main

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Set paths and get packages

```
rm(list = ls())
#path = '~/Documents/LSE/Dissertation/Code/ANOVA-kernel/'
#path_stan = '~/Documents/LSE/Dissertation/Code/Additive-GP-Kronecker-main/Code/Stan/'
library(ggplot2)
library(plyr)
library(cmdstanr)
```

```
## This is cmdstanr version 0.5.3
```

```
## - CmdStanR documentation and vignettes: mc-stan.org/cmdstanr
```

```
## - CmdStan path: /Users/rickholubec/.cmdstan/cmdstan-2.32.1
```

```
## - CmdStan version: 2.32.1
```

```
##
## A newer version of CmdStan is available. See ?install_cmdstan() to install it.
## To disable this check set option or environment variable CMDSTANR_NO_VER_CHECK=TRUE.
```

```
library(rstan)
```

```
## Loading required package: StanHeaders
```

```
## rstan (Version 2.21.8, GitRev: 2e1f913d3ca3)
```

```
## For execution on a local, multicore CPU with excess RAM we recommend calling
## options(mc.cores = parallel::detectCores()).
## To avoid recompilation of unchanged Stan programs, we recommend calling
## rstan_options(auto_write = TRUE)
```

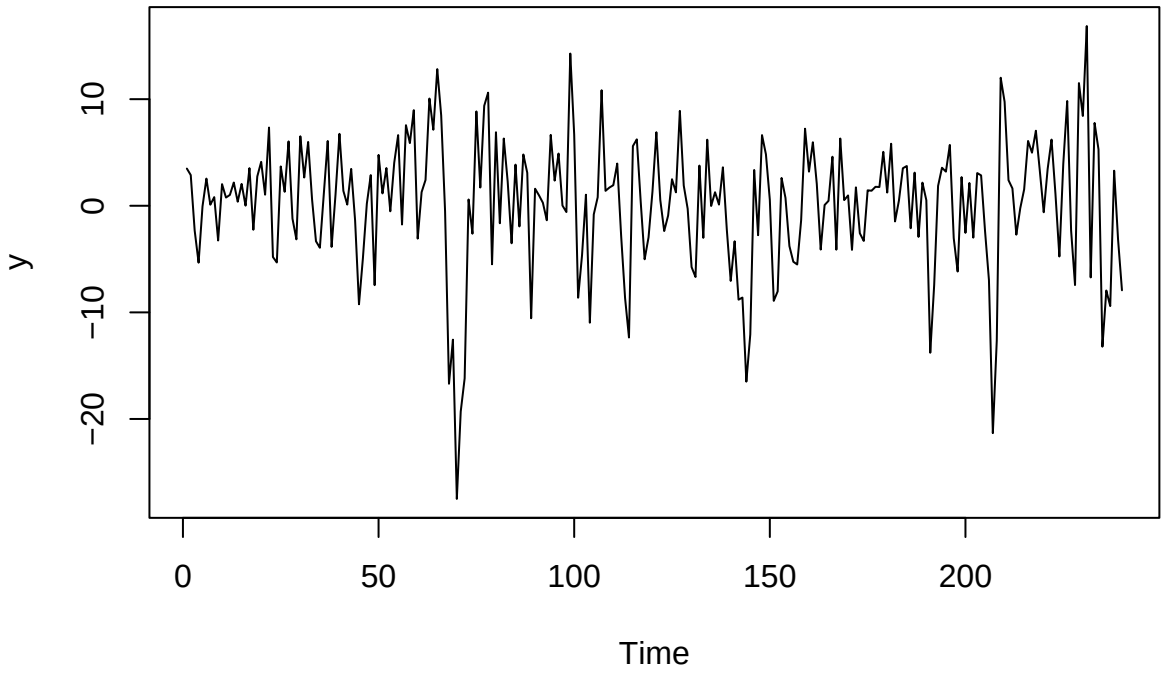
Import data

```r
source("Data-preprocessing.R")
```

```
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo
```

```
## New names:
## New names:
## New names:
## * `` -> `...2`
```

```r
#X_ts<-cbind(y_lag1,y_lag2,y_lag12, cpi, kilian, delta_stock, prod)
#X<-as.data.frame(X_ts)
X_lag1_ts<-cbind(y_lag1, cpi_lag1, kilian_lag1, delta_stock_lag1, prod_lag1)
X_lag1<-as.data.frame(X_lag1_ts)
y<-as.vector(y_ts)
# Plots
ts.plot(y)
```




```r
print(adf.test(y))
```

```
## Warning in adf.test(y): p-value smaller than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  y
## Dickey-Fuller = -6.2293, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
```

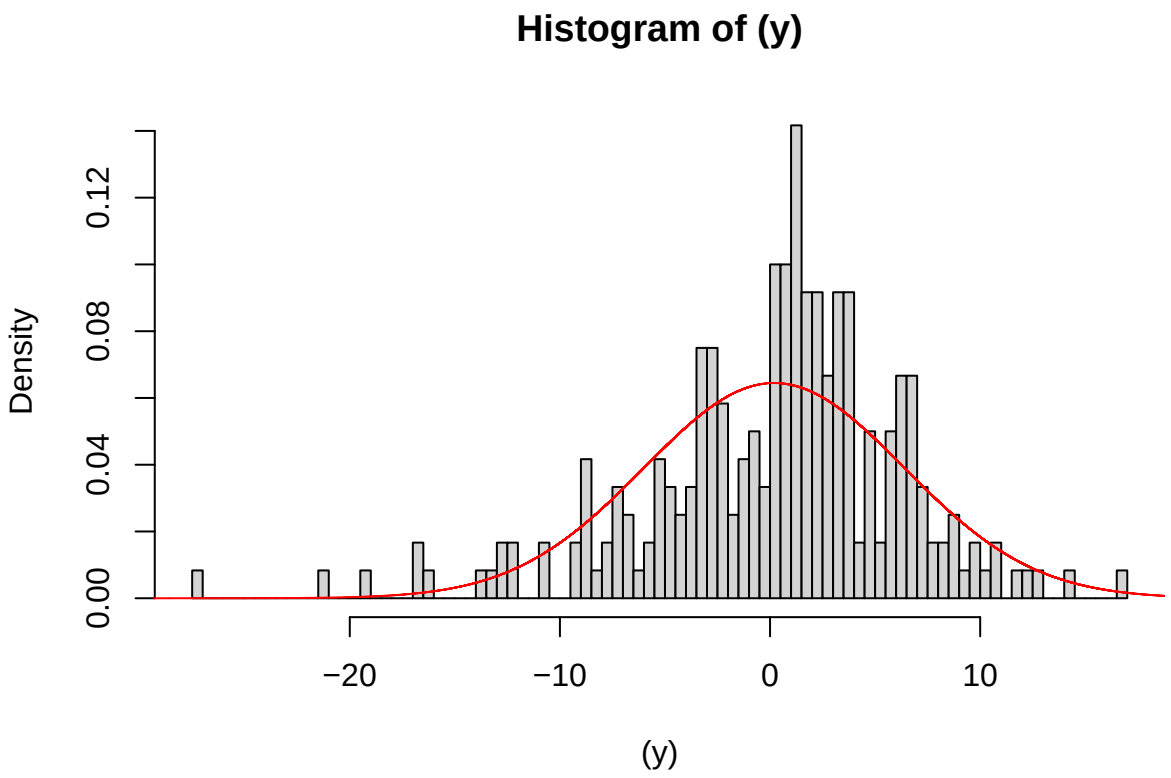
```r
print(jarque.bera.test(y))
```

```
##
##  Jarque Bera Test
##
## data:  y
## X-squared = 77.649, df = 2, p-value < 2.2e-16
```

```r
print(bds.test(y))
```

```
##
##   BDS Test
##
## data:  y
##
## Embedding dimension =  2 3
##
## Epsilon for close points =   3.0939  6.1878  9.2817 12.3756
##
## Standard Normal =
##       [ 3.0939 ] [ 6.1878 ] [ 9.2817 ] [ 12.3756 ]
## [ 2 ]     4.7721     6.1013     7.1416      8.0823
## [ 3 ]     4.2824     6.1999     7.0588      7.9194
##
## p-value =
##       [ 3.0939 ] [ 6.1878 ] [ 9.2817 ] [ 12.3756 ]
## [ 2 ]          0          0          0           0
## [ 3 ]          0          0          0           0
```

```r
hist((y), prob = TRUE,100)
xay<-seq(mean(y)-10*sd(y),mean(y)+10*sd(y),0.0001)
lines(xay,dnorm(xay,mean = mean(y),sd = sd(y)), col="red")
```




```
## model settings
#h-step
h<-1
# test
library(moments)
library(nonlinearTseries)
```

```
##
## Attaching package: 'nonlinearTseries'
##
## The following object is masked from 'package:grDevices':
##
##     contourLines
```

```
abcd<-nonlinearityTest(y, verbose = TRUE)
```

```
##       ** Teraesvirta's neural network test  **
##       Null hypothesis: Linearity in "mean"
##       X-squared =  9.027794  df =  2  p-value =  0.01095568
##
##       ** White neural network test  **
##       Null hypothesis: Linearity in "mean"
##       X-squared =  8.81693  df =  2  p-value =  0.01217385
##
##       ** Keenan's one-degree test for nonlinearity  **
##       Null hypothesis: The time series follows some AR process
##       F-stat =  8.418712  p-value =  0.00406494
##
```

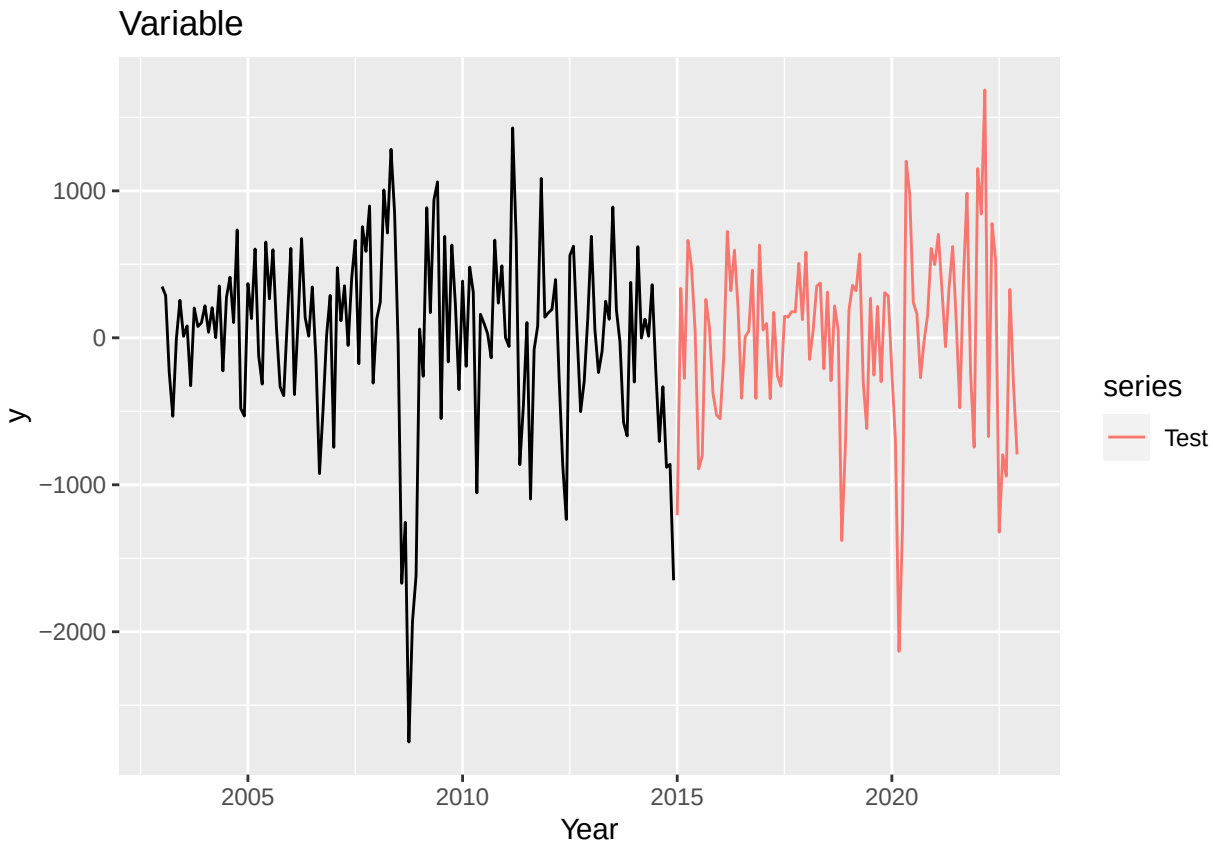
```
##       ** McLeod-Li test  **
##       Null hypothesis: The time series follows some ARIMA process
##       Maximum p-value =  2.692434e-09
##
##       ** Tsay's Test for nonlinearity **
##       Null hypothesis: The time series follows some AR process
##       F-stat =  8.418952  p-value =  0.004064421
##
##       ** Likelihood ratio test for threshold nonlinearity **
##       Null hypothesis: The time series follows some AR process
##       Alternativce hypothesis: The time series follows some TAR process
##       X-squared =  11.06862  p-value =  0.05291588
```

```
bds.test(y)
```

```
##
##   BDS Test
##
## data:  y
##
## Embedding dimension =  2 3
##
## Epsilon for close points =   3.0939  6.1878  9.2817 12.3756
##
## Standard Normal =
##       [ 3.0939 ] [ 6.1878 ] [ 9.2817 ] [ 12.3756 ]
## [ 2 ]     4.7721     6.1013     7.1416      8.0823
## [ 3 ]     4.2824     6.1999     7.0588      7.9194
##
## p-value =
##       [ 3.0939 ] [ 6.1878 ] [ 9.2817 ] [ 12.3756 ]
## [ 2 ]          0          0          0           0
## [ 3 ]          0          0          0           0
```

Train-Val-Test Split

```
set<-Train_Test_Split(X_lag1_ts,y_ts, c(0.6,0.4))
autoplot(100*set$y_train,ylab = "y",xlab = "Year",main = "Variable") +autolayer(100*set$y_test,series =
```




```
#Recession plot
#https://rpubs.com/rfrostbrewer/codethroughexample
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:plyr':
##
##     arrange, count, desc, failwith, id, mutate, rename, summarise,
##     summarize

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(ggpmisc)
```

```
## Loading required package: ggpp

##
## Attaching package: 'ggpp'
```

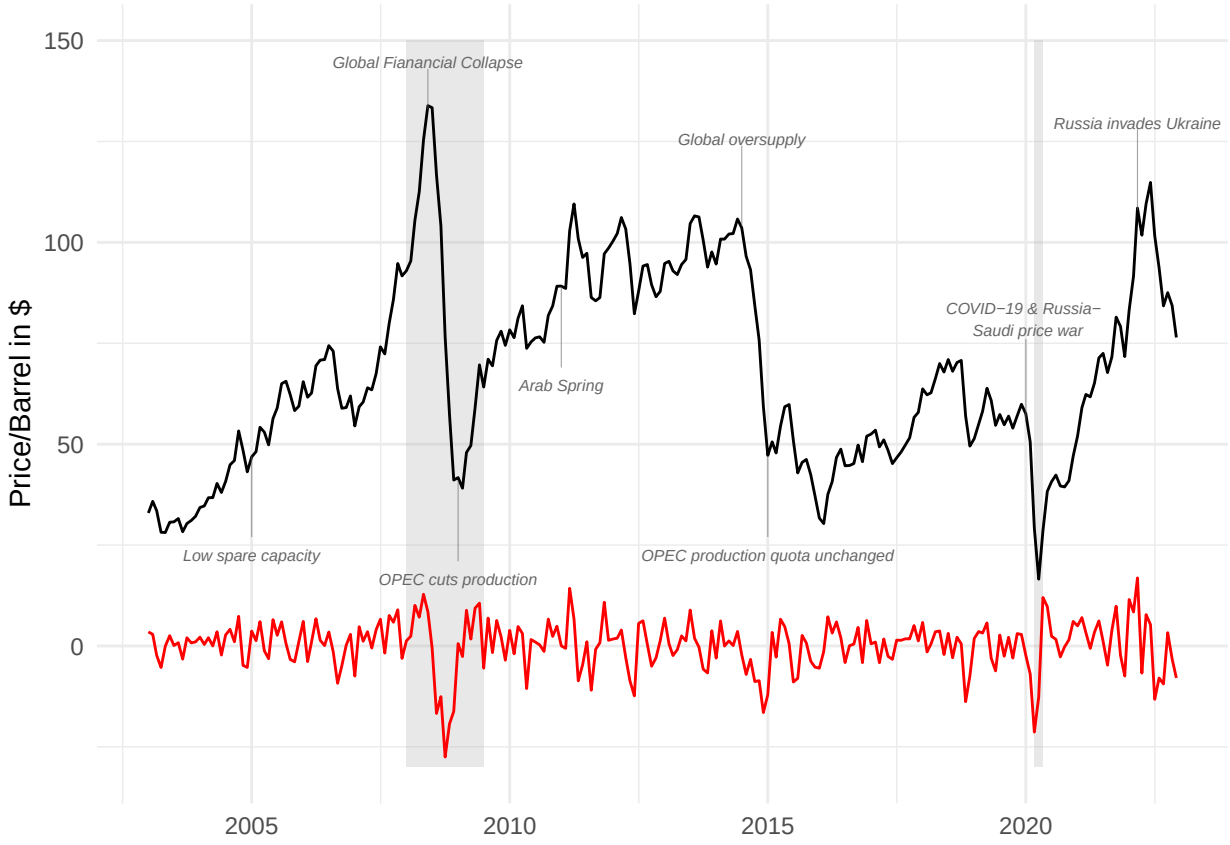
```
## The following object is masked from 'package:ggplot2':
##
##     annotate

## Registered S3 method overwritten by 'ggpmisc':
##   method                  from
##   as.character.polynomial polynom
```

```
data_orig<-Data_Select_Period(data,transform = FALSE,end=c(2022,12))#Data_Transform(data,transform = FA
recession_data_old<-read.csv("data/USREC-2.csv")[-(397:402),]
recession_data<-recession_data_old[(157:dim(recession_data_old)[1]),]

recession_data$DATA<-as.vector(data_orig)
recession_data$REC<-c(0,diff(recession_data$USREC))
recessions_start_end <- recession_data %>%
  mutate(recession_change = USREC - lag(USREC)) %>%
  filter(recession_change != 0)

recessions <- tibble(start = filter(recessions_start_end, recession_change == 1)$DATE,
                     end = filter(recessions_start_end, recession_change == -1)$DATE)
recession_data$RETURN<-y

ggplot(data = recession_data,aes(x = as.Date(DATE)))+
  geom_rect(data = recessions,
            aes(xmin = as.Date(start), xmax = as.Date(end), ymin = -30, ymax = 150),
            inherit.aes = FALSE, fill = "grey70", alpha = 0.3) + #grey70, blue
  geom_line(aes(y = DATA,colour="WTI"),colour="black")+
  labs(x = NULL,
       y = "Price/Barrel in $",
       color = NULL
       #title = "WTI Crude Oil Prices from 2003-2023",
       #subtitle = "From 1987-2021, comparing the top 1% and bottom 50% \n(National recessions shaded)"
       #caption = "Source: Federal Reserve Economic Data"
       ) +
  # annotate("segment", x = as.Date.factor("2001-06-01"),
  #          xend = as.Date.factor("2001-06-01"),
  #          y = 28, yend = 48, colour = "#666666", size=0.2, alpha=0.6) +
  # annotate(geom = "text", x = as.Date.factor("2001-06-01"), y = 58,
  #          label = "Bush Tax Cut  \n Jun 2001 & May 2003  ",
  #          fontface = "italic", vjust = 1, color = "#666666", size = 2) +
  annotate("segment", x = as.Date.factor("2008-06-01"),
           xend = as.Date.factor("2008-06-01"),
           y = 133, yend = 143, colour = "#666666", size=0.2, alpha=0.6) +
  annotate(geom = "text", x = as.Date.factor("2008-06-01"), y = 146,
           label = "Global Fianancial Collapse",
           fontface = "italic", vjust = 1, color = "#666666", size = 2) +
  annotate("segment", x = as.Date.factor("2020-01-01"),
           xend = as.Date.factor("2020-01-01"),
           y = 56, yend = 76, colour = "#666666", size=0.2, alpha=0.6) +
  annotate(geom = "text", x = as.Date.factor("2020-01-01"), y = 85,
           label = "COVID-19 & Russia- \n Saudi price war",
           fontface = "italic", vjust = 1, color = "#666666", size = 2) +
  annotate("segment", x = as.Date.factor("2009-01-01"),
           xend = as.Date.factor("2009-01-01"),
```

```
         y = 41, yend = 21, colour = "#666666", size=0.2, alpha=0.6) +
annotate(geom = "text", x = as.Date.factor("2009-01-01"), y = 18,
         label = "OPEC cuts production",
         fontface = "italic", vjust = 1, color = "#666666", size = 2) +
# annotate("segment", x = as.Date.factor("2001-09-01"),
#          xend = as.Date.factor("2001-09-01"),
#          y = 26, yend = 46, colour = "#666666", size=0.2, alpha=0.6) +
# annotate(geom = "text", x = as.Date.factor("2001-09-01"), y = 49,
#          label = "9/11 Attacks",
#          fontface = "italic", vjust = 1, color = "#666666", size = 2) +
# annotate("segment", x = as.Date.factor("1999-03-01"),
#          xend = as.Date.factor("1999-03-01"),
#          y = 15, yend = 35, colour = "#666666", size=0.2, alpha=0.6) +
# annotate(geom = "text", x = as.Date.factor("1999-03-01"), y = 38,
#          label = "OPEC cuts production",
#          fontface = "italic", vjust = 1, color = "#666666", size = 2) +
annotate("segment", x = as.Date.factor("2022-03-01"),
         xend = as.Date.factor("2022-03-01"),
         y = 108, yend = 128, colour = "#666666", size=0.2, alpha=0.6) +
annotate(geom = "text", x = as.Date.factor("2022-03-01"), y = 131,
         label = "Russia invades Ukraine",
         fontface = "italic", vjust = 1, color = "#666666", size = 2) +
# annotate("segment", x = as.Date.factor("2003-10-01"),
#          xend = as.Date.factor("2003-10-01"),
#          y = 36, yend = 56, colour = "#666666", size=0.2, alpha=0.6) +
# annotate(geom = "text", x = as.Date.factor("2003-10-01"), y = 59,
#          label = "Iraq invades Kuwait",
#          fontface = "italic", vjust = 1, color = "#666666", size = 2) +
annotate("segment", x = as.Date.factor("2014-07-01"),
         xend = as.Date.factor("2014-07-01"),
         y = 104, yend = 124, colour = "#666666", size=0.2, alpha=0.6) +
annotate(geom = "text", x = as.Date.factor("2014-07-01"), y = 127,
         label = "Global oversupply",
         fontface = "italic", vjust = 1, color = "#666666", size = 2) +
annotate("segment", x = as.Date.factor("2005-01-01"),
         xend = as.Date.factor("2005-01-01"),
         y = 47, yend = 27, colour = "#666666", size=0.2, alpha=0.6) +
annotate(geom = "text", x = as.Date.factor("2005-01-01"), y = 24,
         label = "Low spare capacity",
         fontface = "italic", vjust = 1, color = "#666666", size = 2) +
annotate("segment", x = as.Date.factor("2011-01-01"),
         xend = as.Date.factor("2011-01-01"),
         y = 89, yend = 69, colour = "#666666", size=0.2, alpha=0.6) +
annotate(geom = "text", x = as.Date.factor("2011-01-01"), y = 66,
         label = "Arab Spring",
         fontface = "italic", vjust = 1, color = "#666666", size = 2) +
annotate("segment", x = as.Date.factor("2015-01-01"),
         xend = as.Date.factor("2015-01-01"),
         y = 47, yend = 27, colour = "#666666", size=0.2, alpha=0.6) +
annotate(geom = "text", x = as.Date.factor("2015-01-01"), y = 24,
         label = "OPEC production quota unchanged",
         fontface = "italic", vjust = 1, color = "#666666", size = 2) +
geom_line(aes(x = as.Date(DATE), y = RETURN, colour="Return"), colour = "red")+
```

```
  #scale_colour_manual("",
  #                    values = c("black", "red"))
  theme_minimal()
```

```
## Warning: Using 'size' aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use 'linewidth' instead.
## This warning is displayed once every 8 hours.
## Call 'lifecycle::last_lifecycle_warnings()' to see where this warning was
## generated.
```




```
  #theme_ipsum_rc()

#autoplot(data_orig,ylab = "y",xlab = "Year",main = "Crude Oil Prices from 2003-2023")
```

```
#save csv files for python
X_lag1_ts<-cbind(y_lag1, kilian_lag1, delta_stock_lag1, cpi_lag1,prod_lag1)#
set<-Train_Test_Split(X_lag1_ts,y_ts, c(0.6,0.4))
write.csv(set$X_train, file = "data/Pre-processed data/X_train.csv", row.names = FALSE)
write.csv(set$y_train, file = "data/Pre-processed data/y_train.csv", row.names = FALSE)
write.csv(set$X_val, file = "data/Pre-processed data/X_val.csv", row.names = FALSE)
write.csv(set$y_val, file = "data/Pre-processed data/y_val.csv", row.names = FALSE)
write.csv(set$X_test, file = "data/Pre-processed data/X_test.csv", row.names = FALSE)
write.csv(set$y_test, file = "data/Pre-processed data/y_test.csv", row.names = FALSE)
#write.csv(set$y_train, file = "X_train.csv", row.names = FALSE)
```

Random Walk

```
step <- 12
R <- as.integer(length(set$y_test)/step)
y_hat_RW <- c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
for (i in 1:R){
    y1 <- window(y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    model <- rwf(y1,step)
    #model<-mean(y1)
    y_pred <- predict(model,step)$mean
    #y_pred<-rep(model,step)
    y_hat_RW <- c(y_hat_RW,y_pred)
}
MSPE_RW <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_RW-as.vector(set$y_test))^2))
MAPE_RW <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_RW-as.vector(set$y_test)))
print(paste("MSFE for RW =", MSPE_RW))
```

```
## [1] "MSFE for RW = 9.6173691070722"
```

```
print(paste("MAPE for RW =", MAPE_RW))
```

```
## [1] "MAPE for RW = 7.56552083333334"
```

ARMA

```
library(forecast)
step <- 12
R <- as.integer(length(set$y_test)/step)
y_hat_ARMA <- c()
lower_ARMA<-c()
upper_ARMA<-c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
for (i in 1:R){
    y1 <- window(y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    model <- auto.arima(y1)
    y_pred <- as.vector(forecast(model,step)$mean)
    lower_ARMA <- c(lower_ARMA,as.vector(forecast(model,step)$lower[,2]))
    upper_ARMA <- c(upper_ARMA,as.vector(forecast(model,step)$upper[,2]))
    y_hat_ARMA <- c(y_hat_ARMA,y_pred)
}
MSPE_ARMA <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_ARMA-as.vector(set$y_test))^2))
MAPE_ARMA <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_ARMA-as.vector(set$y_test)))
print(paste("MSFE for ARMA =", MSPE_ARMA))
```

```
## [1] "MSFE for ARMA = 6.24144984110166"
```

```
print(paste("MAPE for ARMA =", MAPE_ARMA))
```

```
## [1] "MAPE for ARMA = 4.84811520135249"
```

ARDL

```
library(forecast)
library(ARDL)
```

```
## To cite the ARDL package in publications:
##
## Use this reference to refer to the validity of the ARDL package.
##
##   Natsiopoulos, Kleanthis, and Tzeremes, Nickolaos G. (2022). ARDL
##   bounds test for cointegration: Replicating the Pesaran et al. (2001)
##   results for the UK earnings equation using R. Journal of Applied
##   Econometrics, 37(5), 1079-1090. https://doi.org/10.1002/jae.2919
##
## Use this reference to cite this specific version of the ARDL package.
##
##   Kleanthis Natsiopoulos and Nickolaos Tzeremes (2023). ARDL: ARDL, ECM
##   and Bounds-Test for Cointegration. R package version 0.2.3.
##   https://CRAN.R-project.org/package=ARDL
```

```
X_ARDL_ts<-cbind(delta_stock_lag12)
step <- 12
R <- as.integer(length(set$y_test)/step)
y_hat_ARDL <- c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
for (i in 1:R){
    X1 <- window(X_ARDL_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    y1 <- window(y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    X2 <- window(X_ARDL_ts, start = c(2003,(T+1+step*(i-1))), end = c(2003,(T+step*(i))))
    model <- auto.arima(y1,xreg=X1)
    y_pred <- predict(model,n.ahead = step,newxreg = X2)$pred
    y_hat_ARDL <- c(y_hat_ARDL,y_pred)
}
MSPE_ARDL <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_ARDL-as.vector(set$y_test))^2))
MAPE_ARDL <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_ARDL-as.vector(set$y_test)))
print(paste("MSFE for ARDL =", MSPE_ARDL))
```

```
## [1] "MSFE for ARDL = 6.18532659248739"
```

```
print(paste("MAPE for ARDL =", MAPE_ARDL))
```

```
## [1] "MAPE for ARDL = 4.8820786850432"
```

VAR

```
library(vars)
```

```
## Loading required package: MASS
```

```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
## Loading required package: strucchange
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

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

```
## Loading required package: sandwich
```

```
##
## Attaching package: 'strucchange'
```

```
## The following object is masked from 'package:rstan':
##
##     monitor
```

```
## Loading required package: urca
```

```
## Loading required package: lmtest
```

```
step <- 12
Y_ts<-cbind(y_ts,kilian,delta_stock)
R <- as.integer(length(set$y_test)/step)
y_hat_VAR <- c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
for (i in 1:R){
    Y1 <- window(Y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    order_select<-as.integer(VARselect(Y1)$selection[1]) #AIC
    model <- VAR(Y1,order_select)
    y_pred <- as.vector(predict(model,n.ahead =step)$fcst$y_ts[,1])
    y_hat_VAR <- c(y_hat_VAR,y_pred)
}
MSPE_VAR <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_VAR-as.vector(set$y_test))^2))
MAPE_VAR <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_VAR-as.vector(set$y_test)))
print(paste("MSFE for VAR =", MSPE_VAR))
```

```
## [1] "MSFE for VAR = 6.10912233191664"
```

```
print(paste("MAPE for VAR =", MAPE_VAR))
```

```
## [1] "MAPE for VAR = 4.72446287269033"
```

tvAR

```
library(tvReg)
```

```
## Loading required package: Matrix
```

```
## Funded by the Horizon 2020. Framework Programme of the European Union.
```

```
##
## Attaching package: 'tvReg'
```

```
## The following object is masked from 'package:forecast':
##
##     forecast
```

```
library(Matrix)
step <- 12
R <- as.integer(length(set$y_test)/step)
y_hat_tvAR <- c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
for (i in 1:R){
    y1 <- window(y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    model <- tvAR(y1,1,type = "const",est = "ll",tkernel = "Epa")
    y_pred <- forecast(model,n.ahead=step)
    y_hat_tvAR <- c(y_hat_tvAR,y_pred)
}
```

```
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
```

```
MSPE_tvAR <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_tvAR-as.vector(set$y_test))^2))
MAPE_tvAR <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_tvAR-as.vector(set$y_test)))
print(paste("MSFE for tvAR =", MSPE_tvAR))
```

```
## [1] "MSFE for tvAR = 6.23128082581619"
```

```r
print(paste("MAPE for tvAR =", MAPE_tvAR))
```

```
## [1] "MAPE for tvAR = 4.91363902702261"
```

tvVAR

```r
step <- 12
Y_ts<-cbind(y_ts,kilian,delta_stock)
R <- as.integer(length(set$y_test)/step)
y_hat_tvVAR <- c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
for (i in 1:R){
    Y1 <- window(Y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    y1<-window(y_lag12, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    y2<-window(y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    model <- tvVAR(Y1,1,type="const", est="ll", tkernel="Epa",z = as.vector(y1))
    y_pred <- forecast(model,n.ahead =step,newz = as.vector(tail(y2,step)))[,1]
    y_hat_tvVAR <- c(y_hat_tvVAR,y_pred)
}
```

```
## Calculating regression bandwidths... bandwidth(s)  208.9 24.59977 208.9
## Calculating regression bandwidths... bandwidth(s)  208.9 24.88 208.9
## Calculating regression bandwidths... bandwidth(s)  208.9 23.98 208.9
## Calculating regression bandwidths... bandwidth(s)  208.9 23.50991 208.9
## Calculating regression bandwidths... bandwidth(s)  208.9 23.37 208.9
## Calculating regression bandwidths... bandwidth(s)  208.9 15.43 208.9
## Calculating regression bandwidths... bandwidth(s)  40.32 34.73 208.9
## Calculating regression bandwidths... bandwidth(s)  178.05 27.96 34.96414
```

```r
MSPE_tvVAR <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_tvVAR-as.vector(set$y_test))^2))
MAPE_tvVAR <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_tvVAR-as.vector(set$y_test)))
print(paste("MSFE for tvVAR =", MSPE_tvVAR))
```

```
## [1] "MSFE for tvVAR = 6.0861540309294"
```

```r
print(paste("MAPE for tvVAR =", MAPE_tvVAR))
```

```
## [1] "MAPE for tvVAR = 4.73132787002926"
```

FAR

```r
library(tvReg)
step <- 12
R <- as.integer(length(set$y_test)/step)
```

```
y_hat_FAR <- c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
for (i in 1:R){
    y1 <- window(y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    y1_lag1<-window(y_lag12, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    model <- tvAR(y1,type=c("const"),1,z=y1_lag1, est="ll", tkernel="Epa")
    y_pred <- forecast(model,n.ahead=step, newz = as.vector(tail(y1,step)))
    y_hat_FAR <- c(y_hat_FAR,y_pred)
}
```

```
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
## Calculating regression bandwidth...
```

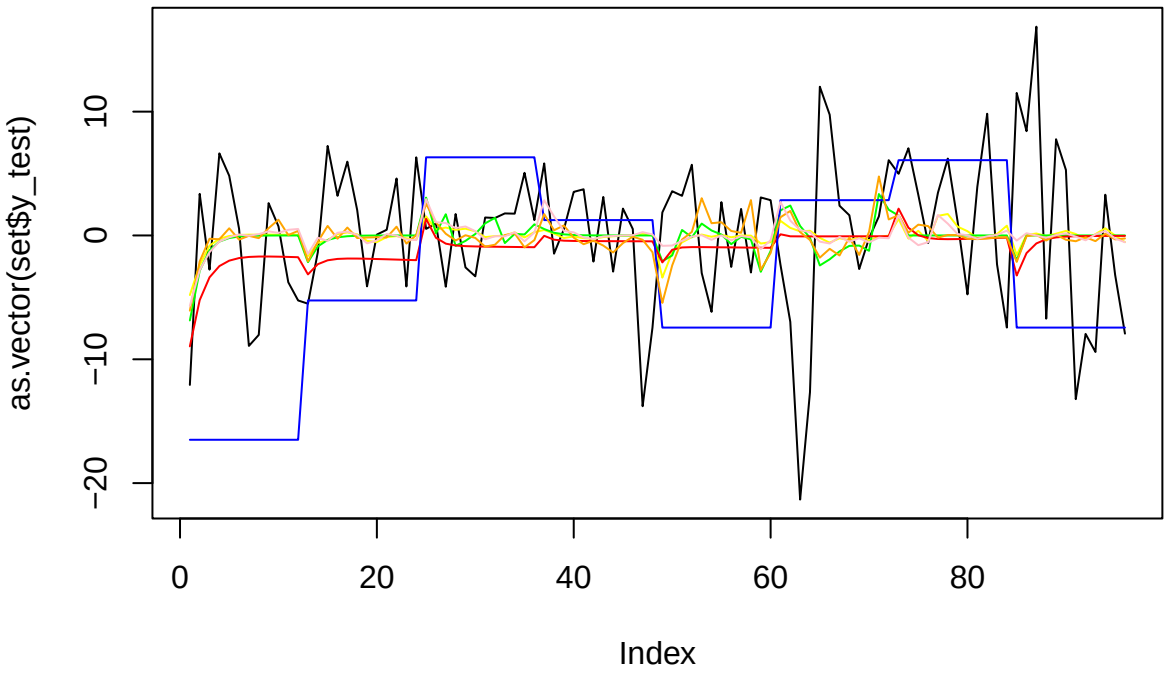
```
MSPE_FAR <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_FAR-as.vector(set$y_test))^2))
MAPE_FAR <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_FAR-as.vector(set$y_test)))
print(paste("MSFE for FAR =", MSPE_FAR))
```

```
## [1] "MSFE for FAR = 6.10457814879958"
```

```
print(paste("MAPE for FAR =", MAPE_FAR))
```

```
## [1] "MAPE for FAR = 4.7428440194226"
```

```
plot(as.vector(set$y_test),type="l")
lines(y_hat_FAR,col="yellow")
lines(y_hat_ARMA,col="green")
lines(y_hat_tvAR,col="red")
lines(y_hat_RW,col="blue")
lines(y_hat_ARDL,col="orange")
lines(y_hat_tvVAR,col="pink")
```




```
#lines(y_hat_GPR,col="purple")
```

```
#library(kableExtra)
library(xtable)
Methods_table <- c("RW", "ARMA", "ARDL", "VAR", "tvAR", "tvVAR","FAR")
MSE_table <- round(c(MSPE_RW, MSPE_ARMA, MSPE_ARDL, MSPE_VAR, MSPE_tvAR,MSPE_tvVAR,MSPE_FAR),2)
MAPE_table <- round(c(MAPE_RW, MAPE_ARMA, MAPE_ARDL, MAPE_VAR, MAPE_tvAR,MAPE_tvVAR,MAPE_FAR),2)

# Create the dataframe
df_results <- data.frame(Method = Methods_table, MSPE = MSE_table, MAPE = MAPE_table)
df_results
```

```
##   Method MSPE MAPE
## 1     RW 9.62 7.57
## 2   ARMA 6.24 4.85
## 3   ARDL 6.19 4.88
## 4    VAR 6.11 4.72
## 5   tvAR 6.23 4.91
## 6  tvVAR 6.09 4.73
## 7    FAR 6.10 4.74
```

```
#xtable(df_results)
```

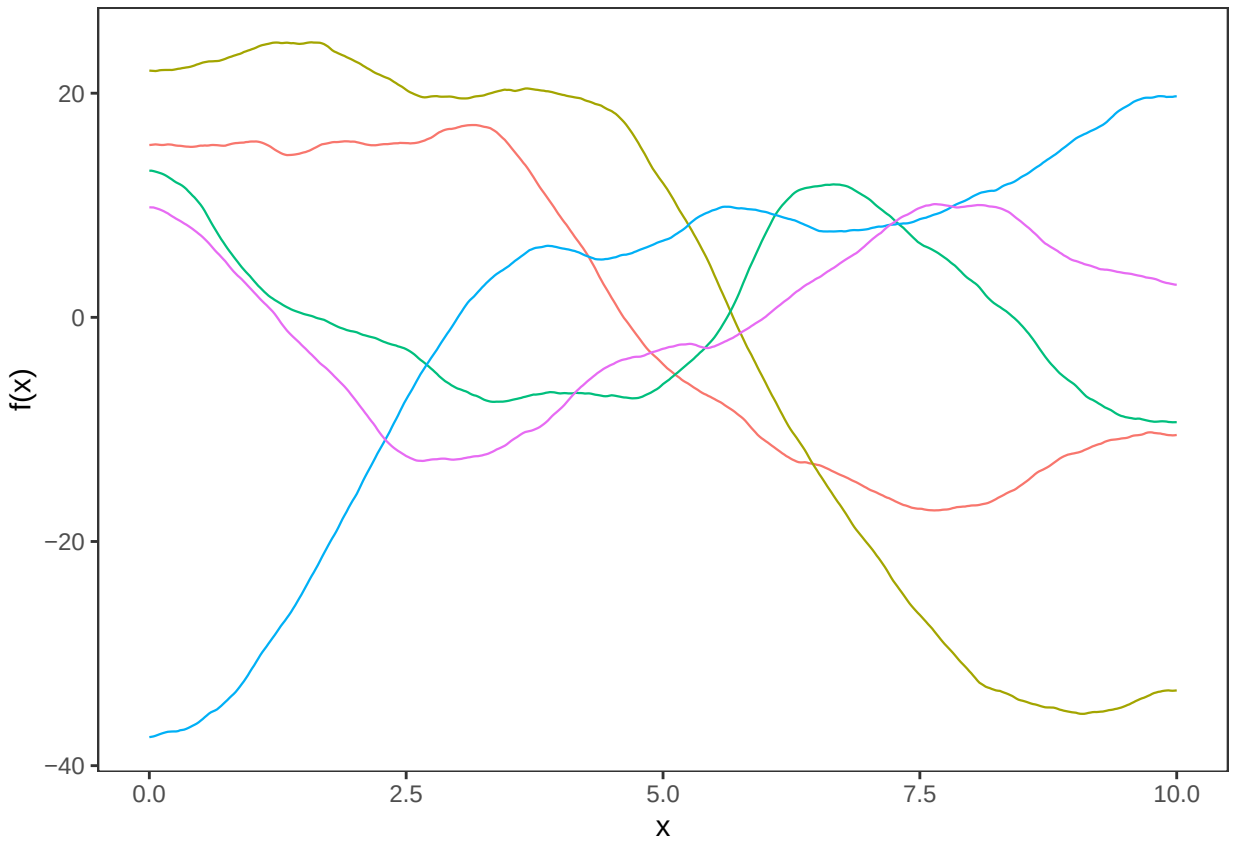
```
dm.test((y_hat_ARMA-as.vector(set$y_test)),(y_hat_FAR-as.vector(set$y_test)),h=12, alternative="greater
```

```
##
##  Diebold-Mariano Test
##
## data:  (y_hat_ARMA - as.vector(set$y_test))(y_hat_FAR - as.vector(set$y_test))
## DM = 0.97981, Forecast horizon = 12, Loss function power = 1, p-value =
## 0.1648
## alternative hypothesis: greater
```

Gaussian Process Regression

BM kernel

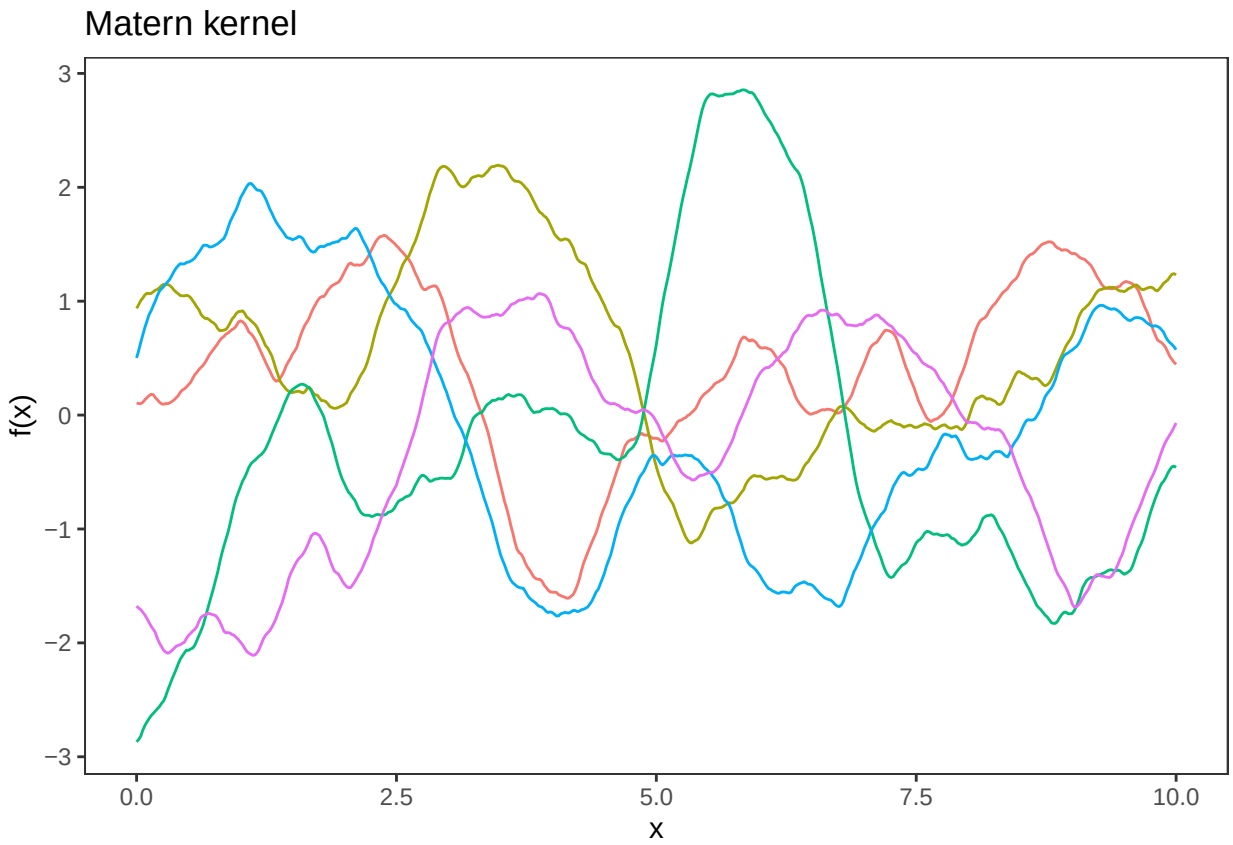
```
library(ggplot2)
source("Kernels.R")
x <- seq(0, 10, length.out = 501)  # x-coordinates
N <- 5  # no. of draws
Y <- draw_samples(x, N, kernel_fn = bm_kernel ,centred=TRUE,squared=TRUE)
df <- data.frame(x = rep(x, N), y = as.vector(Y), group = rep(1:N, each = length(x)))
# Plot the data
plot1<-ggplot(df, aes(x = x, y = y, group = group, color = factor(group))) +
  geom_line(size = 0.4) +
  labs(x = "x", y = "f(x)")+ #, title = "Brownian motion kernel")+
  theme_bw()+
  theme(legend.position = "none",panel.grid.major = element_blank(),
        panel.grid.minor = element_blank())
ggsave("Brownian motion kernel paths (centred+squared).png", plot = plot1, width = 4, height = 4)
plot1
```




```
  #scale_color_manual(values = col_list)
```

Matern Kernel

```
Y <- draw_samples(x, N, kernel_fn = matern_kernel,nu = 1.5, sigma = 1, l = 1)
df <- data.frame(x = rep(x, N), y = as.vector(Y), group = rep(1:N, each = length(x)))
# Plot the data
ggplot(df, aes(x = x, y = y, group = group, color = factor(group))) +
  geom_line(size = 0.5) +
  labs(x = "x", y = "f(x)", title = "Matern kernel")+
  theme_bw()+
  theme(legend.position = "none",panel.grid.major = element_blank(),
        panel.grid.minor = element_blank())
```

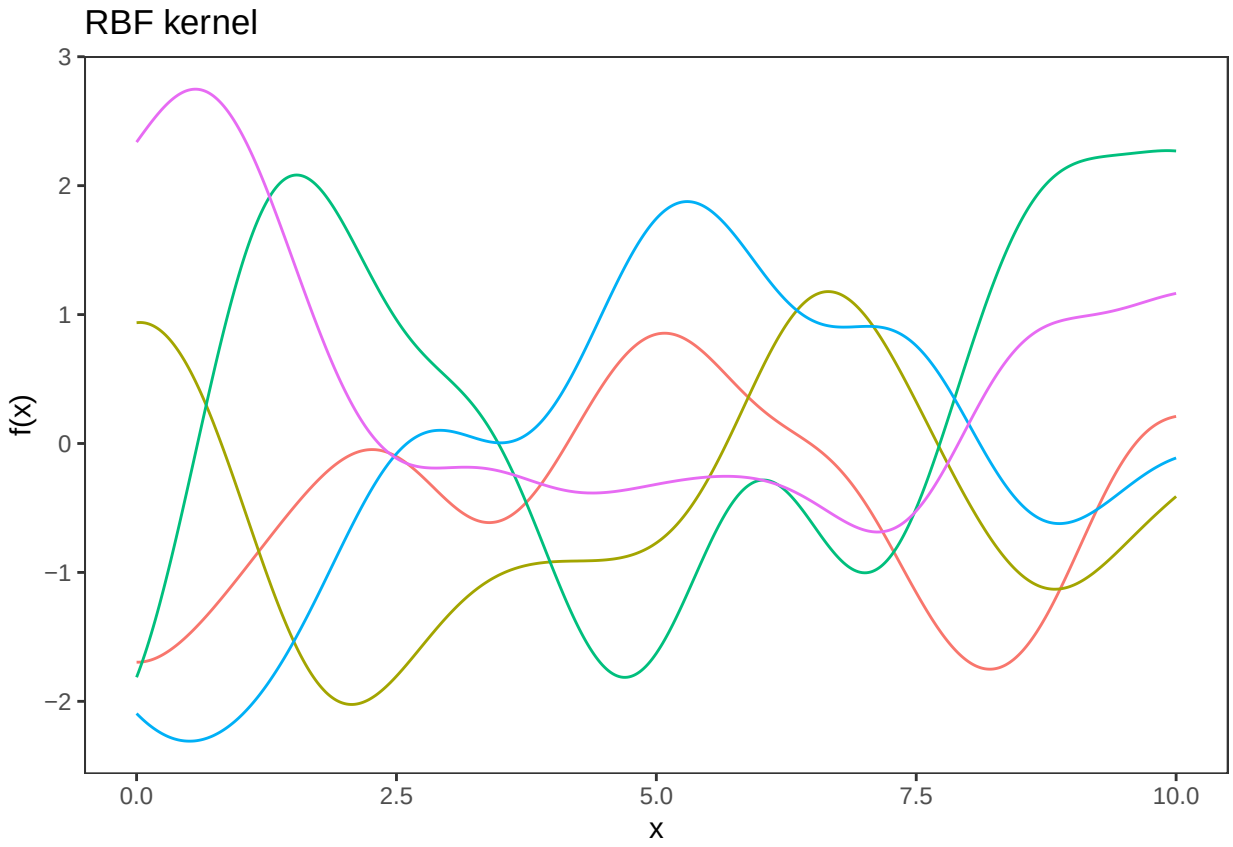



```
  #scale_color_manual(values = col_list)
```

RBF Kernel

```
Y <- draw_samples(x, N, kernel_fn = se_kernel,sigma = 1, length=1)
df <- data.frame(x = rep(x, N), y = as.vector(Y), group = rep(1:N, each = length(x)))
# Plot the data
ggplot(df, aes(x = x, y = y, group = group, color = factor(group))) +
  geom_line(size = 0.5) +
  labs(x = "x", y = "f(x)", title = "RBF kernel")+
  theme_bw()+
```

```
  theme(legend.position = "none",panel.grid.major = element_blank(),
        panel.grid.minor = element_blank())
```



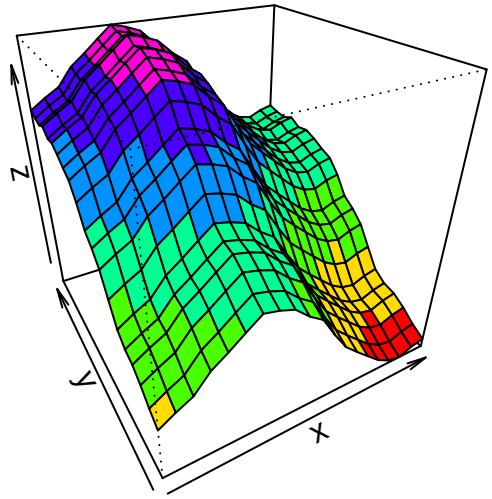

```
  #scale_color_manual(values = col_list)
```

```
source("Kernels.R")
library(mvtnorm)
library(RColorBrewer)
library(plgp)
```

```
## Loading required package: tgp
```

```
levelpersp <- function(x, y, z, colors=topo.colors, ...) {
  ## getting the value of the midpoint
  zz <- (z[-1,-1] + z[-1,-ncol(z)] + z[-nrow(z),-1] + z[-nrow(z),-ncol(z)])/4
  ## calculating the breaks
  breaks <- hist(zz, plot=FALSE)$breaks
  ## cutting up zz
  cols <- colors(length(breaks)-1)
  zzz <- cut(zz, breaks=breaks, labels=cols)
  ## plotting
  persp(x, y, z, col=as.character(zzz), ...)
  ## return breaks and colors for the legend
  list(breaks=breaks, colors=cols)
}
```

```r
# Define the range and number of points for x1 and x2
n_points <- 20
x1 <- seq(0, 3, length.out = n_points)
x2 <- seq(0, 3, length.out = n_points)

# Sample from the bivariate normal distribution
N <- 1  # Number of samples
Y <- draw_samples_3D(x1, x2, N, seed = 125, kernel_fn = bm_kernel, centred = TRUE, squared = TRUE)

# Create the 3D plots with colors based on z-values using persp
#par(mfrow = c(1, 3))
levelpersp(x1, x2, (matrix(Y, ncol = n_points)), theta = -30, phi = 30, colors = rainbow)
```




```
## $breaks
## [1] -20 -15 -10  -5   0   5  10  15
##
## $colors
## [1] "#FF0000" "#FFDB00" "#49FF00" "#00FF92" "#0092FF" "#4900FF" "#FF00DB"
```

```r
#levelpersp(x1, x2, (matrix(Y[2, ], ncol = n_points)), theta = -30, phi = 30, colors = topo.colors)
#levelpersp(x1, x2, (matrix(Y[3, ], ncol = n_points)), theta = -30, phi = 30, colors = topo.colors)
```

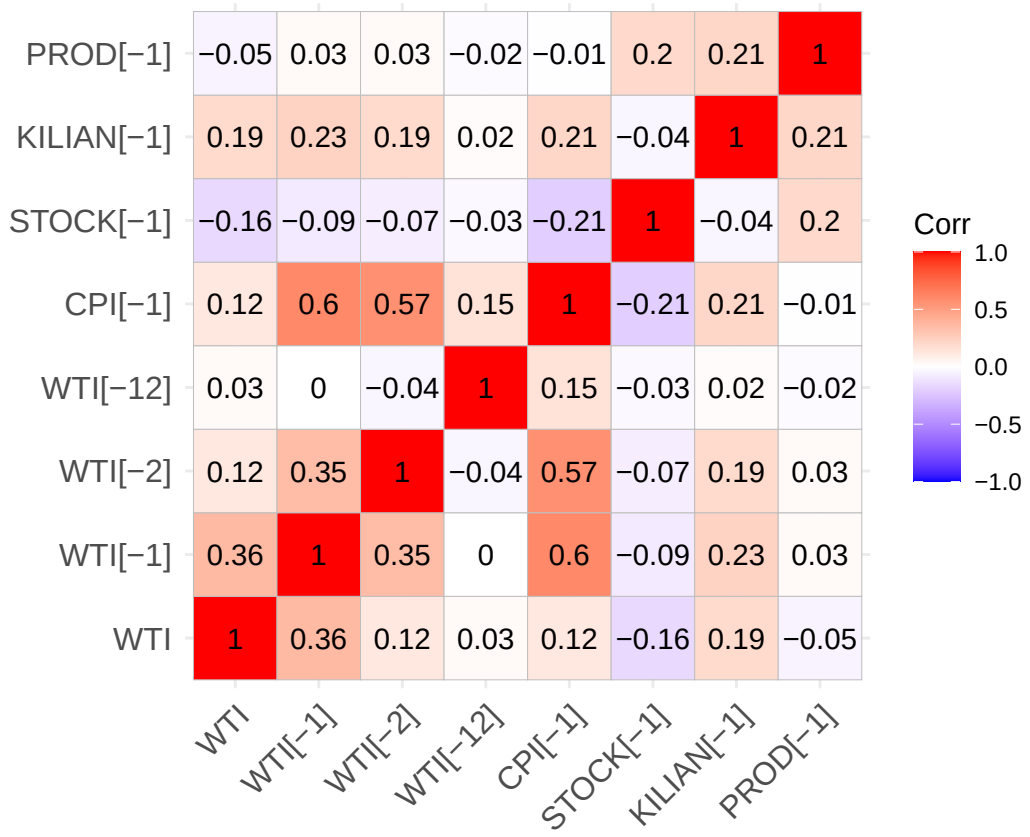
```r
library(corrplot)
```

```
## corrplot 0.92 loaded
```

```r
source("Data-preprocessing.R")
```

```
## New names:
## * `` -> `...2`

## New names:
## New names:
## * `` -> `...1`
## * `` -> `...2`
```

```r
X_corr<-as.data.frame(cbind(y_ts, y_lag1, y_lag2, y_lag12, cpi_lag1,delta_stock_lag1, kilian_lag1,prod_l
colnames(X_corr) <- c("WTI", "WTI[-1]","WTI[-2]", "WTI[-12]", "CPI[-1]", "STOCK[-1]","KILIAN[-1]", "PRO
# Compute the correlation matrix (replace 'data' with your actual dataset)
correlation_matrix <- cor(X_corr)
library(ggcorrplot)
# Create a fancy correlation plot
#corrplot(correlation_matrix)
 ggcorrplot(t(correlation_matrix),
           hc.order = FALSE,
           #type = "upper",
           lab = TRUE)
```




```r
# library(PerformanceAnalytics)
# chart.Correlation(correlation_matrix)
#ggpairs(X_corr)
# corrplot(correlation_matrix, method = "color", #type = "upper",
#          tl.cex = 0.8, tl.col = "black", tl.srt = 45,
#          #col = colorRampPalette(c("blue", "white", "red"))(100),
#          addCoef.col = "black", number.cex = 0.7)
```

Gaussian Process Regression implementation

```r
# print(fit$summary())
# library(shinystan)
```

```r
# launch_shinystan(fit)
```

```r
# Fit the model
library(ggplot2)
library(plyr)
library(cmdstanr)
library(rstan)
N<-length(set$y_train)
mod = cmdstan_model("MCMC pred.stan",include_paths = "~/Documents/LSE/Dissertation/Code/ANOVA-kernel/")
y_stan<-as.vector(set$y_train)
#data=list(N=N,K_gram1=K_gram(set$X_train[,1],kernel_fn = bm_kernel_L2,centred = TRUE,squared = TRUE),
data_MCMC<-list(N=length(set$y_train),
          x1=as.vector(set$X_train[,1]),
          x2=as.vector(set$X_train[,2]),
          y=as.vector(set$y_train),
          M=1,
          x_new1=as.matrix(1),
          x_new2=as.matrix(1)
          )
fit = mod$sample(
  data = data_MCMC,
  seed = 123,
  iter_warmup = 200,
  iter_sampling = 300,
  save_warmup = TRUE,
  chains = 2,
  parallel_chains = 2,
  refresh = 10
)
```

```
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.07451e+24, but A[2,1] = 1.0745

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like cova

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.76399e+26, but A[2,1] = 1.7639

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like cova
```

```
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 3.3645e+08, but A[2,1] = 3.3645e+

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 7.09232e+118, but A[2,1] = 7.0923

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.81707e+32, but A[2,1] = 1.8170
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.41364e+11, but A[2,1] = 1.4136
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,19] = -6.83085e+06, but A[19,1] = -6.8
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[10,71] = -5.24597e+06, but A[71,10] = -5
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
```

```
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.14789e+135, but A[2,1] = 1.1478

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[19,137] = 7.57908e+06, but A[137,19] = 7

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 2.533e+32, but A[2,1] = 2.533e+31

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)
```

```
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,11] = 2.24709e+07, but A[11,1] = 2.247

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 3.15281e+08, but A[2,1] = 3.1528

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 6.69044e+28, but A[2,1] = 6.6904

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
```

```
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
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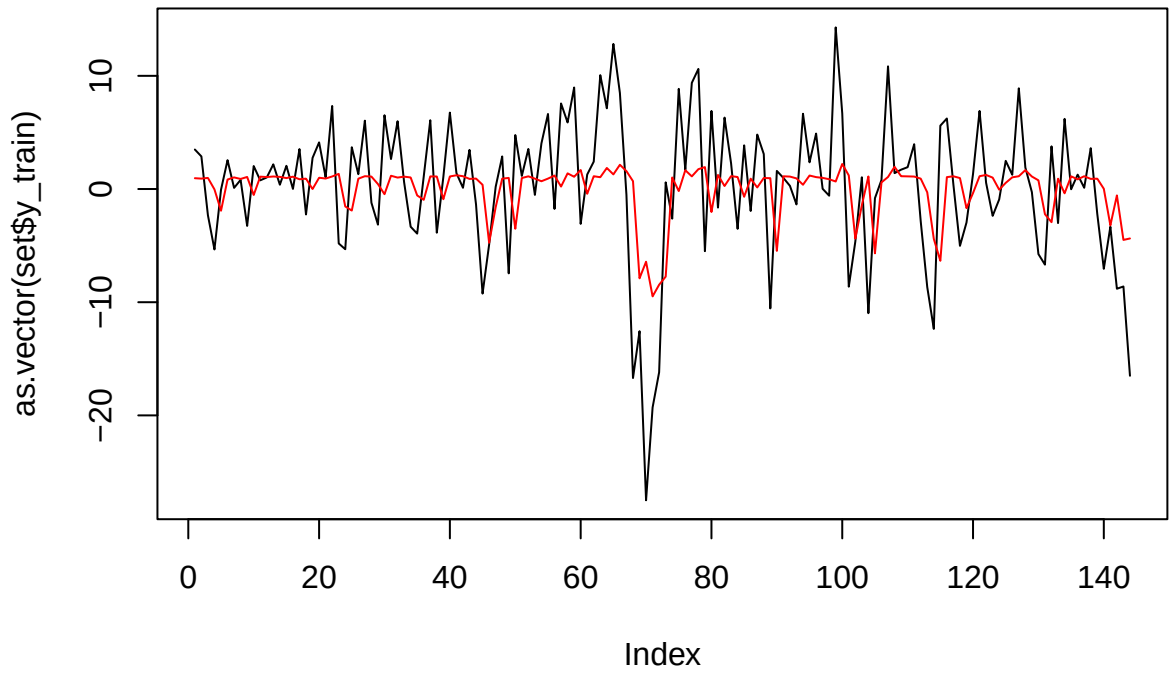
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
```

```
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 finished in 7.9 seconds.
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 8.5 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 8.2 seconds.
## Total execution time: 8.6 seconds.
```

```
impact_1<-as.vector(fit$summary(variables = "f_one")$mean)
impact_2<-as.vector(fit$summary(variables = "f_two")$mean)
plot(as.vector(set$y_train),type="l")
lines(impact_1, col="red")
```




```
#lines(impact_2)
#lines(impact_1+impact_2,col="green")
```

```
#time_idx<-as.Date(time(set$y_test))
#y_hat_LSTM_1_step<-as.numeric(read.csv("y_hat_LSTM_1_step.csv",header=FALSE))
#y_hat_ANN_1_step<-as.numeric(read.csv("y_hat_ANN_1_step.csv",header=FALSE))
# results_data_1_step<-as.data.frame(cbind(time_idx,as.vector(set$y_test), y_hat_ARMA,y_hat_GPR_1_step,
# ggplot(data =results_data_1_step,aes(x = as.Date(time_idx)))+
#   geom_line(aes(y = V2),colour="black")+#,colour="black"
#   geom_line(aes(y = y_hat_ARMA,colour="ARMA"),alpha=0.7)+#,colour="red"
```

```
#   #geom_line(aes(y = y_hat_GPR_1_step,colour="GPR"),alpha=0.7)+#,colour="blue"
#   geom_line(aes(y = y_hat_FAR,colour="FAR"),alpha=0.7)+#,colour="green"
#   geom_line(aes(y = y_hat_ANN_1_step,colour="ANN"),alpha=0.7)+#,colour="ANN"
#   labs(x = NULL,
#        y = "WTI",
#        color = NULL
#        #title = "WTI Crude Oil Prices from 2003-2023",
#        #subtitle = "From 1987-2021, comparing the top 1% and bottom 50% \n(National recessions shaded
#        #caption = "Source: Federal Reserve Economic Data"
#        ) +
#   scale_color_manual(values = c( "ARMA" = "red", "FAR" = "green", "ANN" = "blue"),
#                      breaks = c( "ARMA", "FAR", "ANN"),
#                      labels = c( "ARMA", "FAR", "ANN")) +
#   theme_minimal()+
#   theme(legend.position = "bottom")
```

```
#mu_wti<-as.vector(fit$summary(variables = "mu_predicted")$mean)
#t_wti<-seq(-28,17,0.5)
#mu_kilian<-as.vector(fit$summary(variables = "mu_predicted")$mean)
#t_kilian<-seq(-100,85,0.5)
#mu_delta_stock<-as.vector(fit$summary(variables = "mu_predicted")$mean)
#t_delta_stock<-seq(-90,84,0.5)
#plot(delta_stock_lag1,y)
#lines(seq(-90,84,0.5),as.vector(fit$summary(variables = "mu_predicted")$mean), col="red")
#plot(kilian_lag1,y, col="red")
#points(kilian_lag1,y-impact_1-impact_3-impact_4-impact_5-impact_0)
#lines(t_kilian,mu_kilian)
# library(ggplot2)
#
# # Create a data frame for your data
# data_123 <- data.frame(
#   delta_stock_lag1 = delta_stock_lag1,
#   y = y,
#   impact_adjusted = y - impact_1 - impact_2 - impact_4 - impact_5 - impact_0
# )
# data_1234<-data.frame(
#    t_delta_stock = t_delta_stock,
#   mu_delta_stock = mu_delta_stock
# )
#
# # Create the ggplot with layers
# gg<-ggplot() +
#   geom_point(data = data_123, aes(x = delta_stock_lag1, y = y), color = "chartreuse", size=1) +
#   geom_point(data = data_123, aes(x = delta_stock_lag1, y = impact_adjusted), color = "blue3", size=1
#   geom_line(data = data_1234, aes(x = t_delta_stock, y = mu_delta_stock), color = "black") +
#   labs(
#     #title = "Kilian Lag Plot",
#     x = "STOCK[-1]",
#     y = "WTI"
#   ) +
#   theme_minimal() +
#   theme(
#     plot.title = element_text(size = 16, hjust = 0.5),
```

```
#     legend.position = "top",
#     aspect.ratio = 1
#   )
# #ggsave("Kilian.png",plot=gg, path="plots/",width = 10, height=10, units="cm")
# print(gg)
```

```
#impact_0<-as.vector(fit$summary(variables = "f_zero")$mean)
#impact_1<-as.vector(fit$summary(variables = "f_one")$mean)
#impact_2<-as.vector(fit$summary(variables = "f_two")$mean)
#impact_3<-as.vector(fit$summary(variables = "f_three")$mean)
#impact_4<-as.vector(fit$summary(variables = "f_four")$mean)
#impact_5<-as.vector(fit$summary(variables = "f_five")$mean)
#total<-as.vector(fit$summary(variables = "f")$mean)
#time_idx1<-as.Date(time(y_ts))
# ANOVA_data<-as.data.frame(cbind(time_idx1,impact_0,impact_1,impact_2,impact_3,impact_4,impact_5,y))[6
# ggplot(data =ANOVA_data,aes(x = as.Date(time_idx1)))+
#   geom_line(aes(y = y),colour="black")+#,colour="black"
#   geom_line(aes(y = impact_1,colour="WTI[-1]"),alpha=0.7)+#,colour="red"
#   geom_line(aes(y = impact_2,colour="KILIAN[-1]"),alpha=0.7)+#,colour="green"
#   geom_line(aes(y = impact_3,colour="STOCK[-1]"),alpha=0.7)+#,colour="ANN"
#   geom_line(aes(y = (impact_0+impact_4+impact_5),colour="CONST+CPI[-1]+PROD[-1]"),alpha=0.7)+
#   geom_line(aes(y = (impact_1+impact_2+impact_3),colour="WTI[-1]+KILIAN[-1]+STOCK[-1]"))+
#   labs(x = NULL,
#        y = "WTI",
#        color = NULL
#        #title = "WTI Crude Oil Prices from 2003-2023",
#        #subtitle = "From 1987-2021, comparing the top 1% and bottom 50% \n(National recessions shaded
#        #caption = "Source: Federal Reserve Economic Data"
#        ) +
#   scale_color_manual(values = c( "WTI[-1]" = "darkblue", "KILIAN[-1]" = "royalblue", "STOCK[-1]" = "l
#                      breaks = c( "WTI[-1]", "KILIAN[-1]", "STOCK[-1]","CONST+CPI[-1]+PROD[-1]","WTI[-
#                      labels = c( "WTI[-1]", "KILIAN[-1]", "STOCK[-1]","REST","TOTAL")) +
#   theme_minimal()+
#   theme(legend.position = "bottom",
#     plot.title = element_text(size = 16, hjust = 0.5),
#     aspect.ratio = 1
#   )
```

```
# uncertain_data1<-as.data.frame(cbind(time_idx,y_hat_ARMA,lower_ARMA,upper_ARMA,set$y_test))[37:95,]
# ggplot(data =uncertain_data1,aes(x = as.Date(time_idx)))+
#   geom_ribbon(aes(ymin = lower_ARMA, ymax = upper_ARMA), fill = 'grey90') +
#   geom_line(aes(y = set$y_test[37:95]),colour="black")+
#   geom_line(aes(y = y_hat_ARMA),colour="red")+#,colour="red"
#   labs(x = NULL,
#        y = "WTI",
#        color = NULL
#        ) +
#   theme_minimal()+
#   theme(
#     aspect.ratio = 1
#   )
```

```
# uncertain_data<-as.data.frame(cbind(time_idx,y_hat_GPR,lower_GPR,upper_GPR,set$y_test))[37:95,]
# ggplot(data =uncertain_data,aes(x = as.Date(time_idx)))+
#   geom_ribbon(aes(ymin = lower_GPR, ymax = upper_GPR), fill = 'grey90') +
#   geom_line(aes(y = set$y_test[37:95]),colour="black")+
#   geom_line(aes(y = y_hat_GPR),colour="blue")+#,colour="red"
#   labs(x = NULL,
#        y = "WTI",
#        color = NULL
#        ) +
#   theme_minimal()+
#   theme(
#     aspect.ratio = 1
#   )
```

```
# Fit the model
library(ggplot2)
library(plyr)
library(cmdstanr)
library(rstan)
step <- 12
R <- as.integer(length(set$y_test)/step)
y_hat_GPR <- c()
lower_GPR <- c()
upper_GPR <- c()
T1 <- dim(set$X_train)[1]+dim(set$X_test)[1]
T <- T1-R*step
X_lag1_ts<-cbind(y_lag12,kilian_lag12,delta_stock_lag12,cpi_lag12, prod_lag12,y_lag1)#kilian_lag1
#X_ts<-cbind(y, cpi, kilian, delta_stock, prod)
for (i in 1:R){
    y_train <- window(y_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    X_train <- window(X_lag1_ts, start = c(2003,(1+(i-1)*step)), end = c(2003,(T+step*(i-1))))
    X_test <- window(X_lag1_ts, start = c(2003,(T+1+step*(i-1))), end = c(2003,(T+step*(i))))
    data_MCMC<-list(N=length(y_train),
          x1=as.vector(X_train[,1]), #lag1
          x2=as.vector(X_train[,2]), #cpi
          x3=as.vector(X_train[,3]), #kilian
          x4=as.vector(X_train[,4]), #delta stock
          x5=as.vector(X_train[,5]), #prod
          x6=as.vector(X_train[,6]), #y_lag2
          y=as.vector(y_train),
          M=step,
          x_new1=as.matrix(X_test[,1]),
          x_new2=as.matrix(X_test[,2]),
          x_new3=as.matrix(X_test[,3]),
          x_new4=as.matrix(X_test[,4]),
          x_new5=as.matrix(X_test[,5]),
          x_new6=as.matrix(X_test[,6])
          )
    mod = cmdstan_model("MCMC.stan",include_paths = "~/Documents/LSE/Dissertation/Code/ANOVA-kernel/")
    fit <- mod$sample(
            data = data_MCMC,
            seed = 123,
            iter_warmup = 200,
```

```
            iter_sampling = 300,
            save_warmup = TRUE,
            chains = 2,
            parallel_chains = 2,
            refresh = 10
            )
    y_pred <- as.vector(fit$summary(variables = c("mu_predicted"))$mean)
    sig<-fit$summary(variables = c("sigma"))$mean
    diag_cov <- diag(matrix(fit$summary(variables = c("var_predicted"))$mean,nrow=step,ncol=step))
    lower_GPR<-c(lower_GPR, y_pred-1.96*sqrt(diag_cov+sig^2))
    upper_GPR<-c(upper_GPR, y_pred+1.96*sqrt(diag_cov+sig^2))
    y_hat_GPR <- c(y_hat_GPR,y_pred)
    print(i)
}
```

```
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.73223e+35, but A[2,1] = 1.7322

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 5.62648e+37, but A[2,1] = 5.6264

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.78837e+11, but A[2,1] = 1.7883

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1
```

```
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[82,86] = -5.93634e+06, but A[86,82] = -5

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 6.13117e+150, but A[2,1] = 6.131

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 3.17351e+40, but A[2,1] = 3.1735

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 2.84851e+13, but A[2,1] = 2.8485
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,41] = -1.07897e+07, but A[41,1] = -1.0
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.89677e+09, but A[2,1] = 1.8967
```

```
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 4.95589e+32, but A[2,1] = 4.9558

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 7.96324e+21, but A[2,1] = 7.9632

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1
```

```
## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[2,67] = -97321.3, but A[67,2] = -97321.3

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 1 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 2 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
```

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## Chain 1 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 8.6 seconds.
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 1 finished in 9.1 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 8.9 seconds.
## Total execution time: 9.2 seconds.
##
## [1] 1
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,3] = -4.23895e+33, but A[3,1] = -4.238

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 7.26075e+36, but A[2,1] = 7.26075

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,3] = -3.07203e+10, but A[3,1] = -3.071

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 7.01645e+145, but A[2,1] = 7.016
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.6904e+39, but A[2,1] = 1.6904e
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,3] = 1.0729e+13, but A[3,1] = 1.0729e
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[2,19] = -4.4983e+06, but A[19,2] = -4.4
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 2
```

```
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 7.20949e+83, but A[2,1] = 7.2094

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.38397e+09, but A[2,1] = 1.3839

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,3] = -9.24608e+46, but A[3,1] = -9.246
```

```
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like cova

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1

## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[2,19] = -4.25692e+06, but A[19,2] = -4.

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like cova

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1

## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
```

```
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 8.6 seconds.
## Chain 1 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 1 finished in 10.7 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 9.6 seconds.
## Total execution time: 10.8 seconds.
##
## [1] 2
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th
```

```
## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 3.48441e+36, but A[2,1] = 3.4844
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 4.12994e+38, but A[2,1] = 4.1299
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,3] = -7.20176e+10, but A[3,1] = -7.20
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 1
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[58,74] = 6.40993e+06, but A[74,58] = 6.4
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m
## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
```

```
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.16448e+156, but A[2,1] = 1.164
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.34414e+42, but A[2,1] = 1.3441
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.46646e+14, but A[2,1] = 1.4664
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,4] = -1.84947e+07, but A[4,1] = -1.849
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[64,97] = 4.96968e+06, but A[97,64] = 4.9
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.32163e+25, but A[2,1] = 1.3216
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2

## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)
```

```
## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.49581e+08, but A[2,1] = 1.4958

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,4] = -1.92002e+10, but A[4,1] = -1.920

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 1 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 1 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 1 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
```

```
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 1 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 2 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 2 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 finished in 8.8 seconds.
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
```

```
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 10.2 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 9.5 seconds.
## Total execution time: 10.2 seconds.
##
## [1] 3
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,3] = -6.63521e+44, but A[3,1] = -6.635

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.51479e+47, but A[2,1] = -1.514

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.60488e+13, but A[2,1] = -1.604

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,5] = 1.67898e+07, but A[5,1] = 1.67898

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -inf, but A[2,1] = -inf (in '/var

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -inf, but A[2,1] = -inf (in '/var

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -6.21968e+153, but A[2,1] = -6.21

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.75349e+41, but A[2,1] = -1.753

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -4.11051e+13, but A[2,1] = -4.110
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,5] = 3.31713e+07, but A[5,1] = 3.31713
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[5,110] = 6.47991e+06, but A[110,5] = 6.4
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = nan, but A[2,1] = nan (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.17852e+79, but A[2,1] = -1.178
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
```

```
## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 8.76106e+12, but A[2,1] = 8.7610

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like cova

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1

## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[9,46] = -6.48615e+06, but A[46,9] = -6.4

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like cova

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 2
```

```
## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 1 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 1 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 1 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 2 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 1 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 1 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 2 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
```

```
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 finished in 9.1 seconds.
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 9.6 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 9.4 seconds.
## Total execution time: 9.7 seconds.
##
## [1] 4
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.98599e+48, but A[2,1] = -1.985

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -4.76292e+50, but A[2,1] = -4.763

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.14133e+15, but A[2,1] = -1.14

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,3] = -7.23754e+06, but A[3,1] = -7.23

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 1 Exception: cholesky_decompose: Matrix m is not positive definite (in '/var/folders/v7/0072jt

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -inf, but A[2,1] = -inf (in '/var

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of th

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -inf, but A[2,1] = -inf (in '/var

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or m
```

```
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.63006e+173, but A[2,1] = -1.63
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -3.61757e+46, but A[2,1] = -3.617
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -2.68179e+15, but A[2,1] = -2.681
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -2.55499e+07, but A[2,1] = -2.554
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[34,40] = 7.23672e+06, but A[40,34] = 7.1
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -inf, but A[2,1] = -inf (in '/var

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,3] = -6.91829e+32, but A[3,1] = -6.918

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -5.10504e+13, but A[2,1] = -5.105

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2
```

```
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -2.81213e+10, but A[2,1] = -2.81

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -8.37264e+09, but A[2,1] = -8.37

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
```

```
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
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## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
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## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
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## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
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## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
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## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 1 finished in 9.0 seconds.
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
```

```
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 9.4 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 9.2 seconds.
## Total execution time: 9.5 seconds.
##
## [1] 5
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.97021e+46, but A[2,1] = -1.97

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.30678e+48, but A[2,1] = 1.30678

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.93153e+14, but A[2,1] = -1.93

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,22] = 185347, but A[22,1] = 185347 (in

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 7.25323e+169, but A[2,1] = 7.253

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.6896e+45, but A[2,1] = 1.6896e+

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
```

```
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 3.30122e+14, but A[2,1] = 3.3012
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,9] = 6.94525e+06, but A[9,1] = 6.9452
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[3,47] = -4.36536e+06, but A[47,3] = -4.3
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = nan, but A[2,1] = nan (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.26991e+61, but A[2,1] = 1.2699
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
```

```
## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,3] = 1.0178e+23, but A[3,1] = 1.0178e+

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 2.62241e+11, but A[2,1] = 2.6224

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 2 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
```

```
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 9.2 seconds.
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 1 finished in 10.7 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 9.9 seconds.
## Total execution time: 10.9 seconds.
##
## [1] 6
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 4.64649e+21, but A[2,1] = 4.6464

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.65977e+24, but A[2,1] = 1.6597

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.16464e+08, but A[2,1] = 1.1646
```

```
## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 2.45755e+142, but A[2,1] = 2.4575

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 3.82265e+38, but A[2,1] = 3.82265

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2
```

```
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.4378e+13, but A[2,1] = 1.4378e+
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,6] = 7.59987e+06, but A[6,1] = 7.5998
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[9,103] = -4.5829e+06, but A[103,9] = -4
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 6.50894e+36, but A[2,1] = 6.5089
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
```

```
## Chain 2

## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)
## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 9.58466e+14, but A[2,1] = 9.5846

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
```

```
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 2 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 1 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 9.9 seconds.
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
```

```
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 1 finished in 11.3 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 10.6 seconds.
## Total execution time: 11.4 seconds.
##
## [1] 7
## Running MCMC with 2 parallel chains...
##
## Chain 1 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 1 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 2.05378e+22, but A[2,1] = 2.0537

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 9.62182e+24, but A[2,1] = 9.6218

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 6.80316e+08, but A[2,1] = 6.8031

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1
```

```
## Chain 2 Iteration:   1 / 500 [  0%]  (Warmup)
## Chain 2 Iteration:  10 / 500 [  2%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 1.26522e+131, but A[2,1] = 1.265

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 3.05636e+36, but A[2,1] = 3.0563

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = 2.24197e+13, but A[2,1] = 2.2419

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
```

```
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,3] = 6.32163e+06, but A[3,1] = 6.3216
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = inf, but A[2,1] = inf (in '/var/f
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the
## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,3] = 2.79449e+65, but A[3,1] = 2.7944
## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar
## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi
## Chain 2

## Chain 2 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 1 Iteration:  20 / 500 [  4%]  (Warmup)
## Chain 2 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  30 / 500 [  6%]  (Warmup)
## Chain 2 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 1 Iteration:  40 / 500 [  8%]  (Warmup)
## Chain 1 Iteration:  50 / 500 [ 10%]  (Warmup)
## Chain 2 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 1 Iteration:  60 / 500 [ 12%]  (Warmup)
## Chain 2 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 1 Iteration:  70 / 500 [ 14%]  (Warmup)
## Chain 2 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 1 Iteration:  80 / 500 [ 16%]  (Warmup)
## Chain 2 Iteration: 110 / 500 [ 22%]  (Warmup)
```

```
## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -5.9717e+16, but A[2,1] = -5.971

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -1.47526e+08, but A[2,1] = -1.475

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -6.53684e+64, but A[2,1] = -6.536

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2

## Chain 2 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 150 / 500 [ 30%]  (Warmup)
## Chain 2 Iteration: 160 / 500 [ 32%]  (Warmup)

## Chain 2 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 2 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -2.67249e+06, but A[2,1] = -2.672

## Chain 2 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 2 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 2
```

```
## Chain 2 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 1 Iteration:  90 / 500 [ 18%]  (Warmup)
## Chain 2 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 2 Iteration: 201 / 500 [ 40%]  (Sampling)
## Chain 2 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 1 Iteration: 100 / 500 [ 20%]  (Warmup)
## Chain 2 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 1 Iteration: 110 / 500 [ 22%]  (Warmup)
## Chain 2 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 2 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 2 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 120 / 500 [ 24%]  (Warmup)
## Chain 2 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 2 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 2 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 1 Iteration: 130 / 500 [ 26%]  (Warmup)
## Chain 2 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 140 / 500 [ 28%]  (Warmup)
## Chain 2 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 150 / 500 [ 30%]  (Warmup)

## Chain 1 Informational Message: The current Metropolis proposal is about to be rejected because of the

## Chain 1 Exception: cholesky_decompose: A is not symmetric. A[1,2] = -2.12377e+19, but A[2,1] = -2.123

## Chain 1 If this warning occurs sporadically, such as for highly constrained variable types like covar

## Chain 1 but if this warning occurs often then your model may be either severely ill-conditioned or mi

## Chain 1

## Chain 2 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 2 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 2 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 160 / 500 [ 32%]  (Warmup)
## Chain 2 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 170 / 500 [ 34%]  (Warmup)
## Chain 2 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 180 / 500 [ 36%]  (Warmup)
## Chain 2 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 2 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 190 / 500 [ 38%]  (Warmup)
## Chain 2 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 2 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 200 / 500 [ 40%]  (Warmup)
## Chain 1 Iteration: 201 / 500 [ 40%]  (Sampling)
```

```
## Chain 2 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 210 / 500 [ 42%]  (Sampling)
## Chain 2 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 220 / 500 [ 44%]  (Sampling)
## Chain 2 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 230 / 500 [ 46%]  (Sampling)
## Chain 2 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 240 / 500 [ 48%]  (Sampling)
## Chain 2 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 2 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 250 / 500 [ 50%]  (Sampling)
## Chain 2 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 2 finished in 8.0 seconds.
## Chain 1 Iteration: 260 / 500 [ 52%]  (Sampling)
## Chain 1 Iteration: 270 / 500 [ 54%]  (Sampling)
## Chain 1 Iteration: 280 / 500 [ 56%]  (Sampling)
## Chain 1 Iteration: 290 / 500 [ 58%]  (Sampling)
## Chain 1 Iteration: 300 / 500 [ 60%]  (Sampling)
## Chain 1 Iteration: 310 / 500 [ 62%]  (Sampling)
## Chain 1 Iteration: 320 / 500 [ 64%]  (Sampling)
## Chain 1 Iteration: 330 / 500 [ 66%]  (Sampling)
## Chain 1 Iteration: 340 / 500 [ 68%]  (Sampling)
## Chain 1 Iteration: 350 / 500 [ 70%]  (Sampling)
## Chain 1 Iteration: 360 / 500 [ 72%]  (Sampling)
## Chain 1 Iteration: 370 / 500 [ 74%]  (Sampling)
## Chain 1 Iteration: 380 / 500 [ 76%]  (Sampling)
## Chain 1 Iteration: 390 / 500 [ 78%]  (Sampling)
## Chain 1 Iteration: 400 / 500 [ 80%]  (Sampling)
## Chain 1 Iteration: 410 / 500 [ 82%]  (Sampling)
## Chain 1 Iteration: 420 / 500 [ 84%]  (Sampling)
## Chain 1 Iteration: 430 / 500 [ 86%]  (Sampling)
## Chain 1 Iteration: 440 / 500 [ 88%]  (Sampling)
## Chain 1 Iteration: 450 / 500 [ 90%]  (Sampling)
## Chain 1 Iteration: 460 / 500 [ 92%]  (Sampling)
## Chain 1 Iteration: 470 / 500 [ 94%]  (Sampling)
## Chain 1 Iteration: 480 / 500 [ 96%]  (Sampling)
## Chain 1 Iteration: 490 / 500 [ 98%]  (Sampling)
## Chain 1 Iteration: 500 / 500 [100%]  (Sampling)
## Chain 1 finished in 10.8 seconds.
##
## Both chains finished successfully.
## Mean chain execution time: 9.4 seconds.
## Total execution time: 10.9 seconds.
##
## [1] 8
```

```
MSPE_GPR <- sqrt(1/(dim(set$X_test)[1])*sum((y_hat_GPR-as.vector(set$y_test))^2))
MAPE_GPR <- 1/(dim(set$X_test)[1])*sum(abs(y_hat_GPR-as.vector(set$y_test)))
print(paste("MSFE for GPR =", MSPE_GPR))
```

```
## [1] "MSFE for GPR = 6.18999213546214"
```

```r
print(paste("MAPE for GPR =", MAPE_GPR))
```

```
## [1] "MAPE for GPR = 4.79852656478769"
```

```r
library(bridgesampling)
library(rstan)
# cores <- 4
# options(mc.cores = cores)
# mod_bridge<-stan_model("MCMC test.stan")
# stanfit <- bridge <- vector("list", 3)
# for (k in 1:3) {
#   stanfit[[k]] <- sampling(mod_bridge,
#    data = list(N=N,
#           K_gram1=K_gram1,
#           K_gram2=K_gram2,
#           y=y_stan
#           ),
#    iter = 11000, warmup = 1000, chains = 4,
#    #init = init_fun(nchains = 4, k = k, m = 1),
#    cores = cores, seed = 1)
#   bridge[[k]] <- bridge_sampler(stanfit[[k]], method = "warp3",
#    repetitions = 10, cores = cores)
# }
mod_bridge<-stan("MCMC.stan", data=data_MCMC,
          seed = 123,
  iter= 30,
  save_warmup = TRUE,
  chains = 2
          )
```

```
##
## SAMPLING FOR MODEL 'MCMC' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.001867 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 18.67 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: WARNING: No variance estimation is
## Chain 1:          performed for num_warmup < 20
## Chain 1:
## Chain 1: Iteration:  1 / 30 [  3%]  (Warmup)
## Chain 1: Iteration:  3 / 30 [ 10%]  (Warmup)
## Chain 1: Iteration:  6 / 30 [ 20%]  (Warmup)
## Chain 1: Iteration:  9 / 30 [ 30%]  (Warmup)
## Chain 1: Iteration: 12 / 30 [ 40%]  (Warmup)
## Chain 1: Iteration: 15 / 30 [ 50%]  (Warmup)
## Chain 1: Iteration: 16 / 30 [ 53%]  (Sampling)
## Chain 1: Iteration: 18 / 30 [ 60%]  (Sampling)
## Chain 1: Iteration: 21 / 30 [ 70%]  (Sampling)
## Chain 1: Iteration: 24 / 30 [ 80%]  (Sampling)
## Chain 1: Iteration: 27 / 30 [ 90%]  (Sampling)
## Chain 1: Iteration: 30 / 30 [100%]  (Sampling)
```

```
## Chain 1:
## Chain 1:  Elapsed Time: 0.722791 seconds (Warm-up)
## Chain 1:                1.01519 seconds (Sampling)
## Chain 1:                1.73798 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'MCMC' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 0.001106 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 11.06 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: WARNING: No variance estimation is
## Chain 2:          performed for num_warmup < 20
## Chain 2:
## Chain 2: Iteration:  1 / 30 [  3%]  (Warmup)
## Chain 2: Iteration:  3 / 30 [ 10%]  (Warmup)
## Chain 2: Iteration:  6 / 30 [ 20%]  (Warmup)
## Chain 2: Iteration:  9 / 30 [ 30%]  (Warmup)
## Chain 2: Iteration: 12 / 30 [ 40%]  (Warmup)
## Chain 2: Iteration: 15 / 30 [ 50%]  (Warmup)
## Chain 2: Iteration: 16 / 30 [ 53%]  (Sampling)
## Chain 2: Iteration: 18 / 30 [ 60%]  (Sampling)
## Chain 2: Iteration: 21 / 30 [ 70%]  (Sampling)
## Chain 2: Iteration: 24 / 30 [ 80%]  (Sampling)
## Chain 2: Iteration: 27 / 30 [ 90%]  (Sampling)
## Chain 2: Iteration: 30 / 30 [100%]  (Sampling)
## Chain 2:
## Chain 2:  Elapsed Time: 0.144438 seconds (Warm-up)
## Chain 2:                0.550138 seconds (Sampling)
## Chain 2:                0.694576 seconds (Total)
## Chain 2:

## Warning: There were 1 chains where the estimated Bayesian Fraction of Missing Information was low. Se
## https://mc-stan.org/misc/warnings.html#bfmi-low

## Warning: Examine the pairs() plot to diagnose sampling problems

## Warning: The largest R-hat is 1.72, indicating chains have not mixed.
## Running the chains for more iterations may help. See
## https://mc-stan.org/misc/warnings.html#r-hat

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

## Warning: Tail Effective Samples Size (ESS) is too low, indicating posterior variances and tail quanti
## Running the chains for more iterations may help. See
## https://mc-stan.org/misc/warnings.html#tail-ess
```

```r
bridge_sampler(mod_bridge)
```

```
## Iteration: 1
## Iteration: 2
## Iteration: 3
## Iteration: 4
## Iteration: 5
## Iteration: 6
## Iteration: 7
## Iteration: 8
## Iteration: 9
## Iteration: 10
## Iteration: 11
## Iteration: 12
## Iteration: 13
## Iteration: 14
## Iteration: 15
## Iteration: 16
## Iteration: 17
## Iteration: 18
## Iteration: 19
```

```
## Bridge sampling estimate of the log marginal likelihood: -475.2413
## Estimate obtained in 19 iteration(s) via method "normal".
```

```r
library(shinystan)
```

```
## Loading required package: shiny
```

```
##
## This is shinystan version 2.6.0
```

```r
launch_shinystan(fit)
```

```
##
## Launching ShinyStan interface... for large models this  may take some time.
```

```
##
## Listening on http://127.0.0.1:3584
```

```r
fit$summary(variables = c("lp__"))$mean
```

```
## [1] -476.9455
```