library(rstan)

library(loo)

library(INLA)

library(zoo)

library(rucm)

library(chron)

# London Airports Passenger Numbers in Millions, Jan 1999-Mar 2014

# https://data.london.gov.uk/dataset/passengers-london-airports

attach("C:/R files BHMRA/DS\_5\_2.Rdata")

#

# MLE estimate

#

y=DS\_5\_2$y

y <- ts(y, start=c(1999, 1), end=c(2014, 3), frequency=12)

model <- ucm(formula = y~0, data = y, irregular = T, level = T,slope=T,season=T, season.length = 12)

plot(model$s.season)

plot(model$s.slope)

plot(model$s.level)

**#**

**# Level, Trend, Monthly Seasonal; Normal Observational**

**#**

BSM.stan = "

data { int<lower=1> n;

// Number of months in forecast

int<lower=1> n\_new;

vector[n] y;

}

transformed data {

int<lower=n> n\_start;

int<lower=n> n\_end;

n\_start= n+1;

n\_end= n+n\_new;

}

parameters { vector<lower=mean(y)-3\*sd(y), upper=mean(y)+3\*sd(y)>[n+n\_new] mu;

vector[n+n\_new] seasonal;

vector[n+n\_new] trend;

real<lower=0> sigma[4];

real eps\_mu;

real eps\_tr;

}

transformed parameters { vector[n+n\_new] level;

vector[n+n\_new] y\_fit;

vector[n+n\_new] tr;

vector[n+n\_new] seas;

for(t in 1:11) { seas[t] = seasonal[t]; }

for(t in 12:n\_end) { seas[t] = - sum(seasonal[t-11:t-1]);}

level = mu;

tr = trend;

for (t in 1:n\_end) {y\_fit[t] =level[t]+seas[t];}

}

model { // frequency = 12

for(t in 12:n\_end) {seasonal[t] ~ normal(- sum(seasonal[t-11:t-1]), sigma[4]);}

trend[1] ~ normal(eps\_tr, sigma[3]);

for(t in 2:n\_end) {trend[t] ~ normal(trend[t-1], sigma[3]);}

mu[1] ~ normal(eps\_mu, sigma[2]);

for (t in 2:n\_end) {mu[t] ~ normal(mu[t-1]+trend[t-1], sigma[2]);}

for (t in 1:n) { y[t] ~ normal(mu[t]+seasonal[t], sigma[1]); }

sigma ~ student\_t(4, 0, 1);

// Preseries means for mu and tr

eps\_mu ~ normal(mean(y),10);

eps\_tr ~ normal(0,10);

}

generated quantities {

vector[n] log\_lik;

vector[n\_new] y\_tilde;

for (t in 1:n ) { log\_lik[t] = normal\_lpdf(y[t] |y\_fit[t], sigma[1]); }

// forecasts

for (t in n\_start:n\_end) { y\_tilde[t-n] = normal\_rng(mu[t] + seasonal[t], sigma[1]);}}

"

**# Initial Values and Estimation**

sm = stan\_model(model\_code=BSM.stan)

INI = list(list(sigma=rep(1,4),eps=8,eps\_tr=0), list(sigma=rep(0.5,4),eps\_mu=8.5,eps\_tr=0) )

pars =c("level","sigma","tr","seas","log\_lik","y\_fit","eps\_mu","eps\_tr","y\_tilde")

fit1 = sampling(sm,data =DS\_5\_2,pars=pars, iter = 5000,warmup=500,chains = 2,seed= 12345,init=INI)

**# Fit**

LOO=loo(as.matrix(fit1,pars="log\_lik"))

**# pointwise LOO-IC**

loocase <- as.vector(LOO$pointwise[,3])

S=seq.dates("01/31/1999", "03/31/2014", by = "months")

S=cut(S, "months")

list.loocase <- data.frame(S,loocase)

list.loocase=list.loocase[order(-list.loocase$loocase),]

head(list.loocase,20)

**# plot**

x=time(zooreg(1:183, as.yearmon("1999-01"), freq = 12))

data <- data.frame(x, loocase)

p=ggplot(data, aes(x, loocase)) + geom\_line() + xlab("") + ylab("")+scale\_x\_yearmon()

p + ggtitle("Pointwise LOO-IC") + xlab("Month") + theme(plot.title = element\_text(hjust = 0.5))

**# WAIC**

W=waic(as.matrix(fit1,pars="log\_lik"))

**# Plots of component series (including forecasts to end of 2014)**

seas=as.matrix(fit1,pars="seas")

seas.m=apply(seas,2,mean)

x=time(zooreg(1:192, as.yearmon("1999-01"), freq = 12))

data <- data.frame(x, seas.m)

p=ggplot(data, aes(x, seas.m)) + geom\_line() + xlab("") + ylab("")+scale\_x\_yearmon()

p + ggtitle("Passenger Numbers (Seasonal Effects)") + xlab("Month") + ylab("Numbers (mill)") +

theme(plot.title = element\_text(hjust = 0.5))

tr=as.matrix(fit1,pars="tr")

tr.m=apply(tr,2,mean)

x=time(zooreg(1:192, as.yearmon("1999-01"), freq = 12))

data <- data.frame(x, tr.m)

p=ggplot(data, aes(x, tr.m)) + geom\_line() + xlab("") + ylab("")+scale\_x\_yearmon()

p + ggtitle("Passenger Numbers (Trend Effects)") + xlab("Month") + ylab("Numbers (mill)") +

theme(plot.title = element\_text(hjust = 0.5))

level=as.matrix(fit1,pars="level")

level.m=apply(level,2,mean)

x=time(zooreg(1:192, as.yearmon("1999-01"), freq = 12))

data <- data.frame(x, level.m)

**# Dip in 2008-09 due to recession**

**# Pronounced Dip in April 2010 is Impact of Eyjafjallajökull Eruption**

p=ggplot(data, aes(x, level.m)) + geom\_line() + xlab("") + ylab("")+scale\_x\_yearmon()

p + ggtitle("Passenger Numbers (Combined Level and Trend)") + xlab("Month") + ylab("Numbers (mill)") +

theme(plot.title = element\_text(hjust = 0.5))

**#**

**# Level, Trend, Monthly Seasonal; Student t Observational**

**#**

BSMt.stan <- "

data { int<lower=1> n;

vector[n] y;

}

parameters { vector<lower=mean(y)-3\*sd(y), upper=mean(y)+3\*sd(y)>[n] mu;

vector[n] seasonal;

vector[n] trend;

real<lower=0> sigma[4];

real eps\_mu;

real eps\_tr;

real <lower=1> nu;

}

transformed parameters { vector[n] level;

vector[n] y\_fit;

vector[n] tr;

vector[n] seas;

for(t in 1:11) {seas[t] = seasonal[t]; }

for(t in 12:n) {seas[t] = - sum(seasonal[t-11:t-1]);}

level = mu;

tr = trend;

for (t in 1:n) {y\_fit[t] =level[t]+seas[t];}

}

model { // seasonal frequency = 12

for(t in 12:n) {seasonal[t] ~ normal(- sum(seasonal[t-11:t-1]), sigma[4]);}

trend[1] ~ normal(eps\_tr, sigma[3]);

for (t in 2:n) {trend[t] ~ normal(trend[t-1], sigma[3]);}

mu[1] ~ normal(eps\_mu, sigma[2]);

for(t in 2:n) {mu[t] ~ normal(mu[t-1]+trend[t-1], sigma[2]);}

y ~ student\_t(nu,level+seasonal, sigma[1]);

sigma ~ student\_t(4, 0, 1);

// Degrees of Freedom

nu ~ exponential(0.1);

// Preseries means for mu and tr

eps\_mu ~ normal(mean(y),10);

eps\_tr ~ normal(0,10);

}

generated quantities {

vector[n] log\_lik;

for (t in 1:n ) { log\_lik[t] = student\_t\_lpdf(y[t] |nu, y\_fit[t], sigma[1]); } }

"

**# Initial Values and Estimation**

sm <- stan\_model(model\_code=BSMt.stan)

INI <- list(list(sigma=rep(1,4),eps=8,eps\_tr=0,nu=10), list(sigma=rep(0.5,4),eps\_mu=8.5,eps\_tr=0,nu=20))

pars =c("level","sigma","tr","seas","log\_lik","y\_fit","eps\_mu","eps\_tr","nu")

fit2 <- sampling(sm,data =DS\_5\_2,pars=pars,iter = 5000,warmup=500,chains = 2,seed= 12345,init=INI)

**# Fit**

loo(as.matrix(fit2,pars="log\_lik"))

waic(as.matrix(fit2,pars="log\_lik"))

**#**

**# R-INLA Estimates**

**#**

attach(DS\_5\_2)

formula = y ~ f(trend,model="rw1",param=c(1,0.001)) +

f(seasonal,model="seasonal",season.length=12,param=c(1,0.1))

fit = inla(formula, family="gaussian", data=DS\_5\_2, control.compute=list(graph=T, waic=T))

**# Overall fit**

fit$waic$waic

**# pointwise WAIC**

waiccase=fit$waic$local.waic

**# plot**

x=time(zooreg(1:183, as.yearmon("1999-01"), freq = 12))

data <- data.frame(x, waiccase)

p=ggplot(data, aes(x, waiccase)) + geom\_line() + xlab("") + ylab("")+scale\_x\_yearmon()

p + ggtitle("Pointwise WAIC") + xlab("Month") + theme(plot.title = element\_text(hjust = 0.5))

**# Series Plots**

x=time(zooreg(1:183, as.yearmon("1999-01"), freq = 12))

seas.m=fit$summary.random$seasonal$mean

data <- data.frame(x, seas.m)

p=ggplot(data, aes(x, seas.m)) + geom\_line() + xlab("") + ylab("")+scale\_x\_yearmon()

p + ggtitle("Passenger Numbers (Seasonal Effects)") + xlab("Month") + ylab("Numbers (mill)") +

theme(plot.title = element\_text(hjust = 0.5))

tr.m=fit$summary.random$trend$mean+ fit$summary.fixed$mean

data <- data.frame(x, tr.m)

p=ggplot(data, aes(x, tr.m)) + geom\_line() + xlab("") + ylab("")+scale\_x\_yearmon()

p + ggtitle("Passenger Numbers (Combined Level and Trend)") + xlab("Month") + ylab("Numbers (mill)")+theme(plot.title = element\_text(hjust = 0.5))