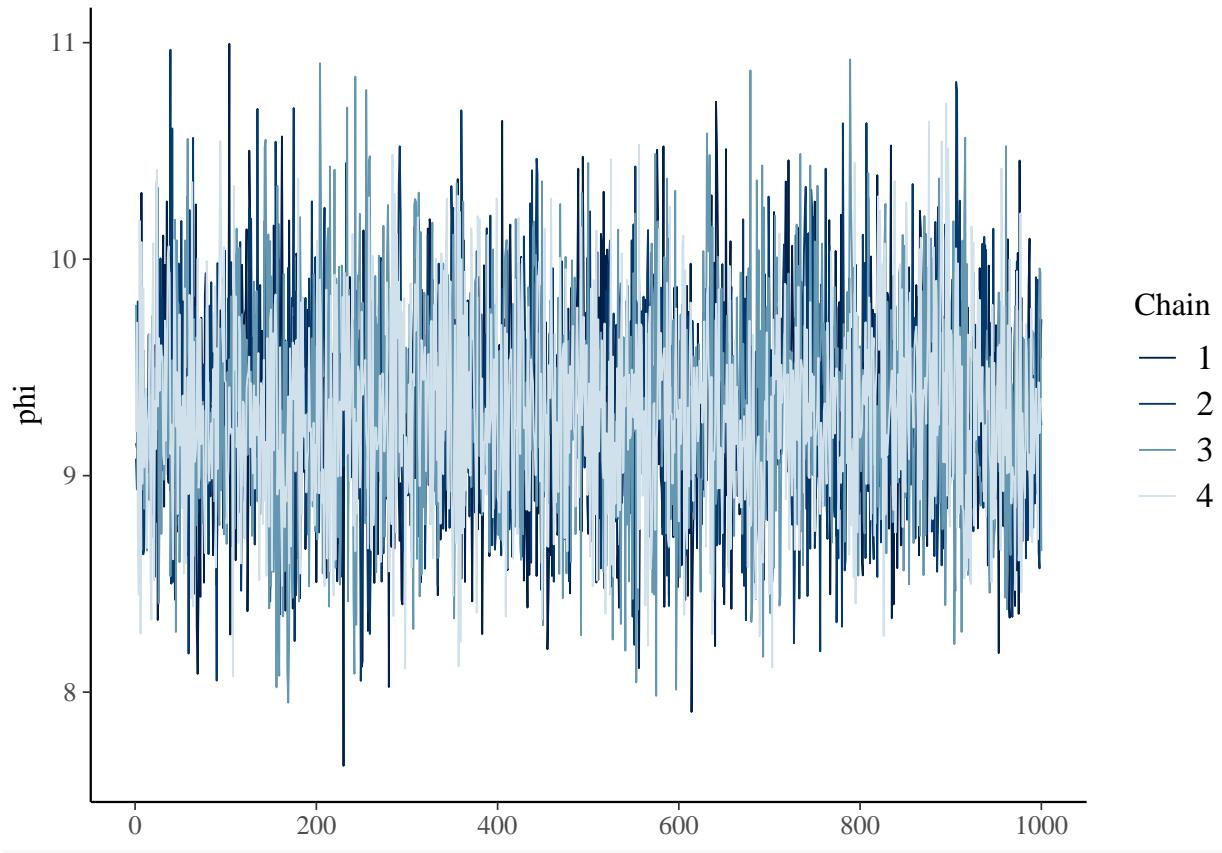


```

mcmc_trace(as.array(fit_hier, pars = c('phi')),
            np = nuts_params(fit_hier)
)

```

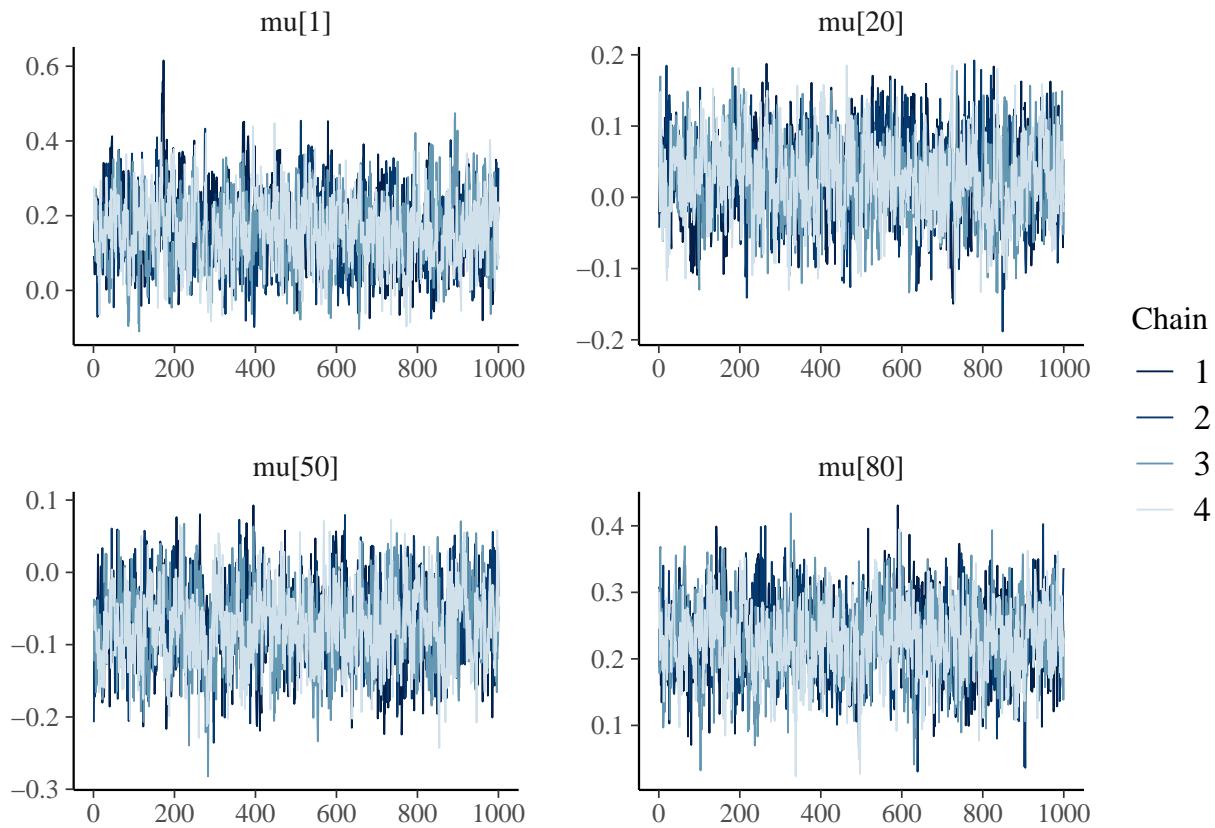
```
## No divergences to plot.
```



```
mcmc_trace(as.array(fit_hier, pars = c('mu[1]', 'mu[20]', 'mu[50]', 'mu[80]')),  
           np = nuts_params(fit_hier))
```

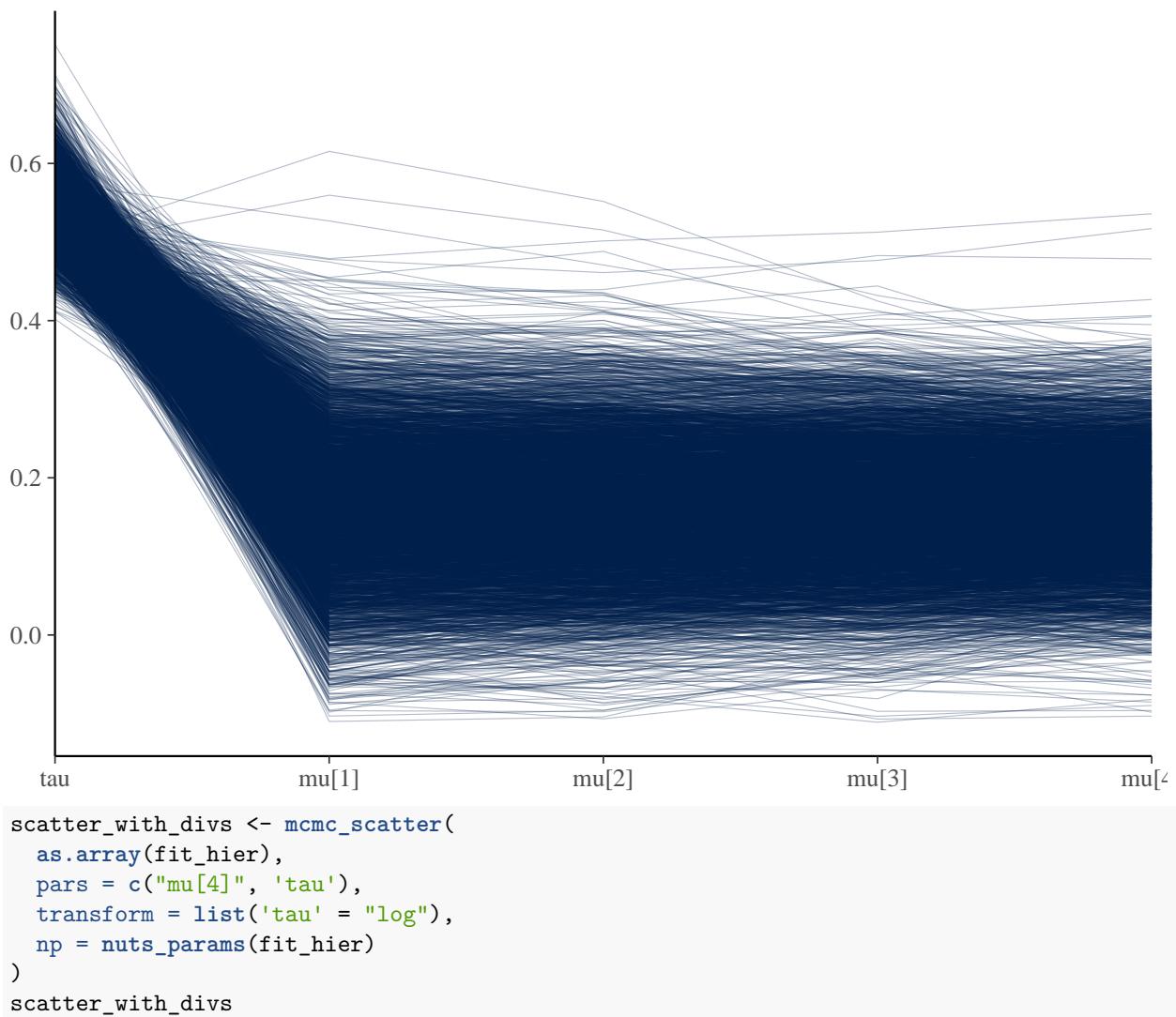
```
)
```

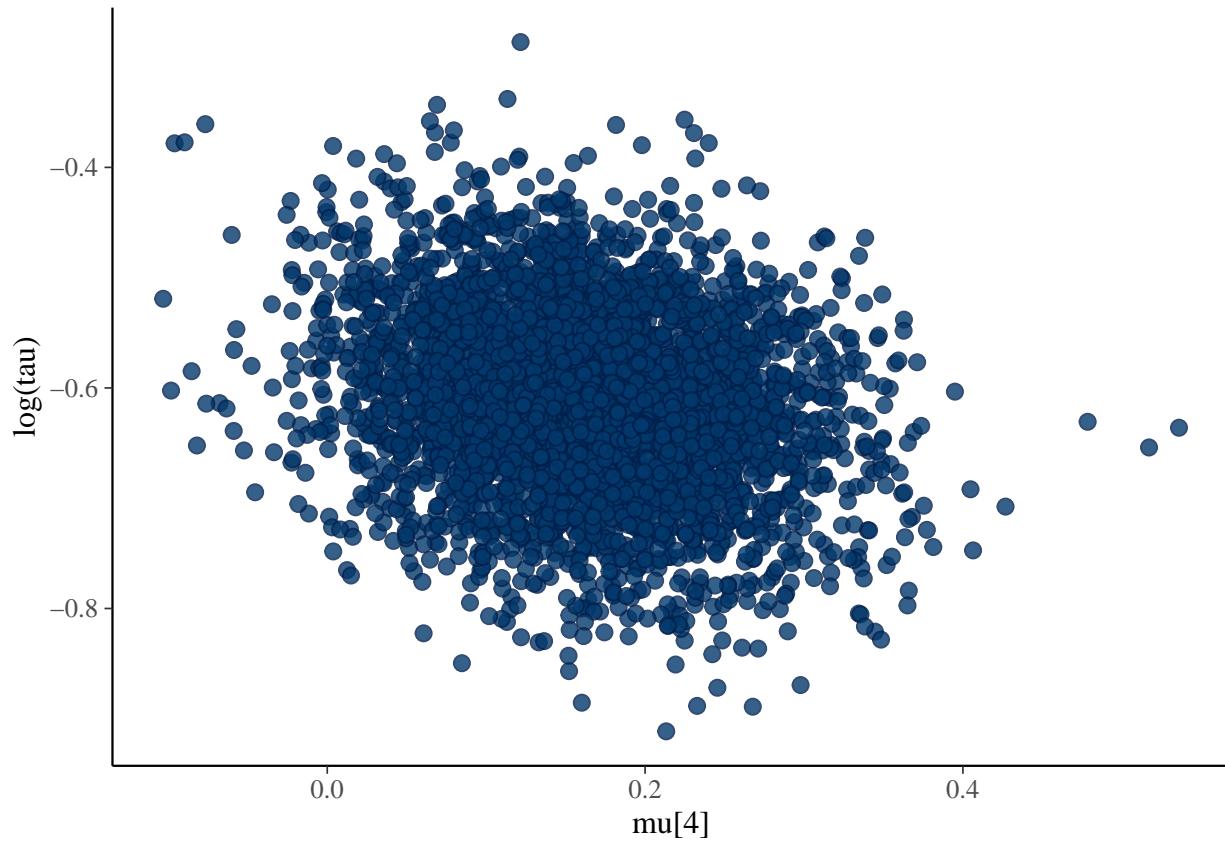
```
## No divergences to plot.
```



Divergent transition

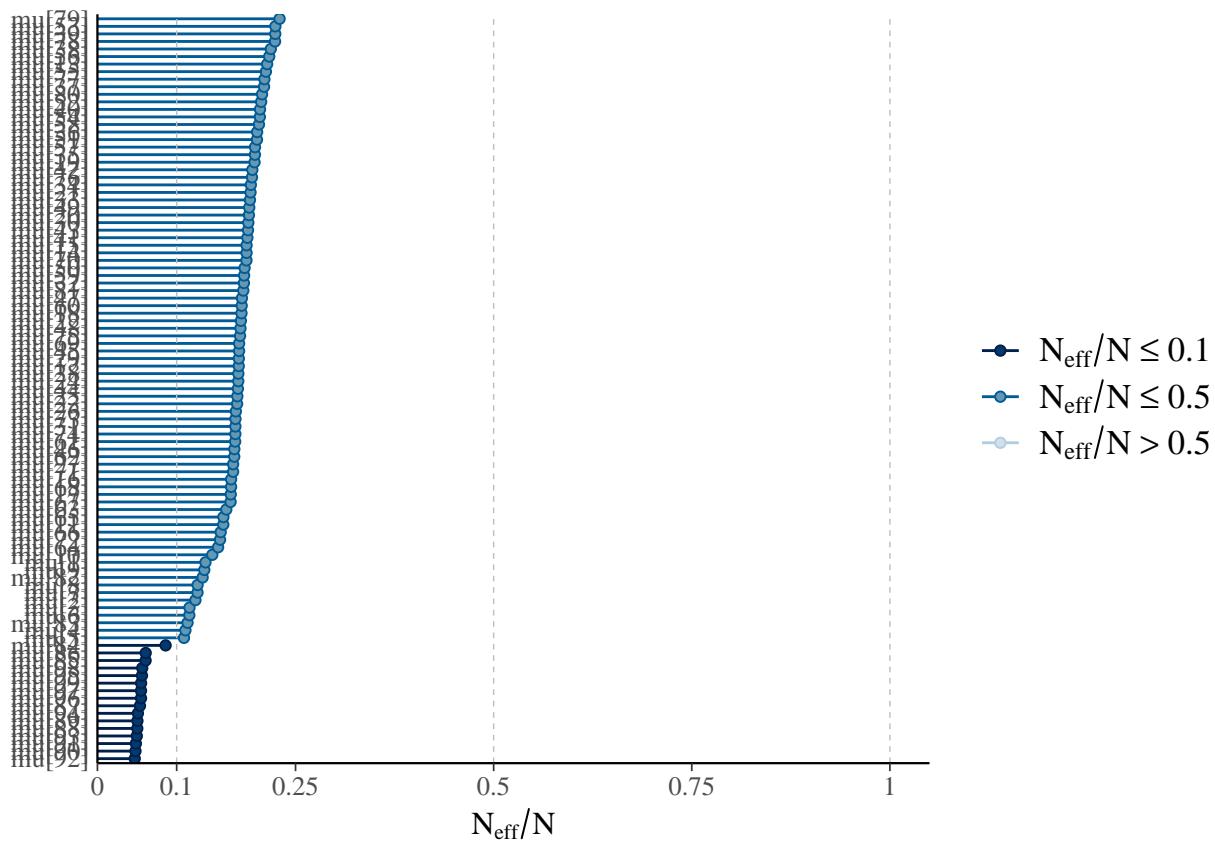
```
parcoord_with_divs <- mcmc_parcoord(
  as.array(fit_hier, pars = c("tau", "mu[1]", "mu[2]", "mu[3]", "mu[4]")),
  np = nuts_params(fit_hier)
)
parcoord_with_divs
```





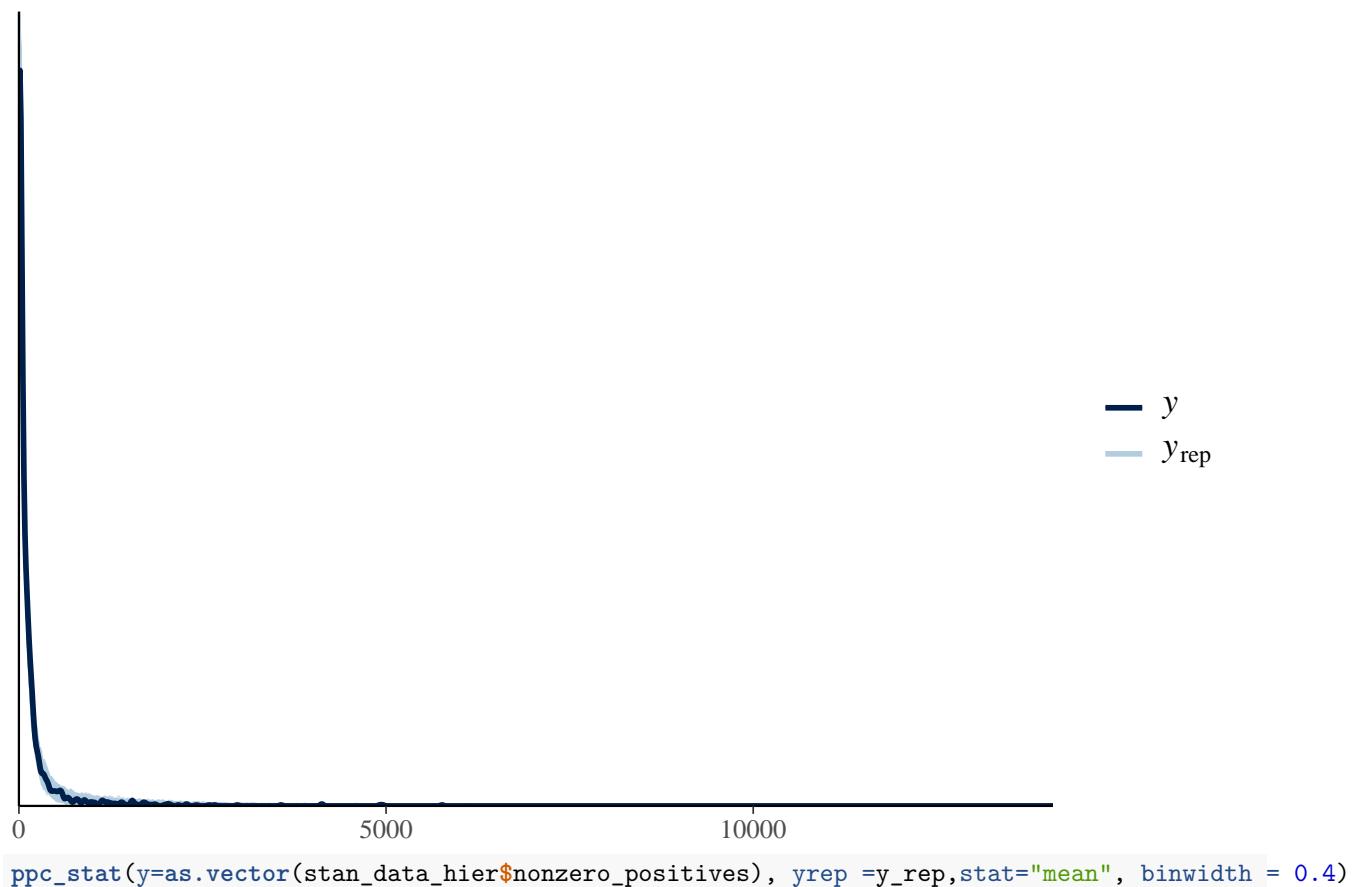
Effective sample size

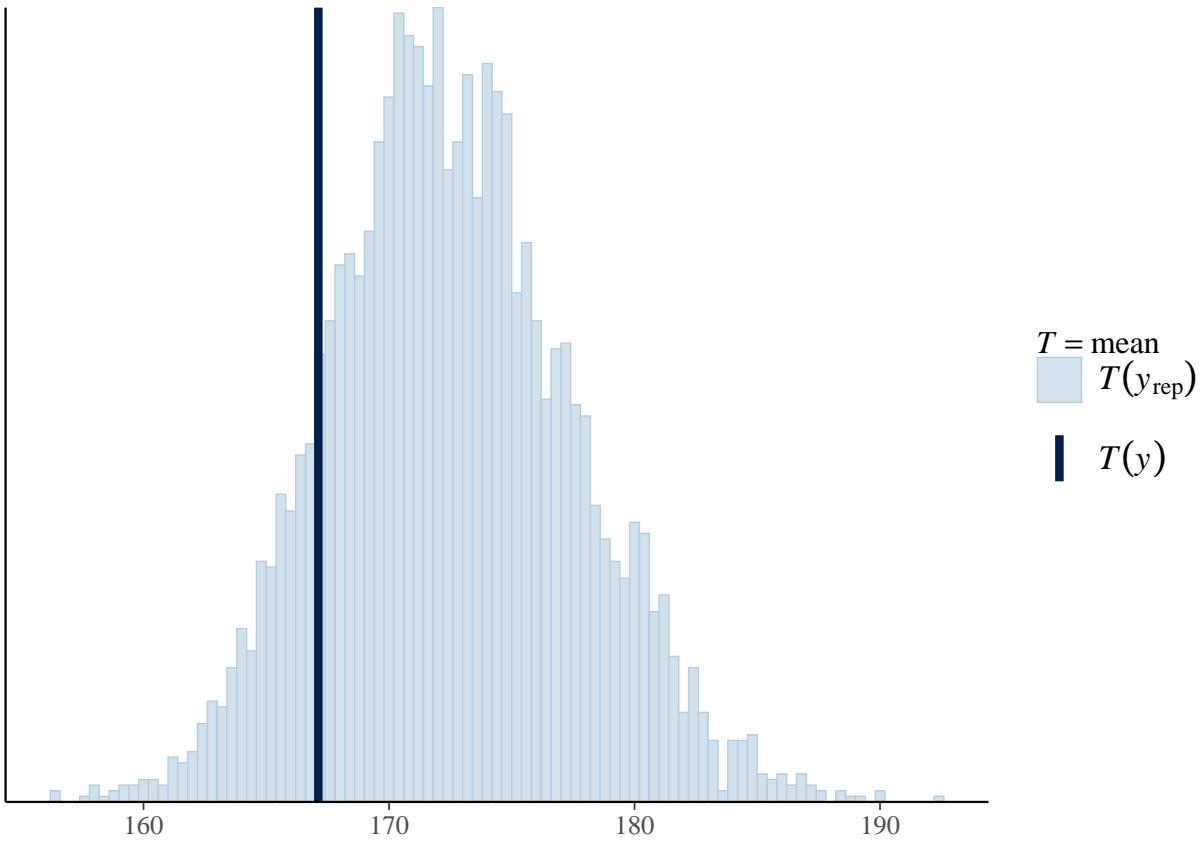
```
ratios1 <- neff_ratio(fit_hier, pars = c('mu'))  
mcmc_neff(ratios1) + yaxis_text(hjust = 1)
```



Posterior predictive check

```
y_rep <- as.matrix(fit_hier, pars = "y_rep")
ppc_dens_overlay(y = as.vector(stan_data_hier$nonzero_positives), y_rep[1:1000, ])
```





Posterior predictive check by region

```

regional_yrep_idx <- function(region, regions_vector, nonzero_days){
  region_idx <- which(regions_vector == region)
  yrep_idx <- (region_idx-1)*length(nonzero_days) + 1
  range <- yrep_idx : (yrep_idx + length(nonzero_days)-1)
  return(range)
}

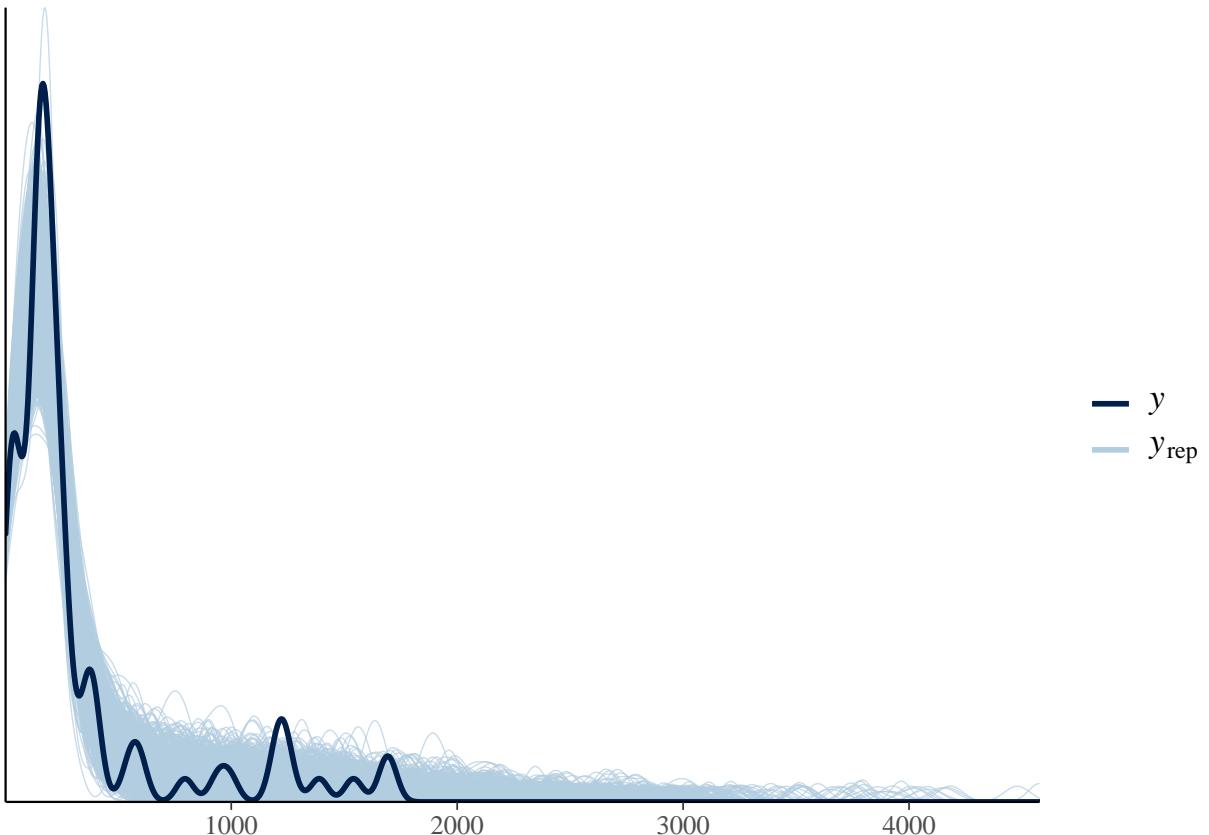
groups <- function(regions, nonzero_days){
  group <- rep(regions[1], length(nonzero_days))
  for(r in 2:length(regions))
    group <- c(group, rep(regions[r], length(nonzero_days)))

  return(group)
}

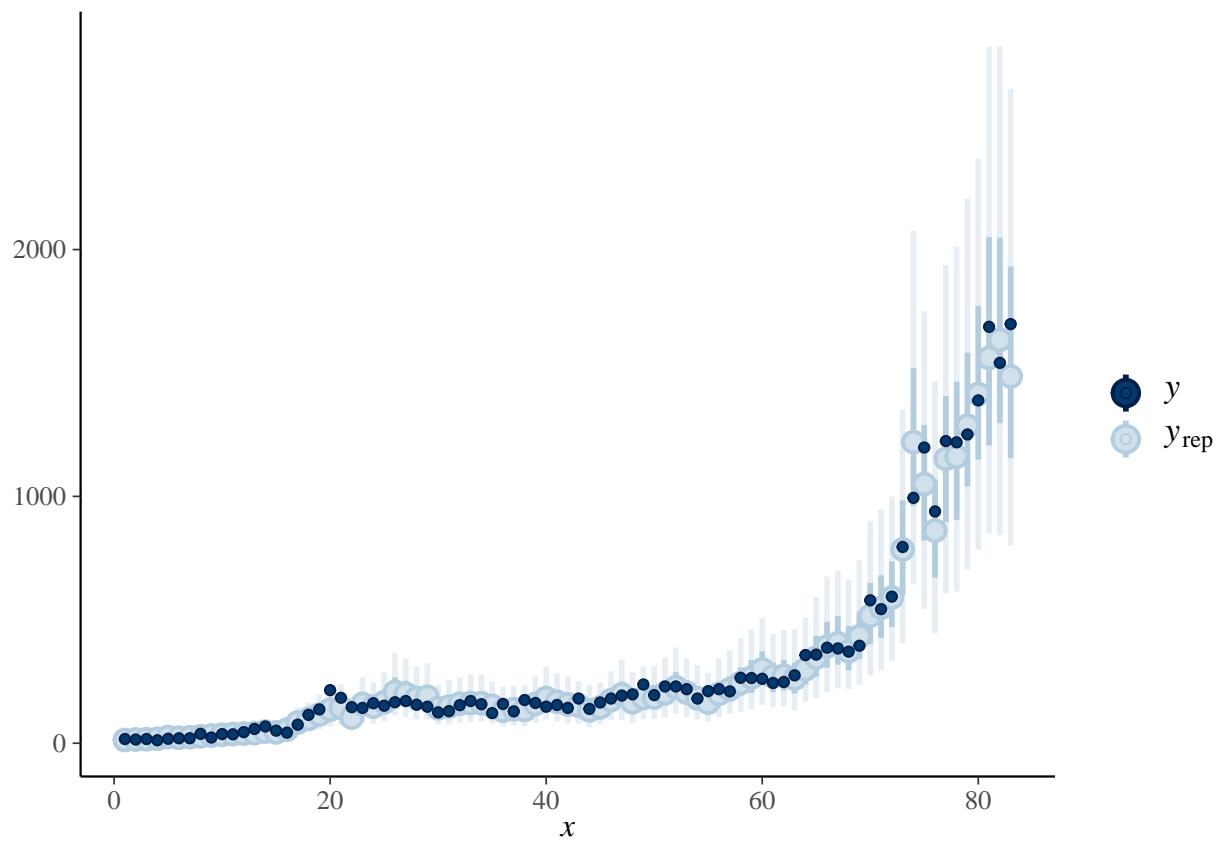
```

Lazio

```
ppc_dens_overlay(y = stan_data_hier$nonzero_positives[, which(regions == 'Lazio')], y_rep[1:1000,regions == 'Lazio'])
```

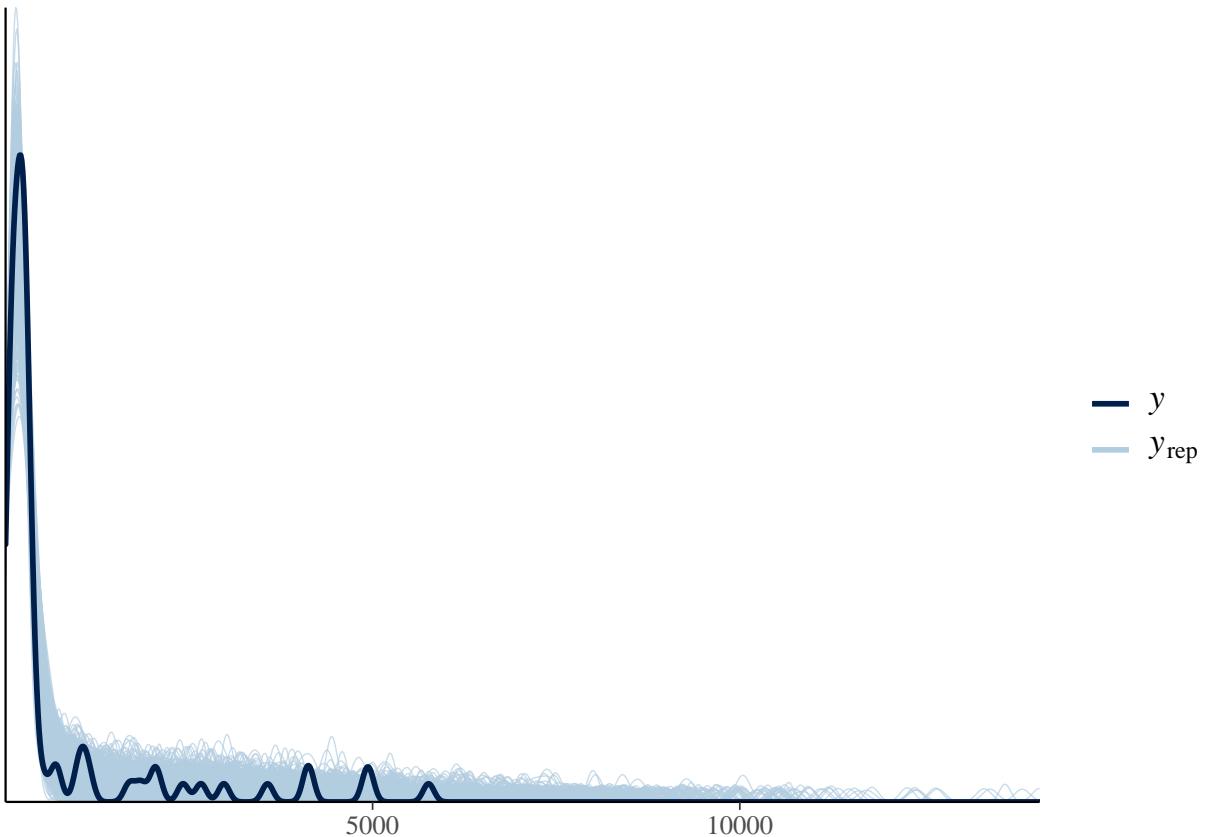


```
ppc_intervals(y = stan_data_hier$nonzero_positives[, which(regions == 'Lazio')], y_rep[1:1000, regional_1])
```

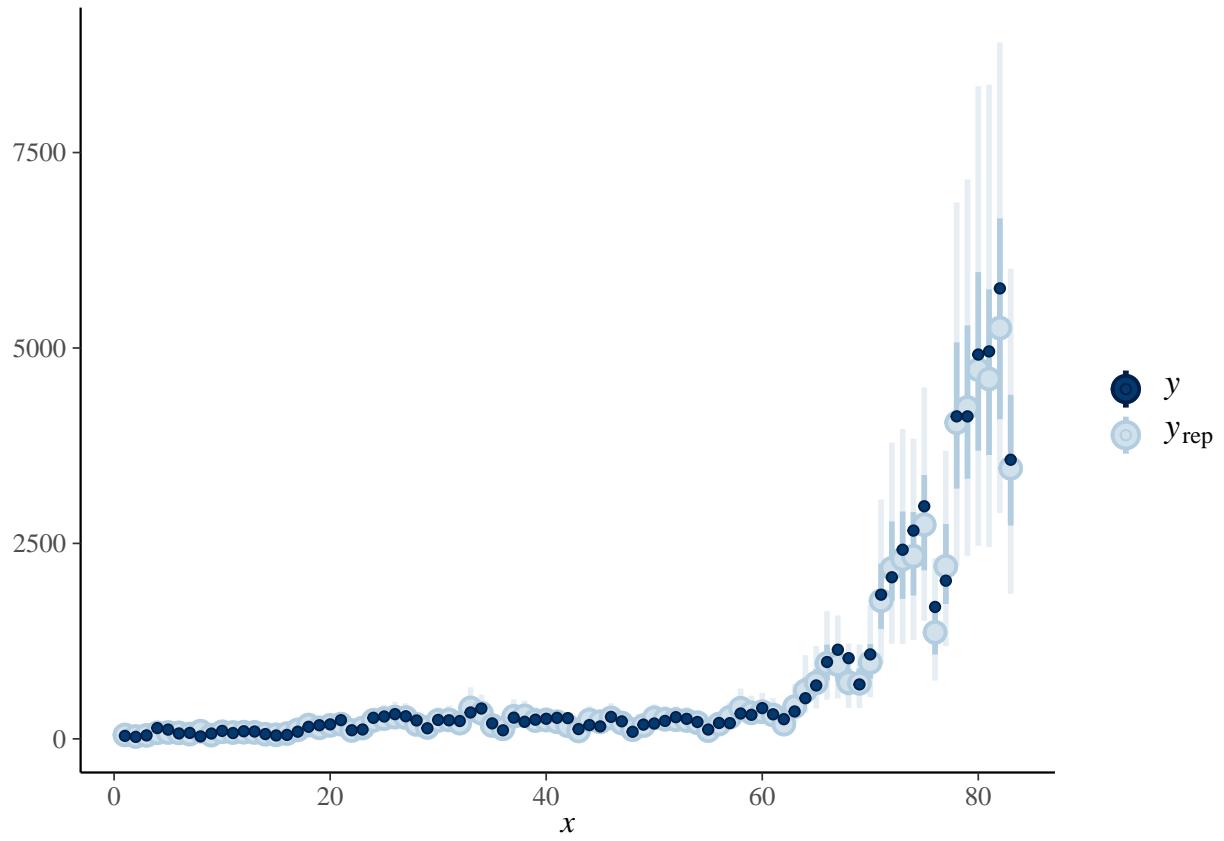


Lombardia

```
ppc_dens_overlay(y = stan_data_hier$nonzero_positives[, which(regions == 'Lombardia')], y_rep[1:1000, rep
```

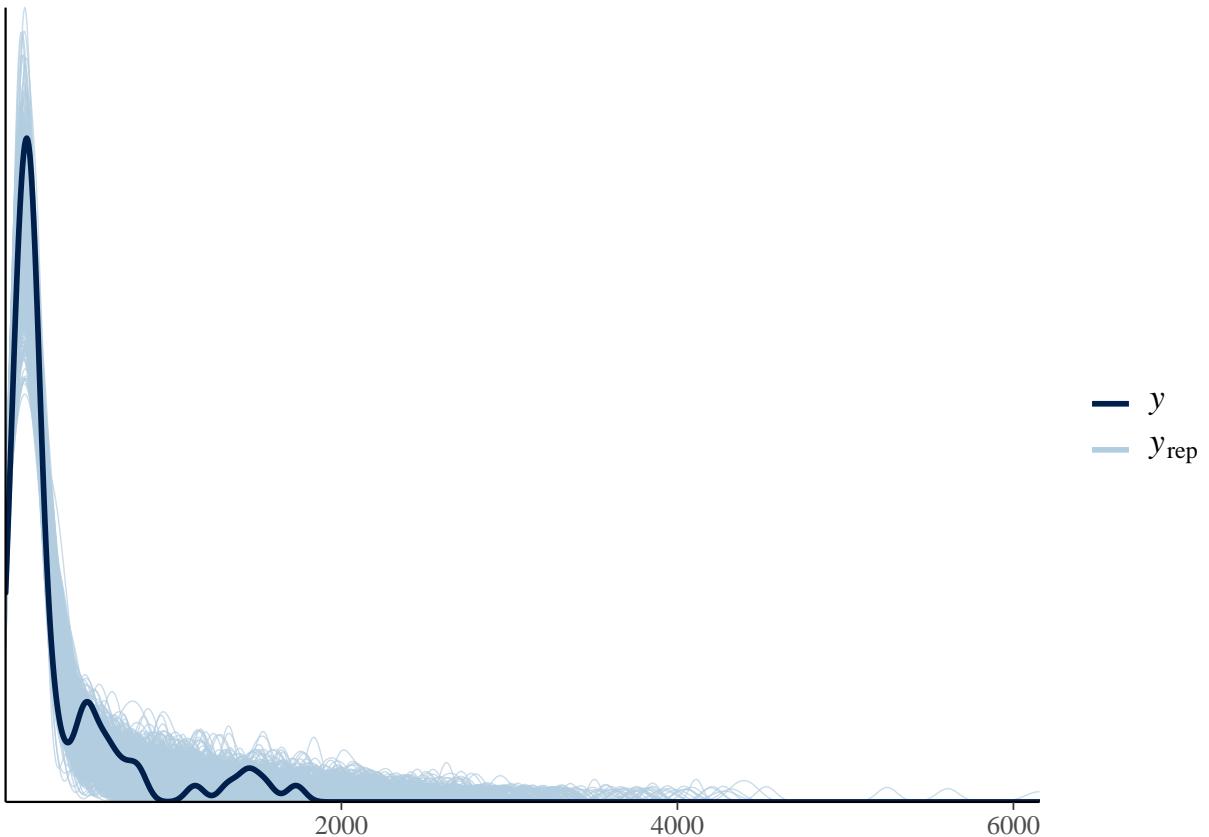


```
ppc_intervals(y = stan_data_hier$nonzero_positives[, which(regions == 'Lombardia')], y_rep[1:1000,region]
```

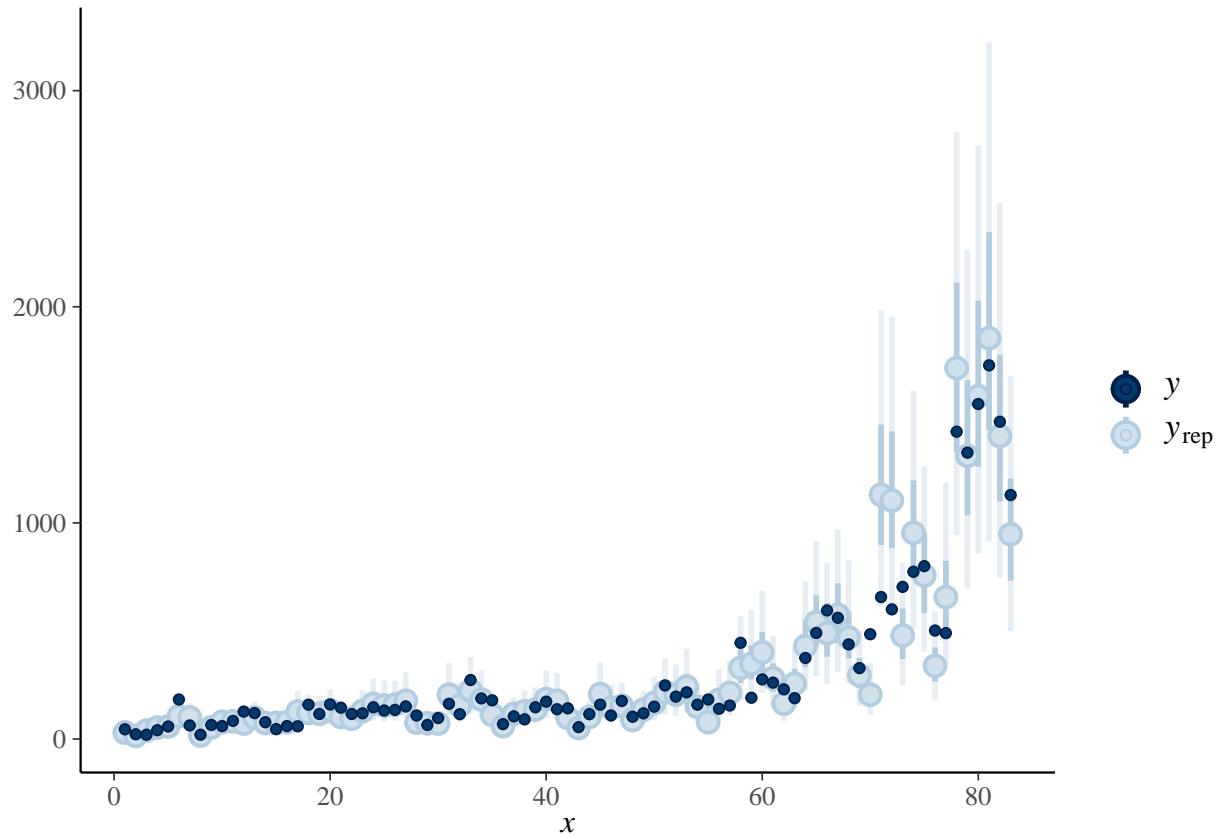


Veneto

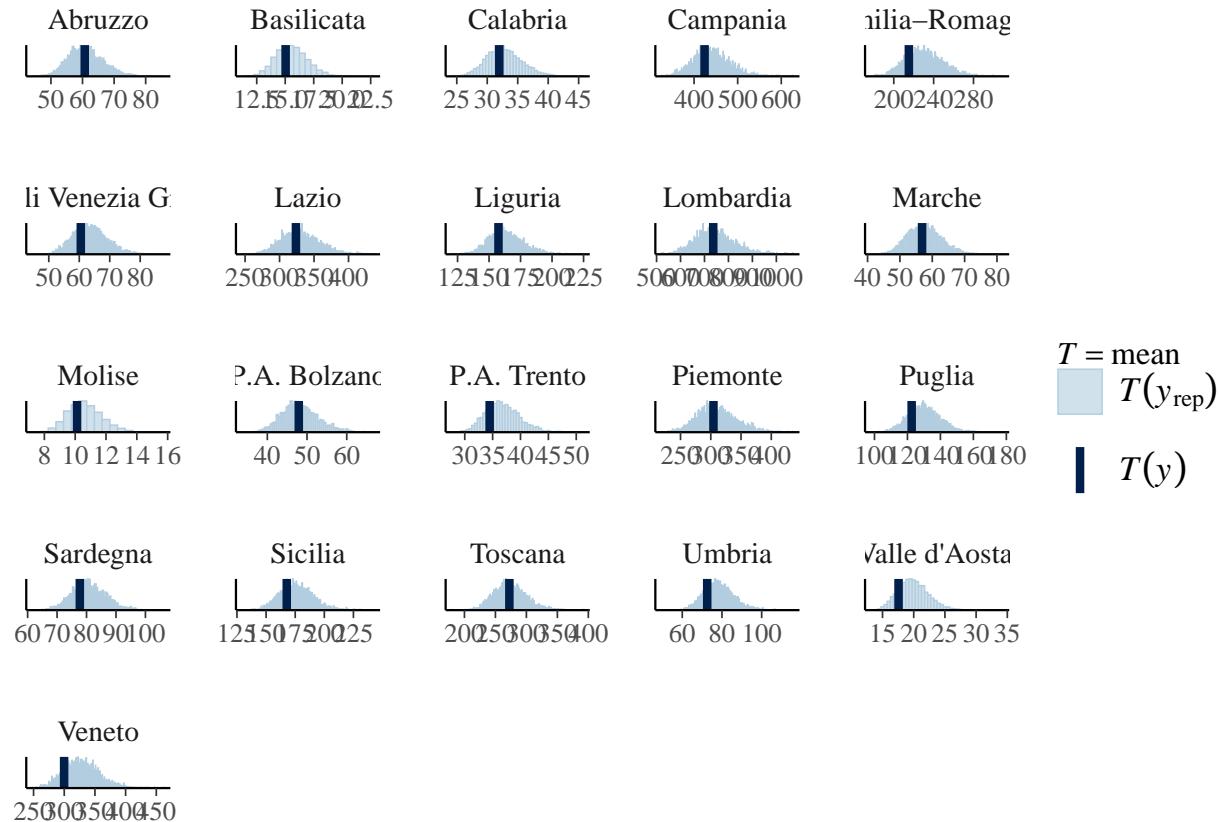
```
ppc_dens_overlay(y = stan_data_hier$nonzero_positives[, which(regions == 'Veneto')], y_rep[1:1000,region]
```



```
ppc_intervals(y = stan_data_hier$nonzero_positives[, which(regions == 'Veneto')], y_rep[1:1000, regional]
```



```
ppc_stat_grouped(y=as.vector(stan_data_hier$nonzero_positives), yrep =y_rep, group = groups(regions, st
```



```
mean_inv_phi<-mean(rstan::extract(fit_hier)$inv_phi)
```

```
mean_y_rep<-colMeans(y_rep)
```

```
std_resid<-(as.vector(stan_data_hier$nonzero_positives)-mean_y_rep)/sqrt(mean_y_rep+mean_y_rep^2*mean_in
```

```
qplot(mean_y_rep, std_resid)+hline_at(2)+hline_at(-2)
```

