```r
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ----------------------- tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.2
## v ggplot2   4.0.0     v tibble    3.3.0
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```r
library(readr)
library(zoo)
```

```
##
## Attaching package: 'zoo'
##
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```r
#redoing so this file can stand alone
hiv_inc <- read.csv("/Users/miraterdiman/Desktop/My Folder Folder/MPH Year 1/PBHLTH 252/FINAL PROJECT_H

hiv_inc_ts <- ts(hiv_inc$Cases, start = c(2016,1), frequency = 12)
decomp <- stl(hiv_inc_ts, s.window = "periodic")

trend <- decomp$time.series[, "trend"]
hiv_inc$trend <- as.numeric(trend)
hiv_inc$month_num <- 1:nrow(hiv_inc)

time_vals <- time(hiv_inc_ts)
hiv_inc$year <- floor(time_vals)
hiv_inc$month_in_year <- round((time_vals - hiv_inc$year) * 12 + 1)
hiv_inc$year_month <- as.Date(as.yearmon(time_vals))

hiv_inc_parse <- hiv_inc %>%
  select(Months..num., trend)
```
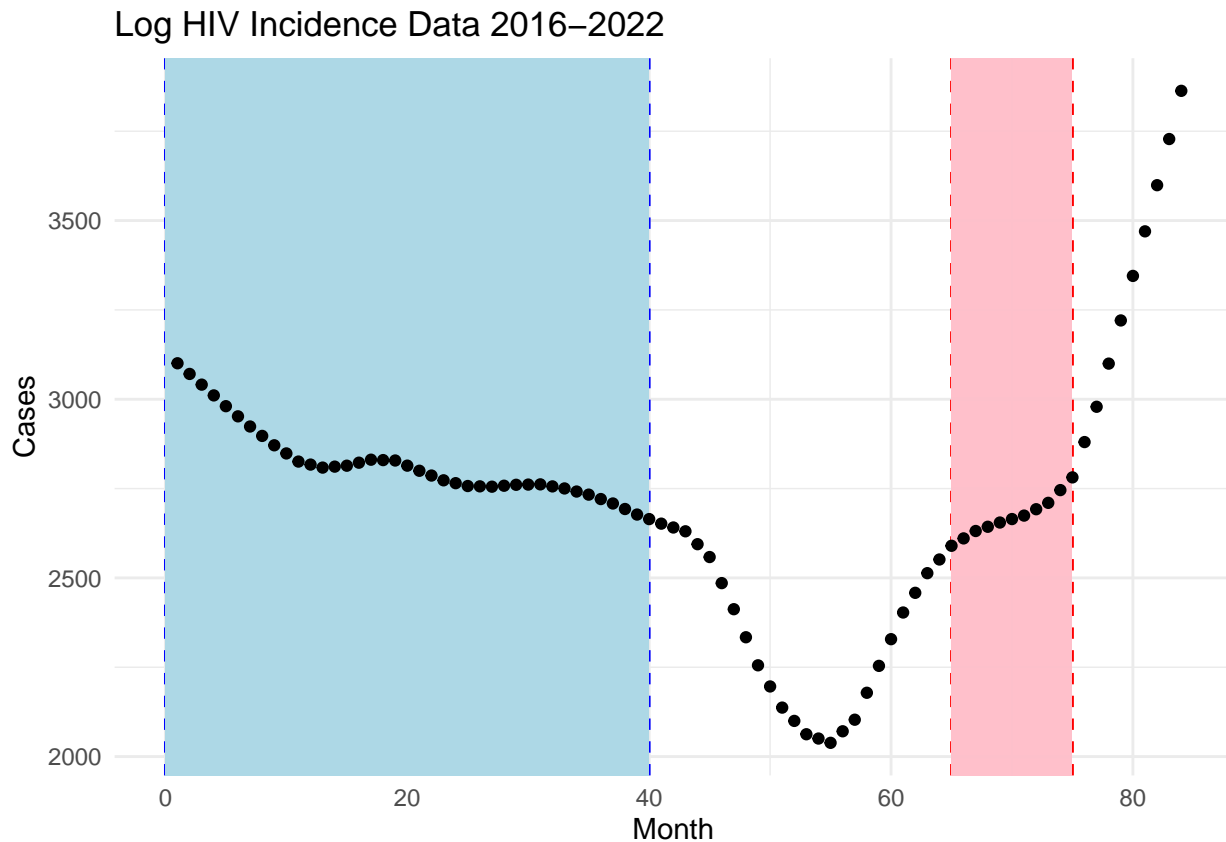
New dataset (only estimating small portion):

```r
hiv_inc_parse %>%
  ggplot(aes(x = Months..num., y = trend)) +
  geom_vline(xintercept = 0, color = "blue", linetype = "dashed") +
  geom_vline(xintercept = 40, color = "blue", linetype = "dashed") +
  geom_vline(xintercept = 65, color = "red", linetype = "dashed") +
  geom_vline(xintercept = 75, color = "red", linetype = "dashed") +
  geom_rect(aes(xmin = 0, xmax = 40, ymin = -Inf, ymax = Inf),
            fill = "lightblue", alpha = 0.4) +
  geom_rect(aes(xmin = 65, xmax = 75, ymin = -Inf, ymax = Inf),
            fill = "pink", alpha = 0.4) +
  geom_point() +
  labs(x = "Month", y = "Cases") +
  ggtitle("Log HIV Incidence Data 2016-2022") +
```

```
theme_minimal()
```

Log HIV Incidence Data 2016–2022

We can see a lot of different sections of the data. I will estimate the R0 before the (presumably) COVID lull (months 0 to 40), and the post COVID increase (months 65 to 75).

```
hiv_inc_pre <- hiv_inc_parse %>%
  filter(Months..num. < 41) %>%
  rename(Month = Months..num.,
         Cases = trend)

hiv_inc_post <- hiv_inc_parse %>%
  filter(Months..num. < 76 & Months..num. > 64) %>%
  rename(Month = Months..num.,
         Cases = trend)
```

Now, we will proceed to use the MCMC Algorithm from recent practicals!

Estimating Pre COVID

```
#installing necessary libraries
library(deSolve)
library(ggplot2)
library(coda)
```

Data cleaning

```
#current variable names are hard to use
time_months <- hiv_inc_pre$Month

#rounding trend cases so they aren't in decimal form (not realistic)
hiv_inc_pre$Cases <- round(hiv_inc_pre$Cases, digits = 0)
IncData <- hiv_inc_pre$Cases
numPoints <- length(time_months)

#converting to years, since our other parameter estimations are in years
time_years <- time_months / 12
```

Coding the SPITU ODE (same ODE as before)

```
HIV_ode <- function(time, state, theta){

  #states
  S <- state["S"]
  P <- state["P"]
  I <- state["I"]
  T <- state["T"]
  U <- state["U"]

  N <- S + P + I + T + U

  #force of infection
  lambda <- theta["c"] * (theta["beta_I"] * I + theta["beta_T"] * T) / N

  #ODEs --> in year units
  dS <- theta["a"] * N - lambda * S - theta["m"] * S - theta["p"] * S + theta["b"] * P
  dP <- theta["p"] * S - theta["b"] * P - theta["m"] * P
  dI <- lambda * S - theta["gamma"] * I - theta["mu"] * I - theta["m"] * I
  dT <- theta["gamma"] * I  - theta["s"] * T - theta["m"] * T
  dU <- theta["s"] * T - theta["m"] * U

  list(c(dS, dP, dI, dT, dU))
}
```

Coding likelihood functions

```
#only coding Prior for estimated parameters
logPrior <- function(theta_MH) {
  beta_I <- theta_MH[["beta_I"]]

  logPriorbeta_I <- dlnorm(beta_I, meanlog = log(0.5), sdlog = 1, log = TRUE)

  return(logPriorbeta_I)
}

# likelihood function for single data point
pointLogLike <- function(i, IncData, IncModel) {
  # Incidence is observed through a Poisson process.
```

```r
    poissonLike <- dpois(x=IncData[i], lambda=IncModel[i], log=TRUE)
    if (is.na(poissonLike)) {
      return(-Inf)
    } else {
      return(poissonLike)
    }
}

# Likelihood function for all data points
trajLogLike <- function(time_years, IncData, theta, initState) {
  # Solve ODE at the observation times (in YEARS)
  traj <- data.frame(ode(
    y = initState,
    times = time_years,
    func  = HIV_ode,
    parms = theta,
    method = "ode45"
  ))

  # Compute modelled incidence for each observation month:
  # lambda(t) * S(t) * (delta t), with  delta t = 1/12 year
  N        <- traj$S + traj$P + traj$I + traj$T + traj$U
  lambda_t <- theta["c"] * (theta["beta_I"] * traj$I + theta["beta_T"] * traj$T) / N
  IncModel <- lambda_t * traj$S * (1/12)   # expected new cases per *month*

  logLike <- 0
  for (i in seq_along(IncData)) {
    logLike <- logLike + pointLogLike(i, IncData, IncModel)
  }
  logLike
}

# Posterior function

logPosterior <- function(time_years, IncData, theta_MH, theta_fixed, initState) {
  theta <- c(theta_MH, theta_fixed)
  lp    <- logPrior(theta_MH)
  ll    <- trajLogLike(time_years, IncData, theta, initState)
  return(lp + ll)
}
```

Setting fixed parameters

```r
theta_fixed <- c(
  # Infectiousness on treatment: beta_T = rho * beta_I, rho fixed
  beta_T = NA_real_,      # will be filled in inside likelihood from rho*beta_I
  c     = 1.5,             # contact rate per year (adjust if given)
  a     = 0.098,          # recruitment per year
  p     = 0.2072,         # PrEP uptake per year
  b     = 1.2,            # PrEP discontinuation per year (10-month persistence)
  gamma = 0.5,            # I -> T per year
  mu    = 0.1,            # HIV mortality untreated per year
  s     = 0.25,           # T -> U per year
```

```
  m       = 1/35              # background mortality per year
)

rho <- 0.1  # relative infectiousness on treatment: beta_T = rho * beta_I

# Initial conditions: at-risk population ~ 6 million
N0 <- 3e6
initState <- c(
  S = N0 - 60000,  # mostly susceptible
  P = 0,
  I = 60000,        # have this be one of the theta parameters (so we can vary it) (for when we are inco
  T = 0,
  U = 0
)


#pre and post covid fittings
```

Metropolis-Hastings Functions

```
logPosteriorMH <- function(MHparams) {
  beta_I <- MHparams[["beta_I"]]

  # fill in beta_T each time
  theta_fixed_use <- theta_fixed
  theta_fixed_use["beta_T"] <- rho * beta_I

  logPosterior(
    time_years = time_years,
    IncData    = IncData,
    theta_MH   = c(beta_I = beta_I),
    theta_fixed = theta_fixed_use,
    initState  = initState
  )
}


mcmcMH <- function(posterior, initTheta, proposalSD, numIterations) {
  posteriorThetaCurrent <- posterior(initTheta)
  thetaCurrent <- initTheta
  samples <- initTheta
  accepted <- 0

  for (i in 1:numIterations) {
    thetaProposed <- rnorm(
      n    = length(thetaCurrent),
      mean = thetaCurrent,
      sd   = proposalSD
    )
    names(thetaProposed) <- names(thetaCurrent)

    posteriorThetaProposed <- posterior(thetaProposed)
    logAcceptance <- posteriorThetaProposed - posteriorThetaCurrent
```

```r
    randNum <- runif(1)

    if (randNum < exp(logAcceptance)) {
      thetaCurrent <- thetaProposed
      posteriorThetaCurrent <- posteriorThetaProposed
      accepted <- accepted + 1
    }

    samples <- c(samples, thetaCurrent)
    cat("iteration:", i,
        "beta_I:", thetaCurrent,
        "acceptance rate:", accepted / i, "\n")
  }

  samples
}
```

Finally Simulating

```r
set.seed(47)

mcmcTrace <- mcmcMH(
  posterior    = logPosteriorMH,
  initTheta    = c(beta_I = 0.5),     # initial guess
  proposalSD   = c(beta_I = 0.003),            # tune for ~20-40% acceptance
  numIterations = 2000
)
```

```
## iteration: 1 beta_I: 0.5 acceptance rate: 0
## iteration: 2 beta_I: 0.5 acceptance rate: 0
## iteration: 3 beta_I: 0.4991547 acceptance rate: 0.3333333
## iteration: 4 beta_I: 0.4991547 acceptance rate: 0.25
## iteration: 5 beta_I: 0.4961983 acceptance rate: 0.4
## iteration: 6 beta_I: 0.4961983 acceptance rate: 0.3333333
## iteration: 7 beta_I: 0.491801 acceptance rate: 0.4285714
## iteration: 8 beta_I: 0.491801 acceptance rate: 0.375
## iteration: 9 beta_I: 0.491801 acceptance rate: 0.3333333
## iteration: 10 beta_I: 0.4864372 acceptance rate: 0.4
## iteration: 11 beta_I: 0.4864372 acceptance rate: 0.3636364
## iteration: 12 beta_I: 0.4838432 acceptance rate: 0.4166667
## iteration: 13 beta_I: 0.481733 acceptance rate: 0.4615385
## iteration: 14 beta_I: 0.481733 acceptance rate: 0.4285714
## iteration: 15 beta_I: 0.481733 acceptance rate: 0.4
## iteration: 16 beta_I: 0.4792385 acceptance rate: 0.4375
## iteration: 17 beta_I: 0.4782591 acceptance rate: 0.4705882
## iteration: 18 beta_I: 0.4782591 acceptance rate: 0.4444444
## iteration: 19 beta_I: 0.4712919 acceptance rate: 0.4736842
## iteration: 20 beta_I: 0.4650168 acceptance rate: 0.5
## iteration: 21 beta_I: 0.4650168 acceptance rate: 0.4761905
## iteration: 22 beta_I: 0.4632695 acceptance rate: 0.5
## iteration: 23 beta_I: 0.4632695 acceptance rate: 0.4782609
## iteration: 24 beta_I: 0.4599875 acceptance rate: 0.5
## iteration: 25 beta_I: 0.4579078 acceptance rate: 0.52
```

```
## iteration: 26 beta_I: 0.4561089 acceptance rate: 0.5384615
## iteration: 27 beta_I: 0.4561089 acceptance rate: 0.5185185
## iteration: 28 beta_I: 0.4561089 acceptance rate: 0.5
## iteration: 29 beta_I: 0.4556448 acceptance rate: 0.5172414
## iteration: 30 beta_I: 0.4556448 acceptance rate: 0.5
## iteration: 31 beta_I: 0.4528841 acceptance rate: 0.516129
## iteration: 32 beta_I: 0.4482569 acceptance rate: 0.53125
## iteration: 33 beta_I: 0.4482569 acceptance rate: 0.5151515
## iteration: 34 beta_I: 0.4482569 acceptance rate: 0.5
## iteration: 35 beta_I: 0.4482569 acceptance rate: 0.4857143
## iteration: 36 beta_I: 0.4473897 acceptance rate: 0.5
## iteration: 37 beta_I: 0.4418996 acceptance rate: 0.5135135
## iteration: 38 beta_I: 0.4418996 acceptance rate: 0.5
## iteration: 39 beta_I: 0.440354 acceptance rate: 0.5128205
## iteration: 40 beta_I: 0.4384155 acceptance rate: 0.525
## iteration: 41 beta_I: 0.4384155 acceptance rate: 0.5121951
## iteration: 42 beta_I: 0.4384155 acceptance rate: 0.5
## iteration: 43 beta_I: 0.4384155 acceptance rate: 0.4883721
## iteration: 44 beta_I: 0.4383522 acceptance rate: 0.5
## iteration: 45 beta_I: 0.4383522 acceptance rate: 0.4888889
## iteration: 46 beta_I: 0.4383522 acceptance rate: 0.4782609
## iteration: 47 beta_I: 0.4383522 acceptance rate: 0.4680851
## iteration: 48 beta_I: 0.4383522 acceptance rate: 0.4583333
## iteration: 49 beta_I: 0.4383522 acceptance rate: 0.4489796
## iteration: 50 beta_I: 0.4383522 acceptance rate: 0.44
## iteration: 51 beta_I: 0.4355351 acceptance rate: 0.4509804
## iteration: 52 beta_I: 0.4355351 acceptance rate: 0.4423077
## iteration: 53 beta_I: 0.4322702 acceptance rate: 0.4528302
## iteration: 54 beta_I: 0.4322702 acceptance rate: 0.4444444
## iteration: 55 beta_I: 0.4328255 acceptance rate: 0.4545455
## iteration: 56 beta_I: 0.4328255 acceptance rate: 0.4464286
## iteration: 57 beta_I: 0.4328255 acceptance rate: 0.4385965
## iteration: 58 beta_I: 0.4328255 acceptance rate: 0.4310345
## iteration: 59 beta_I: 0.4328255 acceptance rate: 0.4237288
## iteration: 60 beta_I: 0.4328255 acceptance rate: 0.4166667
## iteration: 61 beta_I: 0.4328255 acceptance rate: 0.4098361
## iteration: 62 beta_I: 0.4328255 acceptance rate: 0.4032258
## iteration: 63 beta_I: 0.4328255 acceptance rate: 0.3968254
## iteration: 64 beta_I: 0.4328255 acceptance rate: 0.390625
## iteration: 65 beta_I: 0.4328255 acceptance rate: 0.3846154
## iteration: 66 beta_I: 0.4328255 acceptance rate: 0.3787879
## iteration: 67 beta_I: 0.4328374 acceptance rate: 0.3880597
## iteration: 68 beta_I: 0.432883 acceptance rate: 0.3970588
## iteration: 69 beta_I: 0.4316091 acceptance rate: 0.4057971
## iteration: 70 beta_I: 0.4318303 acceptance rate: 0.4142857
## iteration: 71 beta_I: 0.4324267 acceptance rate: 0.4225352
## iteration: 72 beta_I: 0.4324267 acceptance rate: 0.4166667
## iteration: 73 beta_I: 0.4324267 acceptance rate: 0.4109589
## iteration: 74 beta_I: 0.4324267 acceptance rate: 0.4054054
## iteration: 75 beta_I: 0.4324267 acceptance rate: 0.4
## iteration: 76 beta_I: 0.4325468 acceptance rate: 0.4078947
## iteration: 77 beta_I: 0.4325468 acceptance rate: 0.4025974
## iteration: 78 beta_I: 0.4325468 acceptance rate: 0.3974359
## iteration: 79 beta_I: 0.4325468 acceptance rate: 0.3924051
```

```
## iteration: 80 beta_I: 0.4325468 acceptance rate: 0.3875
## iteration: 81 beta_I: 0.4311931 acceptance rate: 0.3950617
## iteration: 82 beta_I: 0.4332053 acceptance rate: 0.402439
## iteration: 83 beta_I: 0.4332053 acceptance rate: 0.3975904
## iteration: 84 beta_I: 0.4332053 acceptance rate: 0.3928571
## iteration: 85 beta_I: 0.4332053 acceptance rate: 0.3882353
## iteration: 86 beta_I: 0.4332053 acceptance rate: 0.3837209
## iteration: 87 beta_I: 0.4332053 acceptance rate: 0.3793103
## iteration: 88 beta_I: 0.4332053 acceptance rate: 0.375
## iteration: 89 beta_I: 0.4322776 acceptance rate: 0.3820225
## iteration: 90 beta_I: 0.4322776 acceptance rate: 0.3777778
## iteration: 91 beta_I: 0.4322776 acceptance rate: 0.3736264
## iteration: 92 beta_I: 0.4322776 acceptance rate: 0.3695652
## iteration: 93 beta_I: 0.4322776 acceptance rate: 0.3655914
## iteration: 94 beta_I: 0.4322776 acceptance rate: 0.3617021
## iteration: 95 beta_I: 0.4323823 acceptance rate: 0.3684211
## iteration: 96 beta_I: 0.4323823 acceptance rate: 0.3645833
## iteration: 97 beta_I: 0.4328946 acceptance rate: 0.371134
## iteration: 98 beta_I: 0.4322548 acceptance rate: 0.377551
## iteration: 99 beta_I: 0.4322548 acceptance rate: 0.3737374
## iteration: 100 beta_I: 0.4328986 acceptance rate: 0.38
## iteration: 101 beta_I: 0.4328986 acceptance rate: 0.3762376
## iteration: 102 beta_I: 0.4328986 acceptance rate: 0.372549
## iteration: 103 beta_I: 0.4325658 acceptance rate: 0.3786408
## iteration: 104 beta_I: 0.4325658 acceptance rate: 0.375
## iteration: 105 beta_I: 0.4325658 acceptance rate: 0.3714286
## iteration: 106 beta_I: 0.4325658 acceptance rate: 0.3679245
## iteration: 107 beta_I: 0.4325658 acceptance rate: 0.364486
## iteration: 108 beta_I: 0.4325658 acceptance rate: 0.3611111
## iteration: 109 beta_I: 0.4325658 acceptance rate: 0.3577982
## iteration: 110 beta_I: 0.4325658 acceptance rate: 0.3545455
## iteration: 111 beta_I: 0.4325658 acceptance rate: 0.3513514
## iteration: 112 beta_I: 0.4325658 acceptance rate: 0.3482143
## iteration: 113 beta_I: 0.4325658 acceptance rate: 0.3451327
## iteration: 114 beta_I: 0.4325658 acceptance rate: 0.3421053
## iteration: 115 beta_I: 0.4325658 acceptance rate: 0.3391304
## iteration: 116 beta_I: 0.4323053 acceptance rate: 0.3448276
## iteration: 117 beta_I: 0.4327104 acceptance rate: 0.3504274
## iteration: 118 beta_I: 0.4319103 acceptance rate: 0.3559322
## iteration: 119 beta_I: 0.4319103 acceptance rate: 0.3529412
## iteration: 120 beta_I: 0.4319103 acceptance rate: 0.35
## iteration: 121 beta_I: 0.4319784 acceptance rate: 0.3553719
## iteration: 122 beta_I: 0.4319784 acceptance rate: 0.352459
## iteration: 123 beta_I: 0.4319784 acceptance rate: 0.3495935
## iteration: 124 beta_I: 0.4324262 acceptance rate: 0.3548387
## iteration: 125 beta_I: 0.4323541 acceptance rate: 0.36
## iteration: 126 beta_I: 0.4323541 acceptance rate: 0.3571429
## iteration: 127 beta_I: 0.4323541 acceptance rate: 0.3543307
## iteration: 128 beta_I: 0.4323541 acceptance rate: 0.3515625
## iteration: 129 beta_I: 0.4323541 acceptance rate: 0.3488372
## iteration: 130 beta_I: 0.4323541 acceptance rate: 0.3461538
## iteration: 131 beta_I: 0.4323541 acceptance rate: 0.3435115
## iteration: 132 beta_I: 0.4323541 acceptance rate: 0.3409091
## iteration: 133 beta_I: 0.4323541 acceptance rate: 0.3383459
```

```
## iteration: 134 beta_I: 0.4323541 acceptance rate: 0.3358209
## iteration: 135 beta_I: 0.4323541 acceptance rate: 0.3333333
## iteration: 136 beta_I: 0.4323541 acceptance rate: 0.3308824
## iteration: 137 beta_I: 0.4323541 acceptance rate: 0.3284672
## iteration: 138 beta_I: 0.4320433 acceptance rate: 0.3333333
## iteration: 139 beta_I: 0.4328087 acceptance rate: 0.3381295
## iteration: 140 beta_I: 0.4328087 acceptance rate: 0.3357143
## iteration: 141 beta_I: 0.4328087 acceptance rate: 0.3333333
## iteration: 142 beta_I: 0.4328087 acceptance rate: 0.3309859
## iteration: 143 beta_I: 0.4317726 acceptance rate: 0.3356643
## iteration: 144 beta_I: 0.4317726 acceptance rate: 0.3333333
## iteration: 145 beta_I: 0.4318795 acceptance rate: 0.337931
## iteration: 146 beta_I: 0.4309036 acceptance rate: 0.3424658
## iteration: 147 beta_I: 0.4304756 acceptance rate: 0.3469388
## iteration: 148 beta_I: 0.4320945 acceptance rate: 0.3513514
## iteration: 149 beta_I: 0.4320945 acceptance rate: 0.3489933
## iteration: 150 beta_I: 0.4320945 acceptance rate: 0.3466667
## iteration: 151 beta_I: 0.4320945 acceptance rate: 0.3443709
## iteration: 152 beta_I: 0.4330057 acceptance rate: 0.3486842
## iteration: 153 beta_I: 0.4330057 acceptance rate: 0.3464052
## iteration: 154 beta_I: 0.4330057 acceptance rate: 0.3441558
## iteration: 155 beta_I: 0.4330057 acceptance rate: 0.3419355
## iteration: 156 beta_I: 0.4329845 acceptance rate: 0.3461538
## iteration: 157 beta_I: 0.4329845 acceptance rate: 0.343949
## iteration: 158 beta_I: 0.4329845 acceptance rate: 0.3417722
## iteration: 159 beta_I: 0.4316556 acceptance rate: 0.3459119
## iteration: 160 beta_I: 0.4316556 acceptance rate: 0.34375
## iteration: 161 beta_I: 0.4326215 acceptance rate: 0.3478261
## iteration: 162 beta_I: 0.4326215 acceptance rate: 0.345679
## iteration: 163 beta_I: 0.4326215 acceptance rate: 0.3435583
## iteration: 164 beta_I: 0.4316348 acceptance rate: 0.347561
## iteration: 165 beta_I: 0.4316348 acceptance rate: 0.3454545
## iteration: 166 beta_I: 0.4316348 acceptance rate: 0.3433735
## iteration: 167 beta_I: 0.4316348 acceptance rate: 0.3413174
## iteration: 168 beta_I: 0.4316348 acceptance rate: 0.3392857
## iteration: 169 beta_I: 0.4316348 acceptance rate: 0.3372781
## iteration: 170 beta_I: 0.4316348 acceptance rate: 0.3352941
## iteration: 171 beta_I: 0.4321107 acceptance rate: 0.3391813
## iteration: 172 beta_I: 0.4321107 acceptance rate: 0.3372093
## iteration: 173 beta_I: 0.4321107 acceptance rate: 0.3352601
## iteration: 174 beta_I: 0.4315824 acceptance rate: 0.3390805
## iteration: 175 beta_I: 0.4315824 acceptance rate: 0.3371429
## iteration: 176 beta_I: 0.4315824 acceptance rate: 0.3352273
## iteration: 177 beta_I: 0.4322902 acceptance rate: 0.3389831
## iteration: 178 beta_I: 0.4322902 acceptance rate: 0.3370787
## iteration: 179 beta_I: 0.4322902 acceptance rate: 0.3351955
## iteration: 180 beta_I: 0.4316118 acceptance rate: 0.3388889
## iteration: 181 beta_I: 0.4312982 acceptance rate: 0.3425414
## iteration: 182 beta_I: 0.4312982 acceptance rate: 0.3406593
## iteration: 183 beta_I: 0.4310648 acceptance rate: 0.3442623
## iteration: 184 beta_I: 0.4310648 acceptance rate: 0.3423913
## iteration: 185 beta_I: 0.4310648 acceptance rate: 0.3405405
## iteration: 186 beta_I: 0.4310648 acceptance rate: 0.3387097
## iteration: 187 beta_I: 0.4310648 acceptance rate: 0.3368984
```

```
## iteration: 188 beta_I: 0.431372 acceptance rate: 0.3404255
## iteration: 189 beta_I: 0.431372 acceptance rate: 0.3386243
## iteration: 190 beta_I: 0.431513 acceptance rate: 0.3421053
## iteration: 191 beta_I: 0.431513 acceptance rate: 0.3403141
## iteration: 192 beta_I: 0.431513 acceptance rate: 0.3385417
## iteration: 193 beta_I: 0.431513 acceptance rate: 0.3367876
## iteration: 194 beta_I: 0.431513 acceptance rate: 0.3350515
## iteration: 195 beta_I: 0.431513 acceptance rate: 0.3333333
## iteration: 196 beta_I: 0.431513 acceptance rate: 0.3316327
## iteration: 197 beta_I: 0.4324844 acceptance rate: 0.3350254
## iteration: 198 beta_I: 0.4324844 acceptance rate: 0.3333333
## iteration: 199 beta_I: 0.4324844 acceptance rate: 0.3316583
## iteration: 200 beta_I: 0.4324844 acceptance rate: 0.33
## iteration: 201 beta_I: 0.4324844 acceptance rate: 0.3283582
## iteration: 202 beta_I: 0.4324844 acceptance rate: 0.3267327
## iteration: 203 beta_I: 0.4324844 acceptance rate: 0.3251232
## iteration: 204 beta_I: 0.4324844 acceptance rate: 0.3235294
## iteration: 205 beta_I: 0.4324844 acceptance rate: 0.3219512
## iteration: 206 beta_I: 0.4324844 acceptance rate: 0.3203883
## iteration: 207 beta_I: 0.4324844 acceptance rate: 0.3188406
## iteration: 208 beta_I: 0.4324844 acceptance rate: 0.3173077
## iteration: 209 beta_I: 0.4314989 acceptance rate: 0.3205742
## iteration: 210 beta_I: 0.4314989 acceptance rate: 0.3190476
## iteration: 211 beta_I: 0.4320419 acceptance rate: 0.3222749
## iteration: 212 beta_I: 0.4320419 acceptance rate: 0.3207547
## iteration: 213 beta_I: 0.4320419 acceptance rate: 0.3192488
## iteration: 214 beta_I: 0.4320419 acceptance rate: 0.317757
## iteration: 215 beta_I: 0.4323961 acceptance rate: 0.3209302
## iteration: 216 beta_I: 0.4323961 acceptance rate: 0.3194444
## iteration: 217 beta_I: 0.4336609 acceptance rate: 0.3225806
## iteration: 218 beta_I: 0.4336609 acceptance rate: 0.3211009
## iteration: 219 beta_I: 0.4336609 acceptance rate: 0.3196347
## iteration: 220 beta_I: 0.4315473 acceptance rate: 0.3227273
## iteration: 221 beta_I: 0.4330496 acceptance rate: 0.3257919
## iteration: 222 beta_I: 0.4330496 acceptance rate: 0.3243243
## iteration: 223 beta_I: 0.4329727 acceptance rate: 0.3273543
## iteration: 224 beta_I: 0.4312222 acceptance rate: 0.3303571
## iteration: 225 beta_I: 0.4313723 acceptance rate: 0.3333333
## iteration: 226 beta_I: 0.4313723 acceptance rate: 0.3318584
## iteration: 227 beta_I: 0.4313723 acceptance rate: 0.3303965
## iteration: 228 beta_I: 0.4328937 acceptance rate: 0.3333333
## iteration: 229 beta_I: 0.4328937 acceptance rate: 0.3318777
## iteration: 230 beta_I: 0.4328937 acceptance rate: 0.3304348
## iteration: 231 beta_I: 0.4311817 acceptance rate: 0.3333333
## iteration: 232 beta_I: 0.4311817 acceptance rate: 0.3318966
## iteration: 233 beta_I: 0.4311817 acceptance rate: 0.3304721
## iteration: 234 beta_I: 0.4311817 acceptance rate: 0.3290598
## iteration: 235 beta_I: 0.4311817 acceptance rate: 0.3276596
## iteration: 236 beta_I: 0.4311817 acceptance rate: 0.3262712
## iteration: 237 beta_I: 0.4311817 acceptance rate: 0.3248945
## iteration: 238 beta_I: 0.4326424 acceptance rate: 0.3277311
## iteration: 239 beta_I: 0.4326424 acceptance rate: 0.3263598
## iteration: 240 beta_I: 0.4326424 acceptance rate: 0.325
## iteration: 241 beta_I: 0.4326424 acceptance rate: 0.3236515
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## iteration: 242 beta_I: 0.4326424 acceptance rate: 0.322314
## iteration: 243 beta_I: 0.4326424 acceptance rate: 0.3209877
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## iteration: 245 beta_I: 0.4326424 acceptance rate: 0.3183673
## iteration: 246 beta_I: 0.4326424 acceptance rate: 0.3170732
## iteration: 247 beta_I: 0.4326424 acceptance rate: 0.3157895
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## iteration: 250 beta_I: 0.4320002 acceptance rate: 0.316
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## iteration: 261 beta_I: 0.4327327 acceptance rate: 0.3180077
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## iteration: 281 beta_I: 0.4310712 acceptance rate: 0.3238434
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## iteration: 284 beta_I: 0.4326887 acceptance rate: 0.3274648
## iteration: 285 beta_I: 0.432179 acceptance rate: 0.3298246
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## iteration: 293 beta_I: 0.4320465 acceptance rate: 0.334471
## iteration: 294 beta_I: 0.4320465 acceptance rate: 0.3333333
## iteration: 295 beta_I: 0.4328437 acceptance rate: 0.3355932
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## iteration: 296 beta_I: 0.4329582 acceptance rate: 0.3378378
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## iteration: 349 beta_I: 0.432999 acceptance rate: 0.3352436
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## iteration: 401 beta_I: 0.4325867 acceptance rate: 0.3266833
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## iteration: 403 beta_I: 0.4325085 acceptance rate: 0.3275434
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## iteration: 457 beta_I: 0.4327847 acceptance rate: 0.3238512
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## iteration: 458 beta_I: 0.4327847 acceptance rate: 0.3231441
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## iteration: 511 beta_I: 0.4322305 acceptance rate: 0.3150685
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## iteration: 574 beta_I: 0.432188 acceptance rate: 0.3379791
## iteration: 575 beta_I: 0.432188 acceptance rate: 0.3373913
## iteration: 576 beta_I: 0.4327401 acceptance rate: 0.3385417
## iteration: 577 beta_I: 0.4327401 acceptance rate: 0.3379549
## iteration: 578 beta_I: 0.4319383 acceptance rate: 0.3391003
## iteration: 579 beta_I: 0.4319383 acceptance rate: 0.3385147
## iteration: 580 beta_I: 0.4319383 acceptance rate: 0.337931
## iteration: 581 beta_I: 0.4317796 acceptance rate: 0.3390706
## iteration: 582 beta_I: 0.4317796 acceptance rate: 0.338488
## iteration: 583 beta_I: 0.4323489 acceptance rate: 0.3396226
## iteration: 584 beta_I: 0.4323489 acceptance rate: 0.3390411
## iteration: 585 beta_I: 0.4323489 acceptance rate: 0.3384615
## iteration: 586 beta_I: 0.4323489 acceptance rate: 0.337884
## iteration: 587 beta_I: 0.4323489 acceptance rate: 0.3373083
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## iteration: 589 beta_I: 0.4323489 acceptance rate: 0.336163
## iteration: 590 beta_I: 0.4323489 acceptance rate: 0.3355932
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## iteration: 592 beta_I: 0.4336517 acceptance rate: 0.3378378
## iteration: 593 beta_I: 0.4336517 acceptance rate: 0.3372681
## iteration: 594 beta_I: 0.4324733 acceptance rate: 0.3383838
## iteration: 595 beta_I: 0.4316702 acceptance rate: 0.3394958
## iteration: 596 beta_I: 0.4316702 acceptance rate: 0.3389262
## iteration: 597 beta_I: 0.4316702 acceptance rate: 0.3383585
## iteration: 598 beta_I: 0.4316702 acceptance rate: 0.3377926
## iteration: 599 beta_I: 0.4316702 acceptance rate: 0.3372287
## iteration: 600 beta_I: 0.4316702 acceptance rate: 0.3366667
## iteration: 601 beta_I: 0.4316702 acceptance rate: 0.3361065
## iteration: 602 beta_I: 0.4316702 acceptance rate: 0.3355482
## iteration: 603 beta_I: 0.4316702 acceptance rate: 0.3349917
## iteration: 604 beta_I: 0.4316702 acceptance rate: 0.3344371
## iteration: 605 beta_I: 0.4316702 acceptance rate: 0.3338843
## iteration: 606 beta_I: 0.4316702 acceptance rate: 0.3333333
## iteration: 607 beta_I: 0.4316702 acceptance rate: 0.3327842
## iteration: 608 beta_I: 0.4316702 acceptance rate: 0.3322368
## iteration: 609 beta_I: 0.4330459 acceptance rate: 0.3333333
## iteration: 610 beta_I: 0.4325311 acceptance rate: 0.3344262
## iteration: 611 beta_I: 0.4325311 acceptance rate: 0.3338789
## iteration: 612 beta_I: 0.4325311 acceptance rate: 0.3333333
## iteration: 613 beta_I: 0.4313099 acceptance rate: 0.3344209
## iteration: 614 beta_I: 0.4313099 acceptance rate: 0.3338762
## iteration: 615 beta_I: 0.4313099 acceptance rate: 0.3333333
## iteration: 616 beta_I: 0.4313099 acceptance rate: 0.3327922
## iteration: 617 beta_I: 0.4313099 acceptance rate: 0.3322528
## iteration: 618 beta_I: 0.4313099 acceptance rate: 0.3317152
## iteration: 619 beta_I: 0.4313099 acceptance rate: 0.3311793
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## iteration: 620 beta_I: 0.4313099 acceptance rate: 0.3306452
## iteration: 621 beta_I: 0.4313099 acceptance rate: 0.3301127
## iteration: 622 beta_I: 0.4315977 acceptance rate: 0.3311897
## iteration: 623 beta_I: 0.4300173 acceptance rate: 0.3322632
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## iteration: 625 beta_I: 0.4300173 acceptance rate: 0.3312
## iteration: 626 beta_I: 0.4300173 acceptance rate: 0.3306709
## iteration: 627 beta_I: 0.4302947 acceptance rate: 0.3317384
## iteration: 628 beta_I: 0.4302947 acceptance rate: 0.3312102
## iteration: 629 beta_I: 0.4302947 acceptance rate: 0.3306836
## iteration: 630 beta_I: 0.4330311 acceptance rate: 0.331746
## iteration: 631 beta_I: 0.4330311 acceptance rate: 0.3312203
## iteration: 632 beta_I: 0.4327216 acceptance rate: 0.3322785
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## iteration: 634 beta_I: 0.4313267 acceptance rate: 0.3343849
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## iteration: 643 beta_I: 0.4320272 acceptance rate: 0.3343701
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## iteration: 645 beta_I: 0.4320272 acceptance rate: 0.3333333
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## iteration: 649 beta_I: 0.4320272 acceptance rate: 0.3312789
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## iteration: 653 beta_I: 0.4324264 acceptance rate: 0.330781
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## iteration: 655 beta_I: 0.4307141 acceptance rate: 0.3312977
## iteration: 656 beta_I: 0.4307141 acceptance rate: 0.3307927
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## iteration: 660 beta_I: 0.431124 acceptance rate: 0.3318182
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## iteration: 662 beta_I: 0.4313525 acceptance rate: 0.3323263
## iteration: 663 beta_I: 0.4313525 acceptance rate: 0.331825
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## iteration: 673 beta_I: 0.4313525 acceptance rate: 0.3268945
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## iteration: 674 beta_I: 0.4323661 acceptance rate: 0.3278932
## iteration: 675 beta_I: 0.4323661 acceptance rate: 0.3274074
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## iteration: 727 beta_I: 0.4314638 acceptance rate: 0.3287483
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## iteration: 781 beta_I: 0.430943 acceptance rate: 0.3277849
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## iteration: 782 beta_I: 0.431896 acceptance rate: 0.3286445
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## iteration: 805 beta_I: 0.4309153 acceptance rate: 0.3279503
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## iteration: 807 beta_I: 0.4309153 acceptance rate: 0.3271375
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## iteration: 817 beta_I: 0.4331824 acceptance rate: 0.3243574
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## iteration: 820 beta_I: 0.432807 acceptance rate: 0.3243902
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## iteration: 824 beta_I: 0.432807 acceptance rate: 0.3228155
## iteration: 825 beta_I: 0.432807 acceptance rate: 0.3224242
## iteration: 826 beta_I: 0.432807 acceptance rate: 0.3220339
## iteration: 827 beta_I: 0.432807 acceptance rate: 0.3216445
## iteration: 828 beta_I: 0.432807 acceptance rate: 0.321256
## iteration: 829 beta_I: 0.432807 acceptance rate: 0.3208685
## iteration: 830 beta_I: 0.432807 acceptance rate: 0.3204819
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## iteration: 832 beta_I: 0.432807 acceptance rate: 0.3197115
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## iteration: 835 beta_I: 0.4323612 acceptance rate: 0.3209581
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## iteration: 836 beta_I: 0.4317126 acceptance rate: 0.3217703
## iteration: 837 beta_I: 0.4317126 acceptance rate: 0.3213859
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## iteration: 889 beta_I: 0.4330343 acceptance rate: 0.3228346
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## iteration: 909 beta_I: 0.4323658 acceptance rate: 0.320132
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## iteration: 917 beta_I: 0.431561 acceptance rate: 0.3227917
## iteration: 918 beta_I: 0.431561 acceptance rate: 0.3224401
## iteration: 919 beta_I: 0.4321477 acceptance rate: 0.3231774
## iteration: 920 beta_I: 0.4321477 acceptance rate: 0.3228261
## iteration: 921 beta_I: 0.4321477 acceptance rate: 0.3224756
## iteration: 922 beta_I: 0.4321477 acceptance rate: 0.3221258
## iteration: 923 beta_I: 0.4321477 acceptance rate: 0.3217768
## iteration: 924 beta_I: 0.4321477 acceptance rate: 0.3214286
## iteration: 925 beta_I: 0.4321477 acceptance rate: 0.3210811
## iteration: 926 beta_I: 0.4321477 acceptance rate: 0.3207343
## iteration: 927 beta_I: 0.4321477 acceptance rate: 0.3203883
## iteration: 928 beta_I: 0.4322482 acceptance rate: 0.3211207
## iteration: 929 beta_I: 0.4322482 acceptance rate: 0.320775
## iteration: 930 beta_I: 0.4322482 acceptance rate: 0.3204301
## iteration: 931 beta_I: 0.4313946 acceptance rate: 0.32116
## iteration: 932 beta_I: 0.4313946 acceptance rate: 0.3208155
## iteration: 933 beta_I: 0.4313946 acceptance rate: 0.3204716
## iteration: 934 beta_I: 0.4318512 acceptance rate: 0.3211991
## iteration: 935 beta_I: 0.4321035 acceptance rate: 0.3219251
## iteration: 936 beta_I: 0.4321035 acceptance rate: 0.3215812
## iteration: 937 beta_I: 0.4321035 acceptance rate: 0.321238
## iteration: 938 beta_I: 0.4321035 acceptance rate: 0.3208955
## iteration: 939 beta_I: 0.4321035 acceptance rate: 0.3205538
## iteration: 940 beta_I: 0.4317874 acceptance rate: 0.3212766
## iteration: 941 beta_I: 0.4317874 acceptance rate: 0.3209352
## iteration: 942 beta_I: 0.4317474 acceptance rate: 0.3216561
## iteration: 943 beta_I: 0.4317474 acceptance rate: 0.321315
```

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## iteration: 944 beta_I: 0.4317474 acceptance rate: 0.3209746
## iteration: 945 beta_I: 0.4326569 acceptance rate: 0.3216931
## iteration: 946 beta_I: 0.4326569 acceptance rate: 0.3213531
## iteration: 947 beta_I: 0.4326569 acceptance rate: 0.3210137
## iteration: 948 beta_I: 0.4326569 acceptance rate: 0.3206751
## iteration: 949 beta_I: 0.4323759 acceptance rate: 0.3213909
## iteration: 950 beta_I: 0.4323759 acceptance rate: 0.3210526
## iteration: 951 beta_I: 0.4323759 acceptance rate: 0.320715
## iteration: 952 beta_I: 0.4323759 acceptance rate: 0.3203782
## iteration: 953 beta_I: 0.4323759 acceptance rate: 0.320042
## iteration: 954 beta_I: 0.4323759 acceptance rate: 0.3197065
## iteration: 955 beta_I: 0.4315401 acceptance rate: 0.3204188
## iteration: 956 beta_I: 0.4314741 acceptance rate: 0.3211297
## iteration: 957 beta_I: 0.4314741 acceptance rate: 0.3207941
## iteration: 958 beta_I: 0.4314741 acceptance rate: 0.3204593
## iteration: 959 beta_I: 0.4314497 acceptance rate: 0.3211679
## iteration: 960 beta_I: 0.4314497 acceptance rate: 0.3208333
## iteration: 961 beta_I: 0.4314497 acceptance rate: 0.3204995
## iteration: 962 beta_I: 0.4314497 acceptance rate: 0.3201663
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## iteration: 966 beta_I: 0.4308741 acceptance rate: 0.3198758
## iteration: 967 beta_I: 0.4308741 acceptance rate: 0.319545
## iteration: 968 beta_I: 0.4308741 acceptance rate: 0.3192149
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## iteration: 973 beta_I: 0.4320954 acceptance rate: 0.31963
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## iteration: 978 beta_I: 0.4319659 acceptance rate: 0.3231084
## iteration: 979 beta_I: 0.4319659 acceptance rate: 0.3227783
## iteration: 980 beta_I: 0.4319659 acceptance rate: 0.322449
## iteration: 981 beta_I: 0.4319659 acceptance rate: 0.3221203
## iteration: 982 beta_I: 0.4319659 acceptance rate: 0.3217923
## iteration: 983 beta_I: 0.4319659 acceptance rate: 0.3214649
## iteration: 984 beta_I: 0.4319659 acceptance rate: 0.3211382
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## iteration: 991 beta_I: 0.4329392 acceptance rate: 0.320888
## iteration: 992 beta_I: 0.431397 acceptance rate: 0.3215726
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## iteration: 995 beta_I: 0.4329424 acceptance rate: 0.321608
## iteration: 996 beta_I: 0.4329424 acceptance rate: 0.3212851
## iteration: 997 beta_I: 0.4329424 acceptance rate: 0.3209629
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## iteration: 998 beta_I: 0.4315684 acceptance rate: 0.3216433
## iteration: 999 beta_I: 0.4315684 acceptance rate: 0.3213213
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## iteration: 1001 beta_I: 0.4322333 acceptance rate: 0.3216783
## iteration: 1002 beta_I: 0.4322333 acceptance rate: 0.3213573
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## iteration: 1005 beta_I: 0.4329271 acceptance rate: 0.321393
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## iteration: 1012 beta_I: 0.4329271 acceptance rate: 0.31917
## iteration: 1013 beta_I: 0.4329271 acceptance rate: 0.3188549
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## iteration: 1035 beta_I: 0.4320928 acceptance rate: 0.3198068
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## iteration: 1038 beta_I: 0.4320928 acceptance rate: 0.3188825
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## iteration: 1051 beta_I: 0.4329958 acceptance rate: 0.320647
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## iteration: 1052 beta_I: 0.4329958 acceptance rate: 0.3203422
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## iteration: 1091 beta_I: 0.4326861 acceptance rate: 0.3180568
## iteration: 1092 beta_I: 0.4326861 acceptance rate: 0.3177656
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## iteration: 1102 beta_I: 0.4326861 acceptance rate: 0.314882
## iteration: 1103 beta_I: 0.4326861 acceptance rate: 0.3145966
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## iteration: 1105 beta_I: 0.4322016 acceptance rate: 0.3149321
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## iteration: 1106 beta_I: 0.4320591 acceptance rate: 0.3155515
## iteration: 1107 beta_I: 0.4330037 acceptance rate: 0.3161698
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## iteration: 1135 beta_I: 0.4324309 acceptance rate: 0.3171806
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## iteration: 1139 beta_I: 0.4324309 acceptance rate: 0.3160667
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## iteration: 1141 beta_I: 0.4317075 acceptance rate: 0.3163891
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## iteration: 1143 beta_I: 0.4327136 acceptance rate: 0.3167104
## iteration: 1144 beta_I: 0.4327136 acceptance rate: 0.3164336
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## iteration: 1157 beta_I: 0.4322743 acceptance rate: 0.3163354
## iteration: 1158 beta_I: 0.4322743 acceptance rate: 0.3160622
## iteration: 1159 beta_I: 0.4322743 acceptance rate: 0.3157895
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## iteration: 1160 beta_I: 0.4322743 acceptance rate: 0.3155172
## iteration: 1161 beta_I: 0.4322743 acceptance rate: 0.3152455
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## iteration: 1203 beta_I: 0.432301 acceptance rate: 0.3133832
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## iteration: 1213 beta_I: 0.4329787 acceptance rate: 0.3132729
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## iteration: 1214 beta_I: 0.4329787 acceptance rate: 0.3130148
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## iteration: 1236 beta_I: 0.4323014 acceptance rate: 0.3106796
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## iteration: 1249 beta_I: 0.4324296 acceptance rate: 0.3122498
## iteration: 1250 beta_I: 0.4324296 acceptance rate: 0.312
## iteration: 1251 beta_I: 0.4324296 acceptance rate: 0.3117506
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## iteration: 1254 beta_I: 0.4324296 acceptance rate: 0.3110048
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## iteration: 1257 beta_I: 0.4324296 acceptance rate: 0.3102625
## iteration: 1258 beta_I: 0.4324296 acceptance rate: 0.3100159
## iteration: 1259 beta_I: 0.4324296 acceptance rate: 0.3097697
## iteration: 1260 beta_I: 0.4324296 acceptance rate: 0.3095238
## iteration: 1261 beta_I: 0.4324296 acceptance rate: 0.3092784
## iteration: 1262 beta_I: 0.4327746 acceptance rate: 0.3098257
## iteration: 1263 beta_I: 0.4327746 acceptance rate: 0.3095804
## iteration: 1264 beta_I: 0.4321042 acceptance rate: 0.3101266
## iteration: 1265 beta_I: 0.4321042 acceptance rate: 0.3098814
## iteration: 1266 beta_I: 0.4321042 acceptance rate: 0.3096367
## iteration: 1267 beta_I: 0.4321042 acceptance rate: 0.3093923
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## iteration: 1268 beta_I: 0.4321042 acceptance rate: 0.3091483
## iteration: 1269 beta_I: 0.4317377 acceptance rate: 0.3096927
## iteration: 1270 beta_I: 0.4317377 acceptance rate: 0.3094488
## iteration: 1271 beta_I: 0.4317377 acceptance rate: 0.3092054
## iteration: 1272 beta_I: 0.4318993 acceptance rate: 0.3097484
## iteration: 1273 beta_I: 0.4326232 acceptance rate: 0.3102907
## iteration: 1274 beta_I: 0.4326232 acceptance rate: 0.3100471
## iteration: 1275 beta_I: 0.4326232 acceptance rate: 0.3098039
## iteration: 1276 beta_I: 0.4329511 acceptance rate: 0.3103448
## iteration: 1277 beta_I: 0.4329511 acceptance rate: 0.3101018
## iteration: 1278 beta_I: 0.4329511 acceptance rate: 0.3098592
## iteration: 1279 beta_I: 0.4314713 acceptance rate: 0.3103987
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## iteration: 1281 beta_I: 0.4314713 acceptance rate: 0.3099141
## iteration: 1282 beta_I: 0.4314713 acceptance rate: 0.3096724
## iteration: 1283 beta_I: 0.4314713 acceptance rate: 0.309431
## iteration: 1284 beta_I: 0.4312105 acceptance rate: 0.3099688
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## iteration: 1286 beta_I: 0.4328189 acceptance rate: 0.3102644
## iteration: 1287 beta_I: 0.4328189 acceptance rate: 0.3100233
## iteration: 1288 beta_I: 0.4328189 acceptance rate: 0.3097826
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## iteration: 1290 beta_I: 0.4316529 acceptance rate: 0.3100775
## iteration: 1291 beta_I: 0.4316529 acceptance rate: 0.3098373
## iteration: 1292 beta_I: 0.4316529 acceptance rate: 0.3095975
## iteration: 1293 beta_I: 0.4316529 acceptance rate: 0.3093581
## iteration: 1294 beta_I: 0.4316529 acceptance rate: 0.309119
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## iteration: 1296 beta_I: 0.4324127 acceptance rate: 0.3094136
## iteration: 1297 beta_I: 0.4324127 acceptance rate: 0.309175
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## iteration: 1299 beta_I: 0.4330058 acceptance rate: 0.3094688
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## iteration: 1301 beta_I: 0.4319665 acceptance rate: 0.3097617
## iteration: 1302 beta_I: 0.4319665 acceptance rate: 0.3095238
## iteration: 1303 beta_I: 0.4319665 acceptance rate: 0.3092863
## iteration: 1304 beta_I: 0.4316518 acceptance rate: 0.309816
## iteration: 1305 beta_I: 0.4316518 acceptance rate: 0.3095785
## iteration: 1306 beta_I: 0.4316518 acceptance rate: 0.3093415
## iteration: 1307 beta_I: 0.4316518 acceptance rate: 0.3091048
## iteration: 1308 beta_I: 0.4332623 acceptance rate: 0.309633
## iteration: 1309 beta_I: 0.4332623 acceptance rate: 0.3093965
## iteration: 1310 beta_I: 0.4332623 acceptance rate: 0.3091603
## iteration: 1311 beta_I: 0.4332623 acceptance rate: 0.3089245
## iteration: 1312 beta_I: 0.432696 acceptance rate: 0.3094512
## iteration: 1313 beta_I: 0.432696 acceptance rate: 0.3092155
## iteration: 1314 beta_I: 0.4330242 acceptance rate: 0.3097412
## iteration: 1315 beta_I: 0.4330242 acceptance rate: 0.3095057
## iteration: 1316 beta_I: 0.4330242 acceptance rate: 0.3092705
## iteration: 1317 beta_I: 0.4330242 acceptance rate: 0.3090357
## iteration: 1318 beta_I: 0.4330242 acceptance rate: 0.3088012
## iteration: 1319 beta_I: 0.4330242 acceptance rate: 0.3085671
## iteration: 1320 beta_I: 0.4330242 acceptance rate: 0.3083333
## iteration: 1321 beta_I: 0.4330242 acceptance rate: 0.3080999
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## iteration: 1322 beta_I: 0.4330242 acceptance rate: 0.3078669
## iteration: 1323 beta_I: 0.4330242 acceptance rate: 0.3076342
## iteration: 1324 beta_I: 0.433005 acceptance rate: 0.3081571
## iteration: 1325 beta_I: 0.433005 acceptance rate: 0.3079245
## iteration: 1326 beta_I: 0.433005 acceptance rate: 0.3076923
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## iteration: 1328 beta_I: 0.433005 acceptance rate: 0.3072289
## iteration: 1329 beta_I: 0.4323923 acceptance rate: 0.3077502
## iteration: 1330 beta_I: 0.4323923 acceptance rate: 0.3075188
## iteration: 1331 beta_I: 0.4323923 acceptance rate: 0.3072878
## iteration: 1332 beta_I: 0.4323923 acceptance rate: 0.3070571
## iteration: 1333 beta_I: 0.4323769 acceptance rate: 0.3075769
## iteration: 1334 beta_I: 0.4323769 acceptance rate: 0.3073463
## iteration: 1335 beta_I: 0.4323769 acceptance rate: 0.3071161
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## iteration: 1338 beta_I: 0.4320689 acceptance rate: 0.3079223
## iteration: 1339 beta_I: 0.4320689 acceptance rate: 0.3076923
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## iteration: 1341 beta_I: 0.4318625 acceptance rate: 0.3079791
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## iteration: 1375 beta_I: 0.4325469 acceptance rate: 0.3083636
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## iteration: 1376 beta_I: 0.4325469 acceptance rate: 0.3081395
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## iteration: 1389 beta_I: 0.43313 acceptance rate: 0.3059755
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## iteration: 1483 beta_I: 0.4314893 acceptance rate: 0.3054619
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## iteration: 1597 beta_I: 0.432402 acceptance rate: 0.298685
## iteration: 1598 beta_I: 0.432402 acceptance rate: 0.2984981
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## iteration: 1631 beta_I: 0.4327382 acceptance rate: 0.2967505
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## iteration: 1636 beta_I: 0.4323632 acceptance rate: 0.297066
## iteration: 1637 beta_I: 0.4323632 acceptance rate: 0.2968845
## iteration: 1638 beta_I: 0.4323632 acceptance rate: 0.2967033
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## iteration: 1642 beta_I: 0.4313565 acceptance rate: 0.2971985
## iteration: 1643 beta_I: 0.4313565 acceptance rate: 0.2970177
## iteration: 1644 beta_I: 0.4313565 acceptance rate: 0.296837
## iteration: 1645 beta_I: 0.4313565 acceptance rate: 0.2966565
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## iteration: 1646 beta_I: 0.4313565 acceptance rate: 0.2964763
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## iteration: 1915 beta_I: 0.4299817 acceptance rate: 0.2955614
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## iteration: 1938 beta_I: 0.431282 acceptance rate: 0.2951496
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## iteration: 1940 beta_I: 0.4342315 acceptance rate: 0.2958763
## iteration: 1941 beta_I: 0.4316908 acceptance rate: 0.2962391
## iteration: 1942 beta_I: 0.4316908 acceptance rate: 0.2960865
## iteration: 1943 beta_I: 0.4316908 acceptance rate: 0.2959341
## iteration: 1944 beta_I: 0.4316908 acceptance rate: 0.2957819
## iteration: 1945 beta_I: 0.432629 acceptance rate: 0.296144
## iteration: 1946 beta_I: 0.432629 acceptance rate: 0.2959918
## iteration: 1947 beta_I: 0.4326931 acceptance rate: 0.2963534
## iteration: 1948 beta_I: 0.4326931 acceptance rate: 0.2962012
## iteration: 1949 beta_I: 0.4319187 acceptance rate: 0.2965623
## iteration: 1950 beta_I: 0.4334521 acceptance rate: 0.2969231
## iteration: 1951 beta_I: 0.4334521 acceptance rate: 0.2967709
## iteration: 1952 beta_I: 0.4334521 acceptance rate: 0.2966189
## iteration: 1953 beta_I: 0.4334521 acceptance rate: 0.296467
## iteration: 1954 beta_I: 0.4334521 acceptance rate: 0.2963153
## iteration: 1955 beta_I: 0.4334521 acceptance rate: 0.2961637
## iteration: 1956 beta_I: 0.4334521 acceptance rate: 0.2960123
## iteration: 1957 beta_I: 0.4334521 acceptance rate: 0.295861
## iteration: 1958 beta_I: 0.4334521 acceptance rate: 0.2957099
## iteration: 1959 beta_I: 0.4334521 acceptance rate: 0.295559
## iteration: 1960 beta_I: 0.4334521 acceptance rate: 0.2954082
## iteration: 1961 beta_I: 0.4334521 acceptance rate: 0.2952575
## iteration: 1962 beta_I: 0.4310975 acceptance rate: 0.2956167
## iteration: 1963 beta_I: 0.4310975 acceptance rate: 0.2954661
## iteration: 1964 beta_I: 0.4310975 acceptance rate: 0.2953157
## iteration: 1965 beta_I: 0.4328026 acceptance rate: 0.2956743
## iteration: 1966 beta_I: 0.4328026 acceptance rate: 0.2955239
## iteration: 1967 beta_I: 0.4328026 acceptance rate: 0.2953737
## iteration: 1968 beta_I: 0.4328026 acceptance rate: 0.2952236
## iteration: 1969 beta_I: 0.4328026 acceptance rate: 0.2950736
```

```
## iteration: 1970 beta_I: 0.4328026 acceptance rate: 0.2949239
## iteration: 1971 beta_I: 0.4317641 acceptance rate: 0.2952816
## iteration: 1972 beta_I: 0.4315606 acceptance rate: 0.2956389
## iteration: 1973 beta_I: 0.4299607 acceptance rate: 0.2959959
## iteration: 1974 beta_I: 0.4299607 acceptance rate: 0.295846
## iteration: 1975 beta_I: 0.4299607 acceptance rate: 0.2956962
## iteration: 1976 beta_I: 0.4299607 acceptance rate: 0.2955466
## iteration: 1977 beta_I: 0.4299607 acceptance rate: 0.2953971
## iteration: 1978 beta_I: 0.4331762 acceptance rate: 0.2957533
## iteration: 1979 beta_I: 0.432719 acceptance rate: 0.2961091
## iteration: 1980 beta_I: 0.4312603 acceptance rate: 0.2964646
## iteration: 1981 beta_I: 0.431193 acceptance rate: 0.2968198
## iteration: 1982 beta_I: 0.431193 acceptance rate: 0.29667
## iteration: 1983 beta_I: 0.431193 acceptance rate: 0.2965204
## iteration: 1984 beta_I: 0.431193 acceptance rate: 0.296371
## iteration: 1985 beta_I: 0.431193 acceptance rate: 0.2962217
## iteration: 1986 beta_I: 0.431193 acceptance rate: 0.2960725
## iteration: 1987 beta_I: 0.431193 acceptance rate: 0.2959235
## iteration: 1988 beta_I: 0.431193 acceptance rate: 0.2957746
## iteration: 1989 beta_I: 0.431193 acceptance rate: 0.2956259
## iteration: 1990 beta_I: 0.431193 acceptance rate: 0.2954774
## iteration: 1991 beta_I: 0.4314544 acceptance rate: 0.2958312
## iteration: 1992 beta_I: 0.4314544 acceptance rate: 0.2956827
## iteration: 1993 beta_I: 0.4314544 acceptance rate: 0.2955344
## iteration: 1994 beta_I: 0.4314544 acceptance rate: 0.2953862
## iteration: 1995 beta_I: 0.4314544 acceptance rate: 0.2952381
## iteration: 1996 beta_I: 0.433287 acceptance rate: 0.2955912
## iteration: 1997 beta_I: 0.4321035 acceptance rate: 0.2959439
## iteration: 1998 beta_I: 0.4321035 acceptance rate: 0.2957958
## iteration: 1999 beta_I: 0.4321035 acceptance rate: 0.2956478
## iteration: 2000 beta_I: 0.4321035 acceptance rate: 0.2955
```
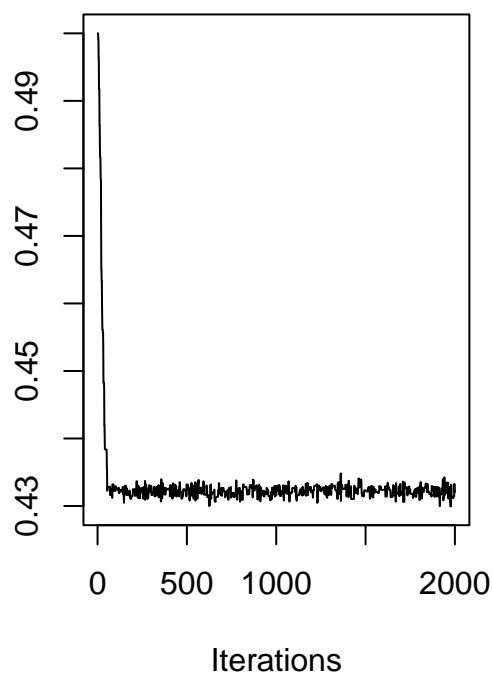
```r
trace_mat <- matrix(mcmcTrace, ncol = 1, byrow = TRUE)
trace     <- mcmc(trace_mat, start = 1)
colnames(trace) <- "beta_I"

plot(trace)
```
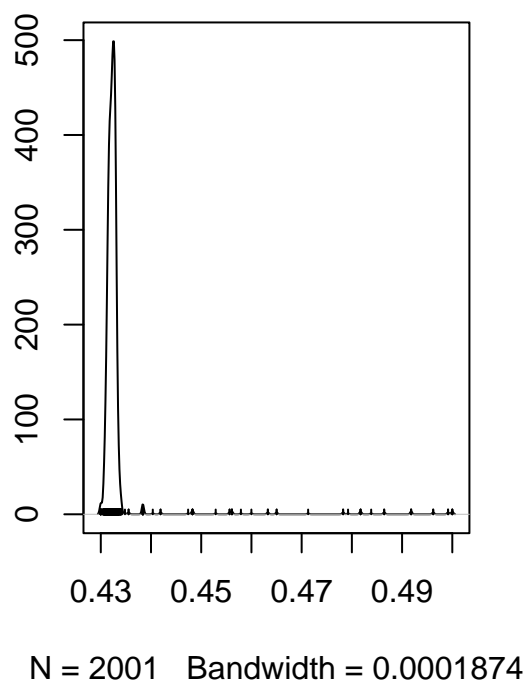
Trace of beta_I

Density of beta_I

Iterations

N = 2001   Bandwidth = 0.0001874

```
summary(trace)
```

```
##
## Iterations = 1:2001
## Thinning interval = 1
## Number of chains = 1
## Sample size per chain = 2001
##
## 1. Empirical mean and standard deviation for each variable,
##    plus standard error of the mean:
##
##          Mean             SD      Naive SE Time-series SE
##     0.4330249      0.0061573     0.0001376      0.0010254
##
## 2. Quantiles for each variable:
##
##   2.5%    25%    50%    75%  97.5%
## 0.4309 0.4317 0.4323 0.4328 0.4384
```

```
beta_I_samples <- as.numeric(trace)
beta_I_hat     <- mean(beta_I_samples)
beta_I_hat
```

```
## [1] 0.4330249
## 9. Compute R0 from posterior mean beta_I ------------------------

S0 <- initState["S"]
N0 <- sum(initState)

gamma <- theta_fixed["gamma"]; mu <- theta_fixed["mu"]
```

```r
s       <- theta_fixed["s"];     m  <- theta_fixed["m"]
c_c     <- theta_fixed["c"]

R0_hat <- (c_c * S0 / N0) * beta_I_hat * (
  1 / (gamma + mu + m) +
  rho * gamma / ((gamma + mu + m) * (s + m))
)

R0_hat
```

```
##        c
## 1.194452
```

Estimated R0

```r
################################################################
## PLOT - MODEL-PREDICTED INCIDENCE VS ACTUAL INCIDENCE   ##
################################################################

# 1. Build final parameter vector using posterior beta_I
theta_final_pre <- theta_fixed
theta_final_pre["beta_T"] <- rho * beta_I_hat
theta_final_pre["beta_I"] <- beta_I_hat

# 2. Solve the ODE over your observation period (in YEARS)
traj_final <- data.frame(ode(
  y       = initState,
  times = time_years,
  func  = HIV_ode,
  parms = theta_final_pre,
  method = "ode45"
))

# 3. Compute incidence for plotting: lambda(t)*S(t)*(1/12)
N_traj <- traj_final$S + traj_final$P + traj_final$I + traj_final$T + traj_final$U

lambda_traj <- theta_final_pre["c"] *
  (theta_final_pre["beta_I"] * traj_final$I +
   theta_final_pre["beta_T"] * traj_final$T) / N_traj

model_inc_monthly <- lambda_traj * traj_final$S * (1/12)

# 4. Build a plotting data frame
plot_df <- data.frame(
  Month = hiv_inc_pre$Month,
  Observed = hiv_inc_pre$Cases,
  Model = model_inc_monthly
)

# 5. Plot
library(ggplot2)

ggplot(plot_df, aes(x = Month)) +
```
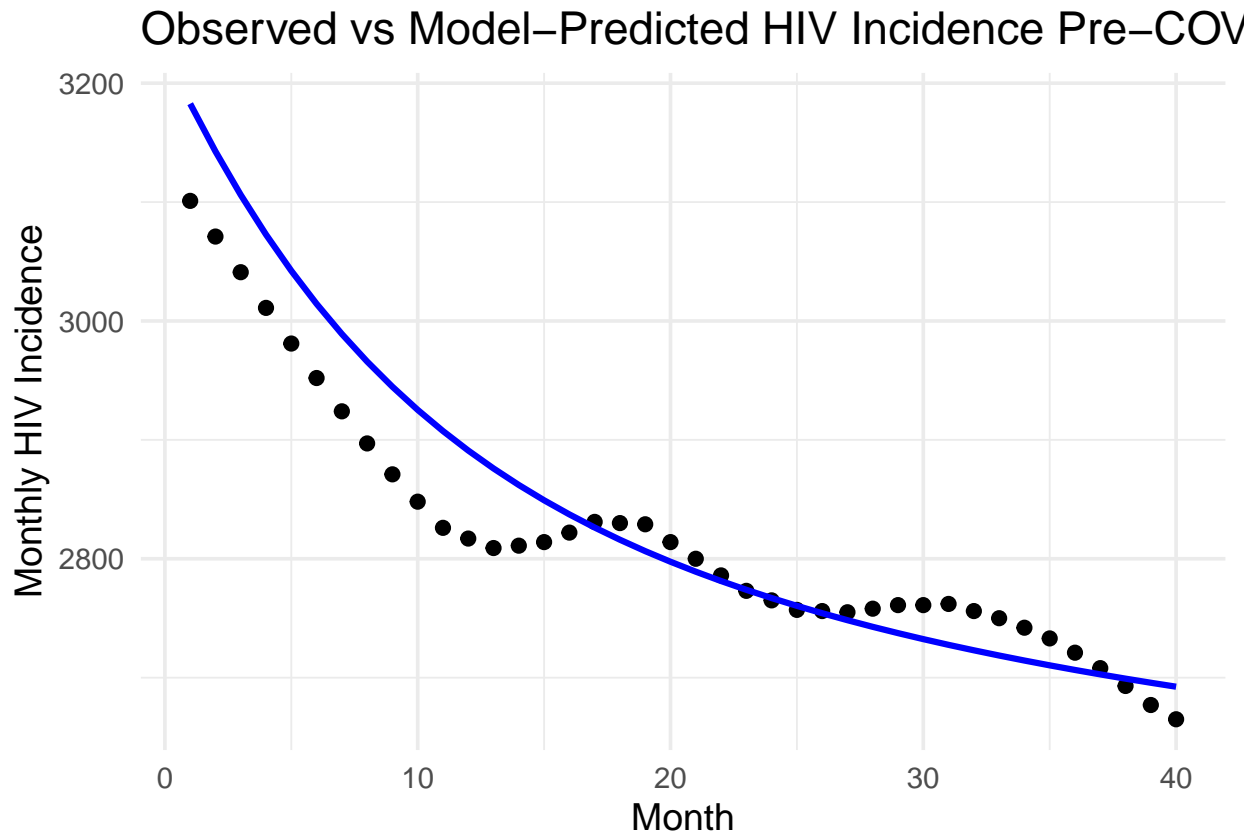
```
  geom_point(aes(y = Observed), color = "black", size = 2) +
  geom_line(aes(y = Model), color = "blue", linewidth = 1.1) +
  labs(
    title = "Observed vs Model-Predicted HIV Incidence Pre-COVID",
    y = "Monthly HIV Incidence",
    x = "Month"
  ) +
  theme_minimal(base_size = 14)
```

Observed vs Model–Predicted HIV Incidence Pre–COV


```
theta_final_pre
```

```
##     beta_T          c          a          p          b      gamma         mu
## 0.04330249 1.50000000 0.09800000 0.20720000 1.20000000 0.50000000 0.10000000
##          s          m      beta_I
## 0.25000000 0.02857143 0.43302495
```

Post COVID Period

Data cleaning

```
#current variable names are hard to use
time_months <- hiv_inc_post$Month

#rounding trend cases so they aren't in decimal form (not realistic)
hiv_inc_post$Cases <- round(hiv_inc_post$Cases, digits = 0)
IncData <- hiv_inc_post$Cases
numPoints <- length(time_months)
```

```
#converting to years, since our other parameter estimations are in years
time_years <- time_months / 12
```

Coding the SPITU ODE (same ODE as before)

```
HIV_ode <- function(time, state, theta){

  #states
  S <- state["S"]
  P <- state["P"]
  I <- state["I"]
  T <- state["T"]
  U <- state["U"]


  N <- S + P + I + T + U


  #force of infection
  lambda <- theta["c"] * (theta["beta_I"] * I + theta["beta_T"] * T) / N

  #ODEs --> in year units
  dS <- theta["a"] * N - lambda * S - theta["m"] * S - theta["p"] * S + theta["b"] * P
  dP <- theta["p"] * S - theta["b"] * P - theta["m"] * P
  dI <- lambda * S - theta["gamma"] * I - theta["mu"] * I - theta["m"] * I
  dT <- theta["gamma"] * I  - theta["s"] * T - theta["m"] * T
  dU <- theta["s"] * T - theta["m"] * U


  list(c(dS, dP, dI, dT, dU))
}
```

Coding likelihood functions

```
#only coding Prior for estimated parameters
logPrior <- function(theta_MH) {
  beta_I <- theta_MH[["beta_I"]]

  logPriorbeta_I <- dlnorm(beta_I, meanlog = log(0.5), sdlog = 1, log = TRUE)

  return(logPriorbeta_I)
}


# likelihood function for single data point
pointLogLike <- function(i, IncData, IncModel) {
  # Incidence is observed through a Poisson process.
  poissonLike <- dpois(x=IncData[i], lambda=IncModel[i], log=TRUE)
  if (is.na(poissonLike)) {
    return(-Inf)
  } else {
    return(poissonLike)
  }
}


# Likelihood function for all data points
```

```r
trajLogLike <- function(time_years, IncData, theta, initState) {
  # Solve ODE at the observation times (in YEARS)
  traj <- data.frame(ode(
    y = initState,
    times = time_years,
    func  = HIV_ode,
    parms = theta,
    method = "ode45"
  ))

  # Compute modelled incidence for each observation month:
  # lambda(t) * S(t) * (delta t), with delta t = 1/12 year
  N        <- traj$S + traj$P + traj$I + traj$T + traj$U
  lambda_t <- theta["c"] * (theta["beta_I"] * traj$I + theta["beta_T"] * traj$T) / N
  IncModel <- lambda_t * traj$S * (1/12)   # expected new cases per *month*

  logLike <- 0
  for (i in seq_along(IncData)) {
    logLike <- logLike + pointLogLike(i, IncData, IncModel)
  }
  logLike
}

# Posterior function

logPosterior <- function(time_years, IncData, theta_MH, theta_fixed, initState) {
  theta <- c(theta_MH, theta_fixed)
  lp    <- logPrior(theta_MH)
  ll    <- trajLogLike(time_years, IncData, theta, initState)
  return(lp + ll)
}
```

Setting fixed parameters

```r
theta_fixed <- c(
  # Infectiousness on treatment: beta_T = rho * beta_I, rho fixed
  beta_T = NA_real_,      # will be filled in inside likelihood from rho*beta_I
  c      = 1.5,           # contact rate per year (adjust if given)
  a      = 0.098,         # recruitment per year
  p      = 0.2072,        # PrEP uptake per year
  b      = 1.2,           # PrEP discontinuation per year (10-month persistence)
  gamma  = 0.5,           # I -> T per year
  mu     = 0.1,           # HIV mortality untreated per year
  s      = 0.25,          # T -> U per year
  m      = 1/35           # background mortality per year
)

rho <- 0.1  # relative infectiousness on treatment: beta_T = rho * beta_I

# Initial conditions: at-risk population ~ 6 million
NO <- 3e6
initState <- c(
  S = NO - 37000,  # mostly susceptible
```

48

```
  P = 0,
  I = 37000,        # have this be one of the theta parameters (so we can vary it) (for when we are inco
  T = 0,
  U = 0
)


#pre and post covid fittings
```

Metropolis-Hastings Functions

```
logPosteriorMH <- function(MHparams) {
  beta_I <- MHparams[["beta_I"]]

  # fill in beta_T each time
  theta_fixed_use <- theta_fixed
  theta_fixed_use["beta_T"] <- rho * beta_I

  logPosterior(
    time_years = time_years,
    IncData    = IncData,
    theta_MH   = c(beta_I = beta_I),
    theta_fixed = theta_fixed_use,
    initState  = initState
  )
}

# quick sanity check
# logPosteriorMH(c(beta_I = 0.07))

mcmcMH <- function(posterior, initTheta, proposalSD, numIterations) {
  posteriorThetaCurrent <- posterior(initTheta)
  thetaCurrent <- initTheta
  samples <- initTheta
  accepted <- 0

  for (i in 1:numIterations) {
    thetaProposed <- rnorm(
      n    = length(thetaCurrent),
      mean = thetaCurrent,
      sd   = proposalSD
    )
    names(thetaProposed) <- names(thetaCurrent)

    posteriorThetaProposed <- posterior(thetaProposed)
    logAcceptance <- posteriorThetaProposed - posteriorThetaCurrent
    randNum <- runif(1)

    if (randNum < exp(logAcceptance)) {
      thetaCurrent <- thetaProposed
      posteriorThetaCurrent <- posteriorThetaProposed
      accepted <- accepted + 1
    }
```

```
    samples <- c(samples, thetaCurrent)
    cat("iteration:", i,
        "beta_I:", thetaCurrent,
        "acceptance rate:", accepted / i, "\n")
  }

  samples
}
```

Finally Simulating

```
set.seed(47)

mcmcTrace <- mcmcMH(
  posterior    = logPosteriorMH,
  initTheta    = c(beta_I = 0.5),    # initial guess
  proposalSD   = c(beta_I = 0.005),          # tune for ~20-40% acceptance
  numIterations = 2000
)
```

```
## iteration: 1 beta_I: 0.5099735 acceptance rate: 1
## iteration: 2 beta_I: 0.514598 acceptance rate: 1
## iteration: 3 beta_I: 0.514598 acceptance rate: 0.6666667
## iteration: 4 beta_I: 0.5217918 acceptance rate: 0.75
## iteration: 5 beta_I: 0.5217918 acceptance rate: 0.6
## iteration: 6 beta_I: 0.5282562 acceptance rate: 0.6666667
## iteration: 7 beta_I: 0.5282562 acceptance rate: 0.5714286
## iteration: 8 beta_I: 0.5289705 acceptance rate: 0.625
## iteration: 9 beta_I: 0.5314396 acceptance rate: 0.6666667
## iteration: 10 beta_I: 0.5314396 acceptance rate: 0.6
## iteration: 11 beta_I: 0.5347935 acceptance rate: 0.6363636
## iteration: 12 beta_I: 0.5347935 acceptance rate: 0.5833333
## iteration: 13 beta_I: 0.5347935 acceptance rate: 0.5384615
## iteration: 14 beta_I: 0.537186 acceptance rate: 0.5714286
## iteration: 15 beta_I: 0.5384317 acceptance rate: 0.6
## iteration: 16 beta_I: 0.5384317 acceptance rate: 0.5625
## iteration: 17 beta_I: 0.5384317 acceptance rate: 0.5294118
## iteration: 18 beta_I: 0.5421855 acceptance rate: 0.5555556
## iteration: 19 beta_I: 0.5421855 acceptance rate: 0.5263158
## iteration: 20 beta_I: 0.5421855 acceptance rate: 0.5
## iteration: 21 beta_I: 0.5446035 acceptance rate: 0.5238095
## iteration: 22 beta_I: 0.5446035 acceptance rate: 0.5
## iteration: 23 beta_I: 0.5490297 acceptance rate: 0.5217391
## iteration: 24 beta_I: 0.5490297 acceptance rate: 0.5
## iteration: 25 beta_I: 0.5490297 acceptance rate: 0.48
## iteration: 26 beta_I: 0.5490297 acceptance rate: 0.4615385
## iteration: 27 beta_I: 0.5518512 acceptance rate: 0.4814815
## iteration: 28 beta_I: 0.5530888 acceptance rate: 0.5
## iteration: 29 beta_I: 0.5530888 acceptance rate: 0.4827586
## iteration: 30 beta_I: 0.5538484 acceptance rate: 0.5
## iteration: 31 beta_I: 0.5538484 acceptance rate: 0.483871
## iteration: 32 beta_I: 0.5538484 acceptance rate: 0.46875
## iteration: 33 beta_I: 0.5590079 acceptance rate: 0.4848485
```

```
## iteration: 34 beta_I: 0.5723109 acceptance rate: 0.5
## iteration: 35 beta_I: 0.5723109 acceptance rate: 0.4857143
## iteration: 36 beta_I: 0.5708655 acceptance rate: 0.5
## iteration: 37 beta_I: 0.5708655 acceptance rate: 0.4864865
## iteration: 38 beta_I: 0.5731931 acceptance rate: 0.5
## iteration: 39 beta_I: 0.5706171 acceptance rate: 0.5128205
## iteration: 40 beta_I: 0.5673862 acceptance rate: 0.525
## iteration: 41 beta_I: 0.5675782 acceptance rate: 0.5365854
## iteration: 42 beta_I: 0.568891 acceptance rate: 0.547619
## iteration: 43 beta_I: 0.568891 acceptance rate: 0.5348837
## iteration: 44 beta_I: 0.5687856 acceptance rate: 0.5454545
## iteration: 45 beta_I: 0.5687856 acceptance rate: 0.5333333
## iteration: 46 beta_I: 0.5687856 acceptance rate: 0.5217391
## iteration: 47 beta_I: 0.5687856 acceptance rate: 0.5106383
## iteration: 48 beta_I: 0.5687856 acceptance rate: 0.5
## iteration: 49 beta_I: 0.5687856 acceptance rate: 0.4897959
## iteration: 50 beta_I: 0.5712302 acceptance rate: 0.5
## iteration: 51 beta_I: 0.5665351 acceptance rate: 0.5098039
## iteration: 52 beta_I: 0.5665351 acceptance rate: 0.5
## iteration: 53 beta_I: 0.5665351 acceptance rate: 0.490566
## iteration: 54 beta_I: 0.5622299 acceptance rate: 0.5
## iteration: 55 beta_I: 0.5631554 acceptance rate: 0.5090909
## iteration: 56 beta_I: 0.5691737 acceptance rate: 0.5178571
## iteration: 57 beta_I: 0.5739481 acceptance rate: 0.5263158
## iteration: 58 beta_I: 0.5739481 acceptance rate: 0.5172414
## iteration: 59 beta_I: 0.5693754 acceptance rate: 0.5254237
## iteration: 60 beta_I: 0.567071 acceptance rate: 0.5333333
## iteration: 61 beta_I: 0.567071 acceptance rate: 0.5245902
## iteration: 62 beta_I: 0.567071 acceptance rate: 0.516129
## iteration: 63 beta_I: 0.567071 acceptance rate: 0.5079365
## iteration: 64 beta_I: 0.5713828 acceptance rate: 0.515625
## iteration: 65 beta_I: 0.5670819 acceptance rate: 0.5230769
## iteration: 66 beta_I: 0.5670819 acceptance rate: 0.5151515
## iteration: 67 beta_I: 0.5671016 acceptance rate: 0.5223881
## iteration: 68 beta_I: 0.5671776 acceptance rate: 0.5294118
## iteration: 69 beta_I: 0.5671776 acceptance rate: 0.5217391
## iteration: 70 beta_I: 0.5671776 acceptance rate: 0.5142857
## iteration: 71 beta_I: 0.5681718 acceptance rate: 0.5211268
## iteration: 72 beta_I: 0.5681718 acceptance rate: 0.5138889
## iteration: 73 beta_I: 0.5681718 acceptance rate: 0.5068493
## iteration: 74 beta_I: 0.5696885 acceptance rate: 0.5135135
## iteration: 75 beta_I: 0.5696885 acceptance rate: 0.5066667
## iteration: 76 beta_I: 0.5698885 acceptance rate: 0.5131579
## iteration: 77 beta_I: 0.5698885 acceptance rate: 0.5064935
## iteration: 78 beta_I: 0.5698885 acceptance rate: 0.5
## iteration: 79 beta_I: 0.5658874 acceptance rate: 0.5063291
## iteration: 80 beta_I: 0.5724994 acceptance rate: 0.5125
## iteration: 81 beta_I: 0.5702432 acceptance rate: 0.5185185
## iteration: 82 beta_I: 0.5702432 acceptance rate: 0.5121951
## iteration: 83 beta_I: 0.5718499 acceptance rate: 0.5180723
## iteration: 84 beta_I: 0.5718499 acceptance rate: 0.5119048
## iteration: 85 beta_I: 0.5718499 acceptance rate: 0.5058824
## iteration: 86 beta_I: 0.5718499 acceptance rate: 0.5
## iteration: 87 beta_I: 0.5665723 acceptance rate: 0.5057471
```

```
## iteration: 88 beta_I: 0.5708247 acceptance rate: 0.5113636
## iteration: 89 beta_I: 0.5692785 acceptance rate: 0.5168539
## iteration: 90 beta_I: 0.5705802 acceptance rate: 0.5222222
## iteration: 91 beta_I: 0.5680949 acceptance rate: 0.5274725
## iteration: 92 beta_I: 0.5680949 acceptance rate: 0.5217391
## iteration: 93 beta_I: 0.5680949 acceptance rate: 0.516129
## iteration: 94 beta_I: 0.5680949 acceptance rate: 0.5106383
## iteration: 95 beta_I: 0.5682695 acceptance rate: 0.5157895
## iteration: 96 beta_I: 0.5682695 acceptance rate: 0.5104167
## iteration: 97 beta_I: 0.5691232 acceptance rate: 0.5154639
## iteration: 98 beta_I: 0.568057 acceptance rate: 0.5204082
## iteration: 99 beta_I: 0.568057 acceptance rate: 0.5151515
## iteration: 100 beta_I: 0.5691299 acceptance rate: 0.52
## iteration: 101 beta_I: 0.5691299 acceptance rate: 0.5148515
## iteration: 102 beta_I: 0.5661093 acceptance rate: 0.5196078
## iteration: 103 beta_I: 0.5661093 acceptance rate: 0.5145631
## iteration: 104 beta_I: 0.5661093 acceptance rate: 0.5096154
## iteration: 105 beta_I: 0.5661093 acceptance rate: 0.5047619
## iteration: 106 beta_I: 0.5661093 acceptance rate: 0.5
## iteration: 107 beta_I: 0.5690403 acceptance rate: 0.5046729
## iteration: 108 beta_I: 0.5656712 acceptance rate: 0.5092593
## iteration: 109 beta_I: 0.5656712 acceptance rate: 0.5045872
## iteration: 110 beta_I: 0.5705762 acceptance rate: 0.5090909
## iteration: 111 beta_I: 0.5672864 acceptance rate: 0.5135135
## iteration: 112 beta_I: 0.5672864 acceptance rate: 0.5089286
## iteration: 113 beta_I: 0.5672864 acceptance rate: 0.5044248
## iteration: 114 beta_I: 0.5687041 acceptance rate: 0.5087719
## iteration: 115 beta_I: 0.5687041 acceptance rate: 0.5043478
## iteration: 116 beta_I: 0.56827 acceptance rate: 0.5086207
## iteration: 117 beta_I: 0.5689451 acceptance rate: 0.5128205
## iteration: 118 beta_I: 0.5676116 acceptance rate: 0.5169492
## iteration: 119 beta_I: 0.5676116 acceptance rate: 0.512605
## iteration: 120 beta_I: 0.5676116 acceptance rate: 0.5083333
## iteration: 121 beta_I: 0.5677251 acceptance rate: 0.5123967
## iteration: 122 beta_I: 0.5646706 acceptance rate: 0.5163934
## iteration: 123 beta_I: 0.5646706 acceptance rate: 0.5121951
## iteration: 124 beta_I: 0.565417 acceptance rate: 0.516129
## iteration: 125 beta_I: 0.5652968 acceptance rate: 0.52
## iteration: 126 beta_I: 0.5652968 acceptance rate: 0.515873
## iteration: 127 beta_I: 0.5696229 acceptance rate: 0.519685
## iteration: 128 beta_I: 0.5696229 acceptance rate: 0.515625
## iteration: 129 beta_I: 0.5696229 acceptance rate: 0.5116279
## iteration: 130 beta_I: 0.5696229 acceptance rate: 0.5076923
## iteration: 131 beta_I: 0.5651157 acceptance rate: 0.5114504
## iteration: 132 beta_I: 0.5680556 acceptance rate: 0.5151515
## iteration: 133 beta_I: 0.5712098 acceptance rate: 0.518797
## iteration: 134 beta_I: 0.5661436 acceptance rate: 0.5223881
## iteration: 135 beta_I: 0.5661436 acceptance rate: 0.5185185
## iteration: 136 beta_I: 0.5661436 acceptance rate: 0.5147059
## iteration: 137 beta_I: 0.5661436 acceptance rate: 0.5109489
## iteration: 138 beta_I: 0.5656256 acceptance rate: 0.5144928
## iteration: 139 beta_I: 0.5669013 acceptance rate: 0.5179856
## iteration: 140 beta_I: 0.5669013 acceptance rate: 0.5142857
## iteration: 141 beta_I: 0.5671359 acceptance rate: 0.5177305
```

```
## iteration: 142 beta_I: 0.5671359 acceptance rate: 0.5140845
## iteration: 143 beta_I: 0.565409 acceptance rate: 0.5174825
## iteration: 144 beta_I: 0.565409 acceptance rate: 0.5138889
## iteration: 145 beta_I: 0.5655872 acceptance rate: 0.5172414
## iteration: 146 beta_I: 0.5639606 acceptance rate: 0.5205479
## iteration: 147 beta_I: 0.5632473 acceptance rate: 0.5238095
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## iteration: 151 beta_I: 0.5659455 acceptance rate: 0.5165563
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## iteration: 167 beta_I: 0.5675012 acceptance rate: 0.508982
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## iteration: 180 beta_I: 0.567463 acceptance rate: 0.4944444
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## iteration: 185 beta_I: 0.5665513 acceptance rate: 0.4918919
## iteration: 186 beta_I: 0.5665513 acceptance rate: 0.4892473
## iteration: 187 beta_I: 0.5665513 acceptance rate: 0.486631
## iteration: 188 beta_I: 0.5670632 acceptance rate: 0.4893617
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## iteration: 190 beta_I: 0.5652863 acceptance rate: 0.4947368
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## iteration: 195 beta_I: 0.5692219 acceptance rate: 0.4923077
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## iteration: 196 beta_I: 0.5692219 acceptance rate: 0.4897959
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## iteration: 249 beta_I: 0.5670823 acceptance rate: 0.4899598
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## iteration: 499 beta_I: 0.5707455 acceptance rate: 0.496994
## iteration: 500 beta_I: 0.5707455 acceptance rate: 0.496
## iteration: 501 beta_I: 0.5707455 acceptance rate: 0.49501
## iteration: 502 beta_I: 0.5707455 acceptance rate: 0.4940239
## iteration: 503 beta_I: 0.5707455 acceptance rate: 0.4930417
## iteration: 504 beta_I: 0.5707455 acceptance rate: 0.4920635
## iteration: 505 beta_I: 0.5699964 acceptance rate: 0.4930693
## iteration: 506 beta_I: 0.5708507 acceptance rate: 0.4940711
## iteration: 507 beta_I: 0.5661986 acceptance rate: 0.495069
## iteration: 508 beta_I: 0.5661986 acceptance rate: 0.4940945
## iteration: 509 beta_I: 0.5653612 acceptance rate: 0.4950884
## iteration: 510 beta_I: 0.5653612 acceptance rate: 0.4941176
## iteration: 511 beta_I: 0.5653612 acceptance rate: 0.4931507
## iteration: 512 beta_I: 0.5653612 acceptance rate: 0.4921875
## iteration: 513 beta_I: 0.5653612 acceptance rate: 0.4912281
## iteration: 514 beta_I: 0.5635998 acceptance rate: 0.4922179
## iteration: 515 beta_I: 0.5643106 acceptance rate: 0.4932039
## iteration: 516 beta_I: 0.5656429 acceptance rate: 0.494186
## iteration: 517 beta_I: 0.5656429 acceptance rate: 0.4932302
## iteration: 518 beta_I: 0.5656429 acceptance rate: 0.492278
## iteration: 519 beta_I: 0.5665852 acceptance rate: 0.4932563
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## iteration: 520 beta_I: 0.5665852 acceptance rate: 0.4923077
## iteration: 521 beta_I: 0.5670528 acceptance rate: 0.4932821
## iteration: 522 beta_I: 0.5670528 acceptance rate: 0.4923372
## iteration: 523 beta_I: 0.5670528 acceptance rate: 0.4913958
## iteration: 524 beta_I: 0.567367 acceptance rate: 0.4923664
## iteration: 525 beta_I: 0.5679759 acceptance rate: 0.4933333
## iteration: 526 beta_I: 0.5648413 acceptance rate: 0.4942966
## iteration: 527 beta_I: 0.5661137 acceptance rate: 0.4952562
## iteration: 528 beta_I: 0.5649246 acceptance rate: 0.4962121
## iteration: 529 beta_I: 0.5650257 acceptance rate: 0.4971645
## iteration: 530 beta_I: 0.5638403 acceptance rate: 0.4981132
## iteration: 531 beta_I: 0.5696371 acceptance rate: 0.4990584
## iteration: 532 beta_I: 0.5678739 acceptance rate: 0.5
## iteration: 533 beta_I: 0.5686796 acceptance rate: 0.5009381
## iteration: 534 beta_I: 0.5701524 acceptance rate: 0.5018727
## iteration: 535 beta_I: 0.5675313 acceptance rate: 0.5028037
## iteration: 536 beta_I: 0.5675313 acceptance rate: 0.5018657
## iteration: 537 beta_I: 0.5669181 acceptance rate: 0.5027933
## iteration: 538 beta_I: 0.5669181 acceptance rate: 0.5018587
## iteration: 539 beta_I: 0.5669181 acceptance rate: 0.5009276
## iteration: 540 beta_I: 0.5670191 acceptance rate: 0.5018519
## iteration: 541 beta_I: 0.5670191 acceptance rate: 0.5009242
## iteration: 542 beta_I: 0.5670191 acceptance rate: 0.5
## iteration: 543 beta_I: 0.5670191 acceptance rate: 0.4990792
## iteration: 544 beta_I: 0.5670191 acceptance rate: 0.4981618
## iteration: 545 beta_I: 0.5695828 acceptance rate: 0.4990826
## iteration: 546 beta_I: 0.5695828 acceptance rate: 0.4981685
## iteration: 547 beta_I: 0.5650823 acceptance rate: 0.4990859
## iteration: 548 beta_I: 0.566442 acceptance rate: 0.5
## iteration: 549 beta_I: 0.5690343 acceptance rate: 0.5009107
## iteration: 550 beta_I: 0.5690343 acceptance rate: 0.5
## iteration: 551 beta_I: 0.5690343 acceptance rate: 0.4990926
## iteration: 552 beta_I: 0.5642792 acceptance rate: 0.5
## iteration: 553 beta_I: 0.5642792 acceptance rate: 0.4990958
## iteration: 554 beta_I: 0.5642792 acceptance rate: 0.4981949
## iteration: 555 beta_I: 0.5645154 acceptance rate: 0.4990991
## iteration: 556 beta_I: 0.5653747 acceptance rate: 0.5
## iteration: 557 beta_I: 0.5629468 acceptance rate: 0.5008977
## iteration: 558 beta_I: 0.5629468 acceptance rate: 0.5
## iteration: 559 beta_I: 0.5629468 acceptance rate: 0.4991055
## iteration: 560 beta_I: 0.5672011 acceptance rate: 0.5
## iteration: 561 beta_I: 0.5671161 acceptance rate: 0.5008913
## iteration: 562 beta_I: 0.5667841 acceptance rate: 0.5017794
## iteration: 563 beta_I: 0.5667841 acceptance rate: 0.5008881
## iteration: 564 beta_I: 0.567516 acceptance rate: 0.501773
## iteration: 565 beta_I: 0.567516 acceptance rate: 0.500885
## iteration: 566 beta_I: 0.5647824 acceptance rate: 0.5017668
## iteration: 567 beta_I: 0.5678526 acceptance rate: 0.5026455
## iteration: 568 beta_I: 0.5678526 acceptance rate: 0.5017606
## iteration: 569 beta_I: 0.5682084 acceptance rate: 0.5026362
## iteration: 570 beta_I: 0.5682084 acceptance rate: 0.5017544
## iteration: 571 beta_I: 0.5658094 acceptance rate: 0.502627
## iteration: 572 beta_I: 0.5658094 acceptance rate: 0.5017483
## iteration: 573 beta_I: 0.5662939 acceptance rate: 0.5026178
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## iteration: 574 beta_I: 0.5662939 acceptance rate: 0.5017422
## iteration: 575 beta_I: 0.5662939 acceptance rate: 0.5008696
## iteration: 576 beta_I: 0.5672142 acceptance rate: 0.5017361
## iteration: 577 beta_I: 0.571742 acceptance rate: 0.5025997
## iteration: 578 beta_I: 0.5704056 acceptance rate: 0.5034602
## iteration: 579 beta_I: 0.5704056 acceptance rate: 0.5025907
## iteration: 580 beta_I: 0.5704056 acceptance rate: 0.5017241
## iteration: 581 beta_I: 0.5701412 acceptance rate: 0.5025818
## iteration: 582 beta_I: 0.5701412 acceptance rate: 0.5017182
## iteration: 583 beta_I: 0.5710899 acceptance rate: 0.5025729
## iteration: 584 beta_I: 0.5672836 acceptance rate: 0.5034247
## iteration: 585 beta_I: 0.5672836 acceptance rate: 0.5025641
## iteration: 586 beta_I: 0.5672836 acceptance rate: 0.5017065
## iteration: 587 beta_I: 0.5672836 acceptance rate: 0.5008518
## iteration: 588 beta_I: 0.5672836 acceptance rate: 0.5
## iteration: 589 beta_I: 0.5684875 acceptance rate: 0.5008489
## iteration: 590 beta_I: 0.5657369 acceptance rate: 0.5016949
## iteration: 591 beta_I: 0.5678543 acceptance rate: 0.5025381
## iteration: 592 beta_I: 0.5679083 acceptance rate: 0.5033784
## iteration: 593 beta_I: 0.5679083 acceptance rate: 0.5025295
## iteration: 594 beta_I: 0.5659442 acceptance rate: 0.503367
## iteration: 595 beta_I: 0.5646058 acceptance rate: 0.5042017
## iteration: 596 beta_I: 0.5646058 acceptance rate: 0.5033557
## iteration: 597 beta_I: 0.5667505 acceptance rate: 0.5041876
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## iteration: 599 beta_I: 0.5667505 acceptance rate: 0.5025042
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## iteration: 605 beta_I: 0.5667505 acceptance rate: 0.4975207
## iteration: 606 beta_I: 0.5667505 acceptance rate: 0.4966997
## iteration: 607 beta_I: 0.5667505 acceptance rate: 0.4958814
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## iteration: 611 beta_I: 0.5681854 acceptance rate: 0.4959083
## iteration: 612 beta_I: 0.5681854 acceptance rate: 0.495098
## iteration: 613 beta_I: 0.56615 acceptance rate: 0.4959217
## iteration: 614 beta_I: 0.56615 acceptance rate: 0.495114
## iteration: 615 beta_I: 0.56615 acceptance rate: 0.4943089
## iteration: 616 beta_I: 0.56615 acceptance rate: 0.4935065
## iteration: 617 beta_I: 0.56615 acceptance rate: 0.4927066
## iteration: 618 beta_I: 0.5740845 acceptance rate: 0.4935275
## iteration: 619 beta_I: 0.5722774 acceptance rate: 0.4943457
## iteration: 620 beta_I: 0.5691616 acceptance rate: 0.4951613
## iteration: 621 beta_I: 0.5666276 acceptance rate: 0.4959742
## iteration: 622 beta_I: 0.5671073 acceptance rate: 0.4967846
## iteration: 623 beta_I: 0.5644733 acceptance rate: 0.4975923
## iteration: 624 beta_I: 0.5644733 acceptance rate: 0.4967949
## iteration: 625 beta_I: 0.5644733 acceptance rate: 0.496
## iteration: 626 beta_I: 0.5642635 acceptance rate: 0.4968051
## iteration: 627 beta_I: 0.5647258 acceptance rate: 0.4976077
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## iteration: 628 beta_I: 0.5647258 acceptance rate: 0.4968153
## iteration: 629 beta_I: 0.5625093 acceptance rate: 0.4976153
## iteration: 630 beta_I: 0.5670701 acceptance rate: 0.4984127
## iteration: 631 beta_I: 0.5670701 acceptance rate: 0.4976228
## iteration: 632 beta_I: 0.5665541 acceptance rate: 0.4984177
## iteration: 633 beta_I: 0.5673775 acceptance rate: 0.4992101
## iteration: 634 beta_I: 0.5673775 acceptance rate: 0.4984227
## iteration: 635 beta_I: 0.5670071 acceptance rate: 0.4992126
## iteration: 636 beta_I: 0.5681056 acceptance rate: 0.5
## iteration: 637 beta_I: 0.566396 acceptance rate: 0.5007849
## iteration: 638 beta_I: 0.5642408 acceptance rate: 0.5015674
## iteration: 639 beta_I: 0.5692904 acceptance rate: 0.5023474
## iteration: 640 beta_I: 0.563879 acceptance rate: 0.503125
## iteration: 641 beta_I: 0.563879 acceptance rate: 0.5023401
## iteration: 642 beta_I: 0.5643184 acceptance rate: 0.5031153
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## iteration: 644 beta_I: 0.5687405 acceptance rate: 0.5031056
## iteration: 645 beta_I: 0.5687405 acceptance rate: 0.5023256
## iteration: 646 beta_I: 0.5687405 acceptance rate: 0.501548
## iteration: 647 beta_I: 0.5687405 acceptance rate: 0.5007728
## iteration: 648 beta_I: 0.5687405 acceptance rate: 0.5
## iteration: 649 beta_I: 0.5687405 acceptance rate: 0.4992296
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## iteration: 652 beta_I: 0.5694057 acceptance rate: 0.4984663
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## iteration: 662 beta_I: 0.5648725 acceptance rate: 0.5030211
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## iteration: 664 beta_I: 0.5715148 acceptance rate: 0.503012
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## iteration: 666 beta_I: 0.5684882 acceptance rate: 0.5045045
## iteration: 667 beta_I: 0.5684882 acceptance rate: 0.5037481
## iteration: 668 beta_I: 0.5684882 acceptance rate: 0.502994
## iteration: 669 beta_I: 0.5641174 acceptance rate: 0.5037369
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## iteration: 674 beta_I: 0.5658068 acceptance rate: 0.5014837
## iteration: 675 beta_I: 0.5658068 acceptance rate: 0.5007407
## iteration: 676 beta_I: 0.5658068 acceptance rate: 0.5
## iteration: 677 beta_I: 0.5658068 acceptance rate: 0.4992614
## iteration: 678 beta_I: 0.5674986 acceptance rate: 0.5
## iteration: 679 beta_I: 0.5674986 acceptance rate: 0.4992636
## iteration: 680 beta_I: 0.5667487 acceptance rate: 0.5
## iteration: 681 beta_I: 0.5653116 acceptance rate: 0.5007342
```

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## iteration: 682 beta_I: 0.5683635 acceptance rate: 0.5014663
## iteration: 683 beta_I: 0.5683635 acceptance rate: 0.5007321
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## iteration: 685 beta_I: 0.5679252 acceptance rate: 0.5007299
## iteration: 686 beta_I: 0.5679252 acceptance rate: 0.5
## iteration: 687 beta_I: 0.5674015 acceptance rate: 0.5007278
## iteration: 688 beta_I: 0.5655721 acceptance rate: 0.5014535
## iteration: 689 beta_I: 0.5652266 acceptance rate: 0.5021771
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## iteration: 692 beta_I: 0.5670369 acceptance rate: 0.5014451
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## iteration: 706 beta_I: 0.5661777 acceptance rate: 0.5014164
## iteration: 707 beta_I: 0.5661777 acceptance rate: 0.5007072
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## iteration: 710 beta_I: 0.5656933 acceptance rate: 0.5014085
## iteration: 711 beta_I: 0.5656933 acceptance rate: 0.5007032
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## iteration: 715 beta_I: 0.5627001 acceptance rate: 0.5020979
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## iteration: 719 beta_I: 0.5669209 acceptance rate: 0.5034771
## iteration: 720 beta_I: 0.5669209 acceptance rate: 0.5027778
## iteration: 721 beta_I: 0.5669209 acceptance rate: 0.5020804
## iteration: 722 beta_I: 0.5669209 acceptance rate: 0.501385
## iteration: 723 beta_I: 0.5672601 acceptance rate: 0.5020747
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## iteration: 725 beta_I: 0.5663314 acceptance rate: 0.502069
## iteration: 726 beta_I: 0.5663314 acceptance rate: 0.5013774
## iteration: 727 beta_I: 0.5660123 acceptance rate: 0.5020633
## iteration: 728 beta_I: 0.5675221 acceptance rate: 0.5027473
## iteration: 729 beta_I: 0.5675221 acceptance rate: 0.5020576
## iteration: 730 beta_I: 0.5651309 acceptance rate: 0.5027397
## iteration: 731 beta_I: 0.563462 acceptance rate: 0.50342
## iteration: 732 beta_I: 0.5708787 acceptance rate: 0.5040984
## iteration: 733 beta_I: 0.5708787 acceptance rate: 0.5034106
## iteration: 734 beta_I: 0.5708787 acceptance rate: 0.5027248
## iteration: 735 beta_I: 0.5623951 acceptance rate: 0.5034014
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## iteration: 736 beta_I: 0.5682944 acceptance rate: 0.5040761
## iteration: 737 beta_I: 0.5682944 acceptance rate: 0.5033921
## iteration: 738 beta_I: 0.5682944 acceptance rate: 0.50271
## iteration: 739 beta_I: 0.5682944 acceptance rate: 0.5020298
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## iteration: 742 beta_I: 0.5650772 acceptance rate: 0.5013477
## iteration: 743 beta_I: 0.565331 acceptance rate: 0.5020188
## iteration: 744 beta_I: 0.565331 acceptance rate: 0.5013441
## iteration: 745 beta_I: 0.5677983 acceptance rate: 0.5020134
## iteration: 746 beta_I: 0.5651517 acceptance rate: 0.502681
## iteration: 747 beta_I: 0.5663154 acceptance rate: 0.5033467
## iteration: 748 beta_I: 0.5617237 acceptance rate: 0.5040107
## iteration: 749 beta_I: 0.5642476 acceptance rate: 0.5046729
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## iteration: 751 beta_I: 0.5715503 acceptance rate: 0.505992
## iteration: 752 beta_I: 0.5680212 acceptance rate: 0.5066489
## iteration: 753 beta_I: 0.5680212 acceptance rate: 0.5059761
## iteration: 754 beta_I: 0.567653 acceptance rate: 0.5066313
## iteration: 755 beta_I: 0.5646013 acceptance rate: 0.5072848
## iteration: 756 beta_I: 0.5655258 acceptance rate: 0.5079365
## iteration: 757 beta_I: 0.5670998 acceptance rate: 0.5085865
## iteration: 758 beta_I: 0.5666391 acceptance rate: 0.5092348
## iteration: 759 beta_I: 0.5666391 acceptance rate: 0.5085639
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## iteration: 765 beta_I: 0.5614291 acceptance rate: 0.5111111
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## iteration: 767 beta_I: 0.5708422 acceptance rate: 0.5123859
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## iteration: 771 beta_I: 0.5651746 acceptance rate: 0.5110246
## iteration: 772 beta_I: 0.5651746 acceptance rate: 0.5103627
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## iteration: 774 beta_I: 0.566855 acceptance rate: 0.5103359
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## iteration: 776 beta_I: 0.5688618 acceptance rate: 0.5103093
## iteration: 777 beta_I: 0.5652753 acceptance rate: 0.5109395
## iteration: 778 beta_I: 0.5652753 acceptance rate: 0.5102828
## iteration: 779 beta_I: 0.5641234 acceptance rate: 0.5109114
## iteration: 780 beta_I: 0.5641234 acceptance rate: 0.5102564
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## iteration: 783 beta_I: 0.5703621 acceptance rate: 0.5108557
## iteration: 784 beta_I: 0.5703621 acceptance rate: 0.5102041
## iteration: 785 beta_I: 0.5690688 acceptance rate: 0.510828
## iteration: 786 beta_I: 0.5701678 acceptance rate: 0.5114504
## iteration: 787 beta_I: 0.5645462 acceptance rate: 0.5120712
## iteration: 788 beta_I: 0.5664241 acceptance rate: 0.5126904
## iteration: 789 beta_I: 0.5664241 acceptance rate: 0.5120406
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## iteration: 790 beta_I: 0.5664241 acceptance rate: 0.5113924
## iteration: 791 beta_I: 0.5666421 acceptance rate: 0.5120101
## iteration: 792 beta_I: 0.5696869 acceptance rate: 0.5126263
## iteration: 793 beta_I: 0.5696869 acceptance rate: 0.5119798
## iteration: 794 beta_I: 0.5696869 acceptance rate: 0.511335
## iteration: 795 beta_I: 0.5696869 acceptance rate: 0.5106918
## iteration: 796 beta_I: 0.5662474 acceptance rate: 0.5113065
## iteration: 797 beta_I: 0.5677757 acceptance rate: 0.5119197
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## iteration: 799 beta_I: 0.565317 acceptance rate: 0.5118899
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## iteration: 801 beta_I: 0.5665144 acceptance rate: 0.5118602
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## iteration: 803 beta_I: 0.5642973 acceptance rate: 0.5118306
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## iteration: 805 beta_I: 0.5642766 acceptance rate: 0.5118012
## iteration: 806 beta_I: 0.5642766 acceptance rate: 0.5111663
## iteration: 807 beta_I: 0.5642766 acceptance rate: 0.5105328
## iteration: 808 beta_I: 0.5642766 acceptance rate: 0.509901
## iteration: 809 beta_I: 0.5622924 acceptance rate: 0.5105068
## iteration: 810 beta_I: 0.5622924 acceptance rate: 0.5098765
## iteration: 811 beta_I: 0.5622924 acceptance rate: 0.5092478
## iteration: 812 beta_I: 0.5622924 acceptance rate: 0.5086207
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## iteration: 816 beta_I: 0.5687353 acceptance rate: 0.5085784
## iteration: 817 beta_I: 0.5687353 acceptance rate: 0.5079559
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## iteration: 819 beta_I: 0.5681096 acceptance rate: 0.5079365
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## iteration: 821 beta_I: 0.5656441 acceptance rate: 0.5079172
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## iteration: 824 beta_I: 0.5677061 acceptance rate: 0.5084951
## iteration: 825 beta_I: 0.5677061 acceptance rate: 0.5078788
## iteration: 826 beta_I: 0.5677061 acceptance rate: 0.5072639
## iteration: 827 beta_I: 0.5683081 acceptance rate: 0.5078597
## iteration: 828 beta_I: 0.5683081 acceptance rate: 0.5072464
## iteration: 829 beta_I: 0.5658409 acceptance rate: 0.5078408
## iteration: 830 beta_I: 0.5658409 acceptance rate: 0.5072289
## iteration: 831 beta_I: 0.5697508 acceptance rate: 0.5078219
## iteration: 832 beta_I: 0.5623792 acceptance rate: 0.5084135
## iteration: 833 beta_I: 0.5623792 acceptance rate: 0.5078031
## iteration: 834 beta_I: 0.5623792 acceptance rate: 0.5071942
## iteration: 835 beta_I: 0.5621773 acceptance rate: 0.5077844
## iteration: 836 beta_I: 0.5610962 acceptance rate: 0.5083732
## iteration: 837 beta_I: 0.5697665 acceptance rate: 0.5089606
## iteration: 838 beta_I: 0.5697665 acceptance rate: 0.5083532
## iteration: 839 beta_I: 0.5670009 acceptance rate: 0.5089392
## iteration: 840 beta_I: 0.5670009 acceptance rate: 0.5083333
## iteration: 841 beta_I: 0.5670009 acceptance rate: 0.5077289
## iteration: 842 beta_I: 0.5670009 acceptance rate: 0.5071259
## iteration: 843 beta_I: 0.5670009 acceptance rate: 0.5065243
```

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## iteration: 844 beta_I: 0.56709 acceptance rate: 0.507109
## iteration: 845 beta_I: 0.56709 acceptance rate: 0.5065089
## iteration: 846 beta_I: 0.5680005 acceptance rate: 0.5070922
## iteration: 847 beta_I: 0.5671617 acceptance rate: 0.5076741
## iteration: 848 beta_I: 0.5641517 acceptance rate: 0.5082547
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## iteration: 850 beta_I: 0.5659579 acceptance rate: 0.5094118
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## iteration: 853 beta_I: 0.5721798 acceptance rate: 0.5111372
## iteration: 854 beta_I: 0.5721798 acceptance rate: 0.5105386
## iteration: 855 beta_I: 0.5681005 acceptance rate: 0.5111111
## iteration: 856 beta_I: 0.5681005 acceptance rate: 0.510514
## iteration: 857 beta_I: 0.5681005 acceptance rate: 0.5099183
## iteration: 858 beta_I: 0.5681005 acceptance rate: 0.509324
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## iteration: 860 beta_I: 0.5674879 acceptance rate: 0.5093023
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## iteration: 868 beta_I: 0.5635468 acceptance rate: 0.5103687
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## iteration: 880 beta_I: 0.5642715 acceptance rate: 0.5136364
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## iteration: 883 beta_I: 0.5681515 acceptance rate: 0.5130238
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## iteration: 885 beta_I: 0.5650518 acceptance rate: 0.5141243
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## iteration: 887 beta_I: 0.5652893 acceptance rate: 0.5140924
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## iteration: 889 beta_I: 0.5652892 acceptance rate: 0.5140607
## iteration: 890 beta_I: 0.5652892 acceptance rate: 0.5134831
## iteration: 891 beta_I: 0.5652892 acceptance rate: 0.5129068
## iteration: 892 beta_I: 0.5652892 acceptance rate: 0.5123318
## iteration: 893 beta_I: 0.5652892 acceptance rate: 0.5117581
## iteration: 894 beta_I: 0.5637679 acceptance rate: 0.5123043
## iteration: 895 beta_I: 0.5681851 acceptance rate: 0.5128492
## iteration: 896 beta_I: 0.5658616 acceptance rate: 0.5133929
## iteration: 897 beta_I: 0.5658616 acceptance rate: 0.5128205
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## iteration: 898 beta_I: 0.5658616 acceptance rate: 0.5122494
## iteration: 899 beta_I: 0.5632378 acceptance rate: 0.512792
## iteration: 900 beta_I: 0.5632378 acceptance rate: 0.5122222
## iteration: 901 beta_I: 0.5656452 acceptance rate: 0.5127636
## iteration: 902 beta_I: 0.5666002 acceptance rate: 0.5133038
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## iteration: 951 beta_I: 0.5651216 acceptance rate: 0.5162986
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## iteration: 1167 beta_I: 0.5672028 acceptance rate: 0.512425
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## iteration: 1182 beta_I: 0.567524 acceptance rate: 0.5135364
## iteration: 1183 beta_I: 0.567524 acceptance rate: 0.5131023
## iteration: 1184 beta_I: 0.567524 acceptance rate: 0.5126689
## iteration: 1185 beta_I: 0.567524 acceptance rate: 0.5122363
## iteration: 1186 beta_I: 0.568216 acceptance rate: 0.5126476
## iteration: 1187 beta_I: 0.5654829 acceptance rate: 0.5130581
## iteration: 1188 beta_I: 0.5654829 acceptance rate: 0.5126263
## iteration: 1189 beta_I: 0.5701428 acceptance rate: 0.5130362
## iteration: 1190 beta_I: 0.5701428 acceptance rate: 0.512605
## iteration: 1191 beta_I: 0.5701428 acceptance rate: 0.5121746
## iteration: 1192 beta_I: 0.5701428 acceptance rate: 0.511745
## iteration: 1193 beta_I: 0.5701428 acceptance rate: 0.511316
## iteration: 1194 beta_I: 0.5688194 acceptance rate: 0.5117253
## iteration: 1195 beta_I: 0.5688194 acceptance rate: 0.5112971
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## iteration: 1198 beta_I: 0.5717922 acceptance rate: 0.5108514
## iteration: 1199 beta_I: 0.5634934 acceptance rate: 0.5112594
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## iteration: 1201 beta_I: 0.567588 acceptance rate: 0.5120733
## iteration: 1202 beta_I: 0.5699065 acceptance rate: 0.5124792
## iteration: 1203 beta_I: 0.5654935 acceptance rate: 0.5128845
## iteration: 1204 beta_I: 0.563708 acceptance rate: 0.513289
## iteration: 1205 beta_I: 0.563708 acceptance rate: 0.5128631
## iteration: 1206 beta_I: 0.5655048 acceptance rate: 0.513267
## iteration: 1207 beta_I: 0.5655048 acceptance rate: 0.5128418
## iteration: 1208 beta_I: 0.5655048 acceptance rate: 0.5124172
## iteration: 1209 beta_I: 0.5655048 acceptance rate: 0.5119934
## iteration: 1210 beta_I: 0.5674313 acceptance rate: 0.5123967
## iteration: 1211 beta_I: 0.5685496 acceptance rate: 0.5127993
## iteration: 1212 beta_I: 0.5719214 acceptance rate: 0.5132013
## iteration: 1213 beta_I: 0.5719214 acceptance rate: 0.5127782
## iteration: 1214 beta_I: 0.5719214 acceptance rate: 0.5123558
## iteration: 1215 beta_I: 0.5659296 acceptance rate: 0.5127572
## iteration: 1216 beta_I: 0.5659296 acceptance rate: 0.5123355
## iteration: 1217 beta_I: 0.5659296 acceptance rate: 0.5119145
## iteration: 1218 beta_I: 0.5668757 acceptance rate: 0.5123153
## iteration: 1219 beta_I: 0.5681055 acceptance rate: 0.5127153
## iteration: 1220 beta_I: 0.5681055 acceptance rate: 0.5122951
## iteration: 1221 beta_I: 0.5681055 acceptance rate: 0.5118755
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## iteration: 1222 beta_I: 0.5681055 acceptance rate: 0.5114566
## iteration: 1223 beta_I: 0.5681055 acceptance rate: 0.5110384
## iteration: 1224 beta_I: 0.5684553 acceptance rate: 0.5114379
## iteration: 1225 beta_I: 0.5684553 acceptance rate: 0.5110204
## iteration: 1226 beta_I: 0.5684553 acceptance rate: 0.5106036
## iteration: 1227 beta_I: 0.5684553 acceptance rate: 0.5101874
## iteration: 1228 beta_I: 0.5684553 acceptance rate: 0.509772
## iteration: 1229 beta_I: 0.5639121 acceptance rate: 0.5101709
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## iteration: 1253 beta_I: 0.5678473 acceptance rate: 0.5107741
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## iteration: 1259 beta_I: 0.5649863 acceptance rate: 0.5091342
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## iteration: 1266 beta_I: 0.5681298 acceptance rate: 0.5086888
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## iteration: 1274 beta_I: 0.5709965 acceptance rate: 0.5102041
## iteration: 1275 beta_I: 0.5709965 acceptance rate: 0.5098039
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## iteration: 1294 beta_I: 0.5623934 acceptance rate: 0.5100464
## iteration: 1295 beta_I: 0.5636598 acceptance rate: 0.5104247
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## iteration: 1328 beta_I: 0.5728264 acceptance rate: 0.5082831
## iteration: 1329 beta_I: 0.5718053 acceptance rate: 0.5086531
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## iteration: 1330 beta_I: 0.5718053 acceptance rate: 0.5082707
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## iteration: 1359 beta_I: 0.5658192 acceptance rate: 0.5091979
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## iteration: 1383 beta_I: 0.5704087 acceptance rate: 0.5068691
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## iteration: 1491 beta_I: 0.5664758 acceptance rate: 0.5023474
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## iteration: 1503 beta_I: 0.5646861 acceptance rate: 0.500998
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## iteration: 1509 beta_I: 0.5681258 acceptance rate: 0.5003313
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## iteration: 1515 beta_I: 0.5672041 acceptance rate: 0.50033
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## iteration: 1519 beta_I: 0.5625583 acceptance rate: 0.5009875
## iteration: 1520 beta_I: 0.5643531 acceptance rate: 0.5013158
## iteration: 1521 beta_I: 0.5643531 acceptance rate: 0.5009862
## iteration: 1522 beta_I: 0.5699848 acceptance rate: 0.5013141
## iteration: 1523 beta_I: 0.5676795 acceptance rate: 0.5016415
## iteration: 1524 beta_I: 0.5676795 acceptance rate: 0.5013123
## iteration: 1525 beta_I: 0.5661152 acceptance rate: 0.5016393
## iteration: 1526 beta_I: 0.566668 acceptance rate: 0.5019659
## iteration: 1527 beta_I: 0.566668 acceptance rate: 0.5016372
## iteration: 1528 beta_I: 0.5657521 acceptance rate: 0.5019634
## iteration: 1529 beta_I: 0.5674498 acceptance rate: 0.5022891
## iteration: 1530 beta_I: 0.5674498 acceptance rate: 0.5019608
## iteration: 1531 beta_I: 0.5683383 acceptance rate: 0.5022861
## iteration: 1532 beta_I: 0.5683383 acceptance rate: 0.5019582
## iteration: 1533 beta_I: 0.5683383 acceptance rate: 0.5016308
## iteration: 1534 beta_I: 0.5681745 acceptance rate: 0.5019557
## iteration: 1535 beta_I: 0.5663858 acceptance rate: 0.5022801
## iteration: 1536 beta_I: 0.5663858 acceptance rate: 0.5019531
## iteration: 1537 beta_I: 0.5663858 acceptance rate: 0.5016265
## iteration: 1538 beta_I: 0.5698081 acceptance rate: 0.5019506
## iteration: 1539 beta_I: 0.5647886 acceptance rate: 0.5022742
## iteration: 1540 beta_I: 0.5638575 acceptance rate: 0.5025974
## iteration: 1541 beta_I: 0.5638575 acceptance rate: 0.5022713
## iteration: 1542 beta_I: 0.5638575 acceptance rate: 0.5019455
## iteration: 1543 beta_I: 0.5665415 acceptance rate: 0.5022683
## iteration: 1544 beta_I: 0.5649736 acceptance rate: 0.5025907
## iteration: 1545 beta_I: 0.5661835 acceptance rate: 0.5029126
```

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## iteration: 1546 beta_I: 0.5661835 acceptance rate: 0.5025873
## iteration: 1547 beta_I: 0.5661835 acceptance rate: 0.5022624
## iteration: 1548 beta_I: 0.5661835 acceptance rate: 0.501938
## iteration: 1549 beta_I: 0.5670996 acceptance rate: 0.5022595
## iteration: 1550 beta_I: 0.5670996 acceptance rate: 0.5019355
## iteration: 1551 beta_I: 0.569257 acceptance rate: 0.5022566
## iteration: 1552 beta_I: 0.569257 acceptance rate: 0.501933
## iteration: 1553 beta_I: 0.569257 acceptance rate: 0.5016098
## iteration: 1554 beta_I: 0.569257 acceptance rate: 0.501287
## iteration: 1555 beta_I: 0.5689995 acceptance rate: 0.5016077
## iteration: 1556 beta_I: 0.5689995 acceptance rate: 0.5012853
## iteration: 1557 beta_I: 0.5685866 acceptance rate: 0.5016057
## iteration: 1558 beta_I: 0.5652616 acceptance rate: 0.5019255
## iteration: 1559 beta_I: 0.5652616 acceptance rate: 0.5016036
## iteration: 1560 beta_I: 0.5652616 acceptance rate: 0.5012821
## iteration: 1561 beta_I: 0.5690038 acceptance rate: 0.5016015
## iteration: 1562 beta_I: 0.5679975 acceptance rate: 0.5019206
## iteration: 1563 beta_I: 0.5679975 acceptance rate: 0.5015995
## iteration: 1564 beta_I: 0.5679975 acceptance rate: 0.5012788
## iteration: 1565 beta_I: 0.5679975 acceptance rate: 0.5009585
## iteration: 1566 beta_I: 0.5679975 acceptance rate: 0.5006386
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## iteration: 1570 beta_I: 0.569237 acceptance rate: 0.5006369
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## iteration: 1572 beta_I: 0.569237 acceptance rate: 0.5
## iteration: 1573 beta_I: 0.5672155 acceptance rate: 0.5003179
## iteration: 1574 beta_I: 0.5676676 acceptance rate: 0.5006353
## iteration: 1575 beta_I: 0.5657061 acceptance rate: 0.5009524
## iteration: 1576 beta_I: 0.5669711 acceptance rate: 0.501269
## iteration: 1577 beta_I: 0.5631432 acceptance rate: 0.5015853
## iteration: 1578 beta_I: 0.5629897 acceptance rate: 0.5019011
## iteration: 1579 beta_I: 0.5629897 acceptance rate: 0.5015833
## iteration: 1580 beta_I: 0.5629897 acceptance rate: 0.5012658
## iteration: 1581 beta_I: 0.5629897 acceptance rate: 0.5009488
## iteration: 1582 beta_I: 0.5629897 acceptance rate: 0.5006321
## iteration: 1583 beta_I: 0.5629897 acceptance rate: 0.5003159
## iteration: 1584 beta_I: 0.5629897 acceptance rate: 0.5
## iteration: 1585 beta_I: 0.5629897 acceptance rate: 0.4996845
## iteration: 1586 beta_I: 0.5622322 acceptance rate: 0.5
## iteration: 1587 beta_I: 0.5622322 acceptance rate: 0.4996849
## iteration: 1588 beta_I: 0.5622322 acceptance rate: 0.4993703
## iteration: 1589 beta_I: 0.5622322 acceptance rate: 0.499056
## iteration: 1590 beta_I: 0.5645571 acceptance rate: 0.4993711
## iteration: 1591 beta_I: 0.5667544 acceptance rate: 0.4996857
## iteration: 1592 beta_I: 0.5667544 acceptance rate: 0.4993719
## iteration: 1593 beta_I: 0.5667544 acceptance rate: 0.4990584
## iteration: 1594 beta_I: 0.5667544 acceptance rate: 0.4987453
## iteration: 1595 beta_I: 0.5620739 acceptance rate: 0.4990596
## iteration: 1596 beta_I: 0.5620739 acceptance rate: 0.4987469
## iteration: 1597 beta_I: 0.5620739 acceptance rate: 0.4984346
## iteration: 1598 beta_I: 0.5620739 acceptance rate: 0.4981227
## iteration: 1599 beta_I: 0.5666956 acceptance rate: 0.4984365
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## iteration: 1600 beta_I: 0.5666956 acceptance rate: 0.498125
## iteration: 1601 beta_I: 0.5666956 acceptance rate: 0.4978139
## iteration: 1602 beta_I: 0.567752 acceptance rate: 0.4981273
## iteration: 1603 beta_I: 0.567752 acceptance rate: 0.4978166
## iteration: 1604 beta_I: 0.567752 acceptance rate: 0.4975062
## iteration: 1605 beta_I: 0.567752 acceptance rate: 0.4971963
## iteration: 1606 beta_I: 0.567752 acceptance rate: 0.4968867
## iteration: 1607 beta_I: 0.567752 acceptance rate: 0.4965775
## iteration: 1608 beta_I: 0.567752 acceptance rate: 0.4962687
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## iteration: 1612 beta_I: 0.5660892 acceptance rate: 0.4962779
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## iteration: 1614 beta_I: 0.5617068 acceptance rate: 0.4962825
## iteration: 1615 beta_I: 0.5617068 acceptance rate: 0.4959752
## iteration: 1616 beta_I: 0.5673568 acceptance rate: 0.4962871
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## iteration: 1618 beta_I: 0.5666661 acceptance rate: 0.4962917
## iteration: 1619 beta_I: 0.5666661 acceptance rate: 0.4959852
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## iteration: 1639 beta_I: 0.5685143 acceptance rate: 0.495424
## iteration: 1640 beta_I: 0.5685143 acceptance rate: 0.495122
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## iteration: 1643 beta_I: 0.5674797 acceptance rate: 0.4954352
## iteration: 1644 beta_I: 0.5674797 acceptance rate: 0.4951338
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## iteration: 1649 beta_I: 0.5662369 acceptance rate: 0.4942389
## iteration: 1650 beta_I: 0.5662369 acceptance rate: 0.4939394
## iteration: 1651 beta_I: 0.5673244 acceptance rate: 0.4942459
## iteration: 1652 beta_I: 0.5651358 acceptance rate: 0.4945521
## iteration: 1653 beta_I: 0.5669321 acceptance rate: 0.4948578
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## iteration: 1654 beta_I: 0.5669321 acceptance rate: 0.4945586
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## iteration: 1707 beta_I: 0.5664737 acceptance rate: 0.4950205
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## iteration: 1708 beta_I: 0.5689979 acceptance rate: 0.4953162
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## iteration: 1759 beta_I: 0.5697009 acceptance rate: 0.4923252
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## iteration: 1761 beta_I: 0.5697203 acceptance rate: 0.4923339
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## iteration: 1762 beta_I: 0.5682975 acceptance rate: 0.492622
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## iteration: 1815 beta_I: 0.5655885 acceptance rate: 0.492011
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## iteration: 1816 beta_I: 0.5673265 acceptance rate: 0.4922907
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## iteration: 1853 beta_I: 0.5680333 acceptance rate: 0.4932542
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## iteration: 1858 beta_I: 0.5632668 acceptance rate: 0.492465
## iteration: 1859 beta_I: 0.5632668 acceptance rate: 0.4922001
## iteration: 1860 beta_I: 0.5663276 acceptance rate: 0.4924731
## iteration: 1861 beta_I: 0.5641984 acceptance rate: 0.4927458
## iteration: 1862 beta_I: 0.5702945 acceptance rate: 0.4930183
## iteration: 1863 beta_I: 0.5702945 acceptance rate: 0.4927536
## iteration: 1864 beta_I: 0.5656991 acceptance rate: 0.4930258
## iteration: 1865 beta_I: 0.5656991 acceptance rate: 0.4927614
## iteration: 1866 beta_I: 0.5656991 acceptance rate: 0.4924973
## iteration: 1867 beta_I: 0.5656991 acceptance rate: 0.4922335
## iteration: 1868 beta_I: 0.5650925 acceptance rate: 0.4925054
## iteration: 1869 beta_I: 0.5676958 acceptance rate: 0.4927769
```

```
## iteration: 1870 beta_I: 0.5676958 acceptance rate: 0.4925134
## iteration: 1871 beta_I: 0.5677843 acceptance rate: 0.4927846
## iteration: 1872 beta_I: 0.5677843 acceptance rate: 0.4925214
## iteration: 1873 beta_I: 0.5675587 acceptance rate: 0.4927923
## iteration: 1874 beta_I: 0.5667001 acceptance rate: 0.493063
## iteration: 1875 beta_I: 0.5667001 acceptance rate: 0.4928
## iteration: 1876 beta_I: 0.5667001 acceptance rate: 0.4925373
## iteration: 1877 beta_I: 0.5672045 acceptance rate: 0.4928077
## iteration: 1878 beta_I: 0.5672045 acceptance rate: 0.4925453
## iteration: 1879 beta_I: 0.5672045 acceptance rate: 0.4922831
## iteration: 1880 beta_I: 0.5683426 acceptance rate: 0.4925532
## iteration: 1881 beta_I: 0.5713909 acceptance rate: 0.492823
## iteration: 1882 beta_I: 0.5717749 acceptance rate: 0.4930925
## iteration: 1883 beta_I: 0.5706296 acceptance rate: 0.4933617
## iteration: 1884 beta_I: 0.5693596 acceptance rate: 0.4936306
## iteration: 1885 beta_I: 0.5693596 acceptance rate: 0.4933687
## iteration: 1886 beta_I: 0.5693596 acceptance rate: 0.4931071
## iteration: 1887 beta_I: 0.5693596 acceptance rate: 0.4928458
## iteration: 1888 beta_I: 0.5676745 acceptance rate: 0.4931144
## iteration: 1889 beta_I: 0.5651675 acceptance rate: 0.4933827
## iteration: 1890 beta_I: 0.5630493 acceptance rate: 0.4936508
## iteration: 1891 beta_I: 0.5626265 acceptance rate: 0.4939186
## iteration: 1892 beta_I: 0.5613871 acceptance rate: 0.494186
## iteration: 1893 beta_I: 0.5628971 acceptance rate: 0.4944532
## iteration: 1894 beta_I: 0.5628971 acceptance rate: 0.4941922
## iteration: 1895 beta_I: 0.5730442 acceptance rate: 0.4944591
## iteration: 1896 beta_I: 0.5730442 acceptance rate: 0.4941983
## iteration: 1897 beta_I: 0.5673799 acceptance rate: 0.4944649
## iteration: 1898 beta_I: 0.5673799 acceptance rate: 0.4942044
## iteration: 1899 beta_I: 0.5673799 acceptance rate: 0.4939442
## iteration: 1900 beta_I: 0.5673799 acceptance rate: 0.4936842
## iteration: 1901 beta_I: 0.5673799 acceptance rate: 0.4934245
## iteration: 1902 beta_I: 0.5673799 acceptance rate: 0.4931651
## iteration: 1903 beta_I: 0.5673799 acceptance rate: 0.4929059
## iteration: 1904 beta_I: 0.5663106 acceptance rate: 0.4931723
## iteration: 1905 beta_I: 0.5663106 acceptance rate: 0.4929134
## iteration: 1906 beta_I: 0.5650254 acceptance rate: 0.4931794
## iteration: 1907 beta_I: 0.5650254 acceptance rate: 0.4929208
## iteration: 1908 beta_I: 0.5637593 acceptance rate: 0.4931866
## iteration: 1909 beta_I: 0.5659158 acceptance rate: 0.4934521
## iteration: 1910 beta_I: 0.5659158 acceptance rate: 0.4931937
## iteration: 1911 beta_I: 0.5675076 acceptance rate: 0.4934589
## iteration: 1912 beta_I: 0.5653293 acceptance rate: 0.4937238
## iteration: 1913 beta_I: 0.5653293 acceptance rate: 0.4934658
## iteration: 1914 beta_I: 0.5629675 acceptance rate: 0.4937304
## iteration: 1915 beta_I: 0.5629675 acceptance rate: 0.4934726
## iteration: 1916 beta_I: 0.5657999 acceptance rate: 0.493737
## iteration: 1917 beta_I: 0.5657999 acceptance rate: 0.4934794
## iteration: 1918 beta_I: 0.5657999 acceptance rate: 0.4932221
## iteration: 1919 beta_I: 0.5657999 acceptance rate: 0.4929651
## iteration: 1920 beta_I: 0.5657999 acceptance rate: 0.4927083
## iteration: 1921 beta_I: 0.5659943 acceptance rate: 0.4929724
## iteration: 1922 beta_I: 0.5659943 acceptance rate: 0.4927159
## iteration: 1923 beta_I: 0.5659943 acceptance rate: 0.4924597
```

```
## iteration: 1924 beta_I: 0.5673414 acceptance rate: 0.4927235
## iteration: 1925 beta_I: 0.5673414 acceptance rate: 0.4924675
## iteration: 1926 beta_I: 0.5673414 acceptance rate: 0.4922118
## iteration: 1927 beta_I: 0.5673414 acceptance rate: 0.4919564
## iteration: 1928 beta_I: 0.5673414 acceptance rate: 0.4917012
## iteration: 1929 beta_I: 0.5691062 acceptance rate: 0.4919647
## iteration: 1930 beta_I: 0.5691062 acceptance rate: 0.4917098
## iteration: 1931 beta_I: 0.5713896 acceptance rate: 0.4919731
## iteration: 1932 beta_I: 0.5713896 acceptance rate: 0.4917184
## iteration: 1933 beta_I: 0.5713896 acceptance rate: 0.491464
## iteration: 1934 beta_I: 0.5661595 acceptance rate: 0.491727
## iteration: 1935 beta_I: 0.5668995 acceptance rate: 0.4919897
## iteration: 1936 beta_I: 0.564306 acceptance rate: 0.4922521
## iteration: 1937 beta_I: 0.564306 acceptance rate: 0.4919979
## iteration: 1938 beta_I: 0.564306 acceptance rate: 0.4917441
## iteration: 1939 beta_I: 0.5649711 acceptance rate: 0.4920062
## iteration: 1940 beta_I: 0.5692219 acceptance rate: 0.492268
## iteration: 1941 beta_I: 0.5649874 acceptance rate: 0.4925296
## iteration: 1942 beta_I: 0.5649874 acceptance rate: 0.492276
## iteration: 1943 beta_I: 0.5649874 acceptance rate: 0.4920226
## iteration: 1944 beta_I: 0.5649874 acceptance rate: 0.4917695
## iteration: 1945 beta_I: 0.5665511 acceptance rate: 0.4920308
## iteration: 1946 beta_I: 0.5665511 acceptance rate: 0.491778
## iteration: 1947 beta_I: 0.5666579 acceptance rate: 0.492039
## iteration: 1948 beta_I: 0.5683387 acceptance rate: 0.4922998
## iteration: 1949 beta_I: 0.5670479 acceptance rate: 0.4925603
## iteration: 1950 beta_I: 0.5696036 acceptance rate: 0.4928205
## iteration: 1951 beta_I: 0.5696036 acceptance rate: 0.4925679
## iteration: 1952 beta_I: 0.5696036 acceptance rate: 0.4923156
## iteration: 1953 beta_I: 0.5696036 acceptance rate: 0.4920635
## iteration: 1954 beta_I: 0.5644506 acceptance rate: 0.4923234
## iteration: 1955 beta_I: 0.5644506 acceptance rate: 0.4920716
## iteration: 1956 beta_I: 0.5644506 acceptance rate: 0.49182
## iteration: 1957 beta_I: 0.5650321 acceptance rate: 0.4920797
## iteration: 1958 beta_I: 0.5650321 acceptance rate: 0.4918284
## iteration: 1959 beta_I: 0.5650321 acceptance rate: 0.4915773
## iteration: 1960 beta_I: 0.5650321 acceptance rate: 0.4913265
## iteration: 1961 beta_I: 0.5652771 acceptance rate: 0.4915859
## iteration: 1962 beta_I: 0.5652771 acceptance rate: 0.4913354
## iteration: 1963 beta_I: 0.5652771 acceptance rate: 0.4910851
## iteration: 1964 beta_I: 0.5652771 acceptance rate: 0.490835
## iteration: 1965 beta_I: 0.5681189 acceptance rate: 0.4910941
## iteration: 1966 beta_I: 0.5681189 acceptance rate: 0.4908444
## iteration: 1967 beta_I: 0.5681189 acceptance rate: 0.4905948
## iteration: 1968 beta_I: 0.5681189 acceptance rate: 0.4903455
## iteration: 1969 beta_I: 0.5649575 acceptance rate: 0.4906044
## iteration: 1970 beta_I: 0.5649575 acceptance rate: 0.4903553
## iteration: 1971 beta_I: 0.5632267 acceptance rate: 0.4906139
## iteration: 1972 beta_I: 0.5628875 acceptance rate: 0.4908722
## iteration: 1973 beta_I: 0.560221 acceptance rate: 0.4911303
## iteration: 1974 beta_I: 0.5694303 acceptance rate: 0.491388
## iteration: 1975 beta_I: 0.5683739 acceptance rate: 0.4916456
## iteration: 1976 beta_I: 0.5683739 acceptance rate: 0.4913968
## iteration: 1977 beta_I: 0.5672354 acceptance rate: 0.491654
```
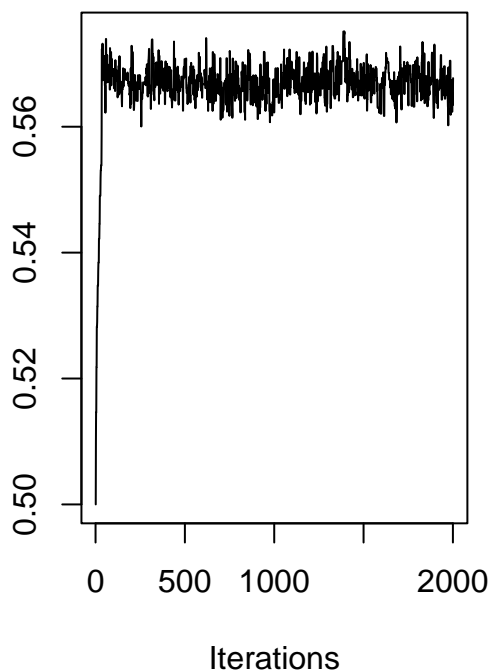
```
## iteration: 1978 beta_I: 0.5672354 acceptance rate: 0.4914055
## iteration: 1979 beta_I: 0.5664734 acceptance rate: 0.4916625
## iteration: 1980 beta_I: 0.5640421 acceptance rate: 0.4919192
## iteration: 1981 beta_I: 0.56393 acceptance rate: 0.4921757
## iteration: 1982 beta_I: 0.5704773 acceptance rate: 0.4924319
## iteration: 1983 beta_I: 0.5704773 acceptance rate: 0.4921836
## iteration: 1984 beta_I: 0.5704773 acceptance rate: 0.4919355
## iteration: 1985 beta_I: 0.5704773 acceptance rate: 0.4916877
## iteration: 1986 beta_I: 0.5619113 acceptance rate: 0.4919436
## iteration: 1987 beta_I: 0.5619113 acceptance rate: 0.491696
## iteration: 1988 beta_I: 0.5669791 acceptance rate: 0.4919517
## iteration: 1989 beta_I: 0.5669791 acceptance rate: 0.4917044
## iteration: 1990 beta_I: 0.5669791 acceptance rate: 0.4914573
## iteration: 1991 beta_I: 0.5674147 acceptance rate: 0.4917127
## iteration: 1992 beta_I: 0.5674147 acceptance rate: 0.4914659
## iteration: 1993 beta_I: 0.5674147 acceptance rate: 0.4912193
## iteration: 1994 beta_I: 0.5674147 acceptance rate: 0.4909729
## iteration: 1995 beta_I: 0.5623642 acceptance rate: 0.4912281
## iteration: 1996 beta_I: 0.5654185 acceptance rate: 0.491483
## iteration: 1997 beta_I: 0.5634461 acceptance rate: 0.4917376
## iteration: 1998 beta_I: 0.5634461 acceptance rate: 0.4914915
## iteration: 1999 beta_I: 0.5656687 acceptance rate: 0.4917459
## iteration: 2000 beta_I: 0.5677173 acceptance rate: 0.492
```
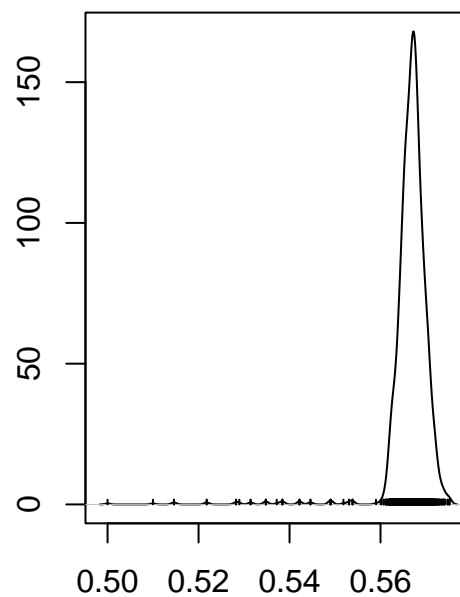
```r
trace_mat <- matrix(mcmcTrace, ncol = 1, byrow = TRUE)
trace     <- mcmc(trace_mat, start = 1)
colnames(trace) <- "beta_I"

plot(trace)
```


Trace of beta_I   **Density of beta_I**

Iterations   N = 2001   Bandwidth = 0.0005715

```r
summary(trace)
```

```
## 
## Iterations = 1:2001
## Thinning interval = 1
## Number of chains = 1
## Sample size per chain = 2001
## 
## 1. Empirical mean and standard deviation for each variable,
##    plus standard error of the mean:
## 
##          Mean             SD      Naive SE Time-series SE
##     0.5665862      0.0048862     0.0001092      0.0005132
## 
## 2. Quantiles for each variable:
## 
##   2.5%    25%    50%    75%  97.5%
## 0.5617 0.5653 0.5670 0.5686 0.5719
```

```r
beta_I_samples <- as.numeric(trace)
beta_I_hat     <- mean(beta_I_samples)
beta_I_hat
```

```
## [1] 0.5665862
```

```r
## 9. Compute R0 from posterior mean beta_I -----------------------

S0 <- initState["S"]
N0 <- sum(initState)

gamma <- theta_fixed["gamma"]; mu <- theta_fixed["mu"]
s     <- theta_fixed["s"];     m  <- theta_fixed["m"]
c_c   <- theta_fixed["c"]

R0_hat <- (c_c * S0 / N0) * beta_I_hat * (
  1 / (gamma + mu + m) +
  rho * gamma / ((gamma + mu + m) * (s + m))
)

R0_hat
```

```
##        c
## 1.575093
```

Estimated R0

```r
#############################################################
## PLOT - MODEL-PREDICTED INCIDENCE VS ACTUAL INCIDENCE  ##
#############################################################

# 1. Build final parameter vector using posterior beta_I
theta_final_post <- theta_fixed
theta_final_post["beta_T"] <- rho * beta_I_hat
theta_final_post["beta_I"] <- beta_I_hat
```

```r
# 2. Solve the ODE over your observation period (in YEARS)
traj_final <- data.frame(ode(
  y     = initState,
  times = time_years,
  func  = HIV_ode,
  parms = theta_final_post,
  method = "ode45"
))

# 3. Compute incidence for plotting: lambda(t)*S(t)*(1/12)
N_traj <- traj_final$S + traj_final$P + traj_final$I + traj_final$T + traj_final$U

lambda_traj <- theta_final_post["c"] *
  (theta_final_post["beta_I"] * traj_final$I +
   theta_final_post["beta_T"] * traj_final$T) / N_traj

model_inc_monthly <- lambda_traj * traj_final$S * (1/12)

# 4. Build a plotting data frame
plot_df <- data.frame(
  Month = hiv_inc_post$Month,
  Observed = hiv_inc_post$Cases,
  Model = model_inc_monthly
)

# 5. Plot
library(ggplot2)

ggplot(plot_df, aes(x = Month)) +
  geom_point(aes(y = Observed), color = "black", size = 2) +
  geom_line(aes(y = Model), color = "blue", linewidth = 1.1) +
  labs(
    title = "Observed vs Model-Predicted HIV Incidence Post-COVID",
    y = "Monthly HIV Incidence",
    x = "Month"
  ) +
  theme_minimal(base_size = 14)
```
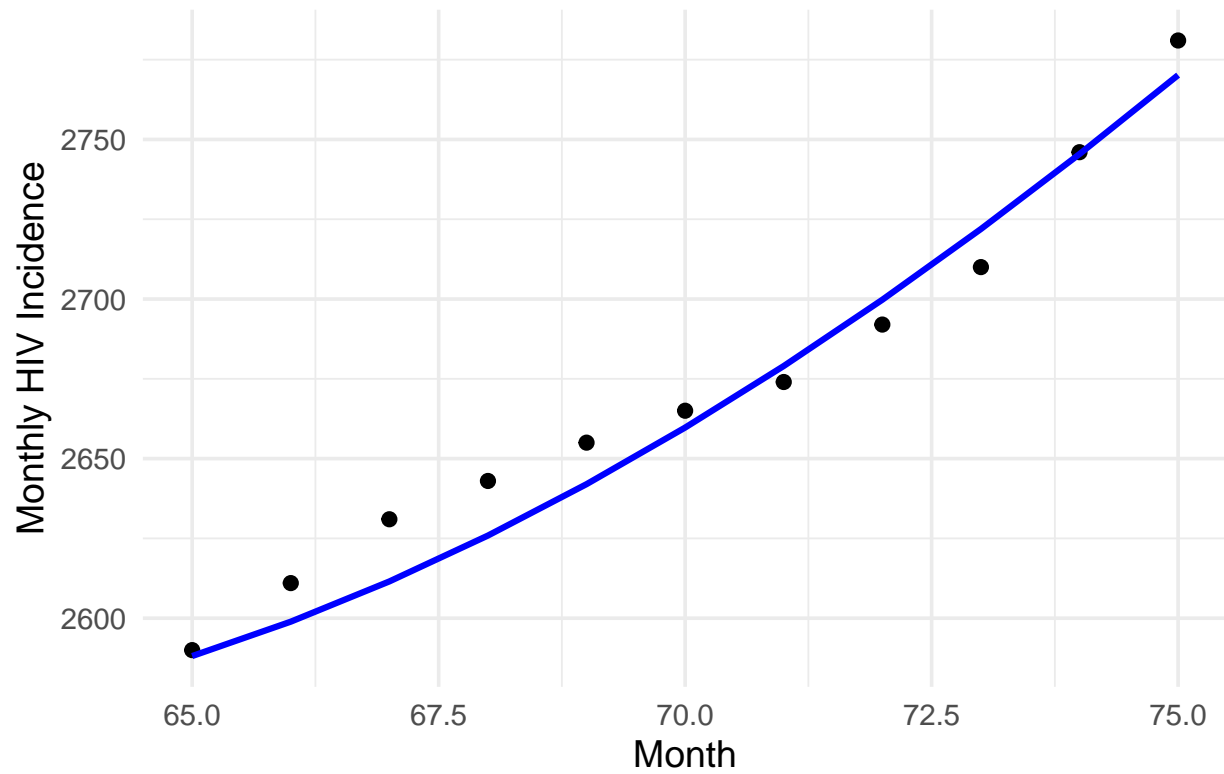
Observed vs Model–Predicted HIV Incidence Post–COV

```
theta_final_post
```

```
##      beta_T           c           a           p           b      gamma          mu
## 0.05665862 1.50000000 0.09800000 0.20720000 1.20000000 0.50000000 0.10000000
##          s           m      beta_I
## 0.25000000 0.02857143 0.56658617
```