TB Vaccination

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Data creation

```
library(data.table)
library(pomp)
library(ggplot2)
library(rstan)

rstan_options(auto_write = TRUE)
options(mc.cores = parallel::detectCores())

#everyone enters on jan 1
#results are for dec 31
newPeople <- data.table(id=1:100,year=2000,age=1,timeNoVax=0,timeWithVax=0,vaccinated=0,ltbi=0,atbi=0)

pomp::bake("data/peopleNoVax.RDS",{
  set.seed(4)
  peopleNoVax <- vector("list",length=17)
  peopleNoVax[[1]] <- newPeople[1,][-1,]
  for(i in 1:17){
    # NO VACCINATIONS
    if(i!=1) peopleNoVax[[i]] <- copy(peopleNoVax[[i-1]])
    peopleNoVax[[i]][,age:=age+1]
    peopleNoVax[[i]] <- rbind(peopleNoVax[[i]],newPeople)
    peopleNoVax[[i]][,year:=2000+i]

    N <- nrow(peopleNoVax[[i]])
    peopleNoVax[[i]][sample(1:N,size=round(N*0.050)),ltbi:=1]
    peopleNoVax[[i]][,timeNoVax:=timeNoVax+1]

    Nltbi <- sum(peopleNoVax[[i]]$ltbi)
    peopleNoVax[[i]][sample(which(peopleNoVax[[i]]$ltbi==1),size=round(Nltbi*0.05)),atbi:=1]
  }
  peopleNoVax
}) -> peopleNoVax

pomp::bake("data/peopleWithVax.RDS",{
  set.seed(4)
  peopleWithVax <- vector("list",length=17)
  peopleWithVax[[1]] <- newPeople[1,][-1,]
  for(i in 1:17){
    # WITH VACCINATIONS, BUT STOPPING THEM AFTERWARDS
    if(i!=1) peopleWithVax[[i]] <- copy(peopleWithVax[[i-1]])
    peopleWithVax[[i]][,age:=age+1]
    peopleWithVax[[i]] <- rbind(peopleWithVax[[i]],newPeople)
    peopleWithVax[[i]][,year:=2000+i]
    N <- nrow(peopleWithVax[[i]])
    if(i>=10){
```

```
      peopleWithVax[[i]][sample(1:N,size=round(N*0.050)),ltbi:=1]
      peopleWithVax[[i]][,timeNoVax:=timeNoVax+1]
    } else {
      peopleWithVax[[i]][sample(1:N,size=round(N*0.050)),ltbi:=1]
      peopleWithVax[[i]][,timeWithVax:=timeWithVax+1]
    }

    Nltbi <- sum(peopleWithVax[[i]]$ltbi)
    peopleWithVax[[i]][sample(which(peopleWithVax[[i]]$ltbi==1),size=round(Nltbi*0.05)),atbi:=1]
  }
  peopleWithVax
}) -> peopleWithVax
```

Detecting LTBI without vaccination

Lets try an easy model, detecting LTBI in unvaccinated people.

We have a Poisson binomial distribution, where the probability of person i not having LTBI is:

$$Pr(Y_i = 0|p, T_i) = 1 - (1 - p)^{T_i}$$

And the probability of person i having LTBI is:

$$Pr(Y_i = 1|p, T_i) = 1 - Pr(Y_i = 0|p, T_i)$$

```
stanData=peopleNoVax[[17]]
data = list(N=nrow(stanData),
            y=stanData$ltbi,
            timeNoVax=stanData$timeNoVax)

stan_code = "
data {
  int<lower=0> N;
  vector[N] timeNoVax;
  int y[N];
}
parameters {
  real<lower=0,upper=0.5> thetaNoVax;
}
model {
  thetaNoVax ~ beta(0.05, 1);

  for (n in 1:N)
    y[n] ~ bernoulli(1-((1-thetaNoVax)^timeNoVax[n]));
}
"
pomp::bake("results/noVaxLTBI.RDS",{
  stan(model_code=stan_code,
               model_name="noVaxLTBI",
               data=data,
               iter=10000, chains=4, init=0, seed=4)
```

```
}) -> fit
summary(fit)$summary
```

```
##                      mean      se_mean          sd          2.5%
## thetaNoVax    0.05034893 2.375728e-05 0.002043574    0.04641664
## lp__       -981.82064720 7.196855e-03 0.709450751 -983.86409211
##                      25%           50%           75%         97.5%
## thetaNoVax    0.04895773    0.05033442    0.05170665    0.05444668
## lp__       -981.98362444 -981.54533698 -981.36898647 -981.32021552
##               n_eff      Rhat
## thetaNoVax 7399.248 1.0003827
## lp__       9717.601 0.9999938
```

Detecting LTBI with vaccination

Lets try a harder model, detecting LTBI when vaccination originally exists, and is then phased out.

We have a Poisson binomial distribution, where the probability of person not i having LTBI is:

$$Pr(Y_i = 0|p_w, p_n, TW_i, TN_i) = 1 - (1 - p_w)^{TW_i} \times (1 - p_n)^{TN_i}$$

And the probability of person i not having LTBI is:

$$Pr(Y_i = 1|p_w, p_n, TW_i, TN_i) = 1 - Pr(Y_i = 0|p_w, p_n, TW_i, TN_i)$$

```
stanData=peopleNoVax[[17]]
data = list(N=nrow(stanData),
            y=stanData$ltbi,
            timeNoVax=stanData$timeNoVax,
            timeWithVax=stanData$timeWithVax
            )

stan_code = "
data {
  int<lower=0> N;
  vector[N] timeWithVax;
  vector[N] timeNoVax;
  int y[N];
}
parameters {
  real<lower=0,upper=0.5> thetaWithVax;
  real<lower=0,upper=0.5> thetaNoVax;
}
model {
  thetaWithVax ~ beta(0.05, 1);
  thetaNoVax ~ beta(0.05, 1);

  for (n in 1:N)
    y[n] ~ bernoulli(1-((1-thetaWithVax)^timeWithVax[n])*((1-thetaNoVax)^timeNoVax[n]));
}
"
pomp::bake("results/withVaxLTBI.RDS",{
```

```
  stan(model_code=stan_code,
               model_name="withVaxLTBI",
               data=data,
               iter=10000, chains=4, init=0, seed=4)
}) -> fit
summary(fit)$summary
```

```
##                       mean      se_mean          sd          2.5%
## thetaWithVax    0.02880084 6.992232e-04 0.081374765  7.771561e-16
## thetaNoVax      0.05034752 2.454918e-05 0.002045221  4.638634e-02
## lp__         -982.60657962 1.151424e-02 0.896442620 -9.849585e+02
##                        25%           50%           75%         97.5%
## thetaWithVax  1.080580e-09  9.262477e-06  4.495898e-03    0.33010887
## thetaNoVax    4.898561e-02  5.032063e-02  5.169885e-02    0.05444483
## lp__         -9.829837e+02 -9.824094e+02 -9.819650e+02 -981.59590828
##                   n_eff     Rhat
## thetaWithVax 13544.026 1.000492
## thetaNoVax    6940.752 1.000386
## lp__          6061.421 1.000427
```