Chib, Shin and Simoni (2018): R package betel2

Siddhartha Chib
Minchul Shin
Washington University in Saint Louis

February 2021

Introduction

This package does the Bayesian estimation and comparison of moment condition models as developed in Chib, Shin, and Simoni (2018).

The models estimated in this package are specified through moment restrictions of the type $\mathbb{E}^P[\boldsymbol{g}(\boldsymbol{X}, \boldsymbol{\theta})] = \mathbf{0}$, where $\boldsymbol{g}(\boldsymbol{X}, \boldsymbol{\theta})$ is a known vector-valued function of a random vector $\boldsymbol{X}$ and an unknown parameter vector $\boldsymbol{\theta}$, and P is the unknown data distribution.

This package conducts the prior-posterior analysis of these models by a one block tailored MCMC method. For further details see Chib and Greenberg (1995) and Chib, Shin, and Simoni (2018). The marginal likelihood of the model is calculated by the method of Chib (1995) as extended to M-H samplers by Chib and Jeliazkov (2001).

Installing the package

The package zip file (for windows) or tar file (for the mac) can be downloaded from https://apps.olin.wustl.edu/faculty/chib/czzg/. The downloaded package can be installed from Rstudio -> Tools -> Install Package -> and changing the Install from option to Package Archive file. Then, scroll to the location where the downloaded package was saved (typically the download files folder), and select the file.

Example Run

Once the package has been installed, you can run the following code that estimates the IV regression example discussed in the source paper.

The model of interest is

$$y = \alpha + x\beta + w\delta + \varepsilon, \qquad \mathbb{E}^P[\varepsilon] = 0$$

where

$$\boldsymbol{\theta} = (\alpha, \beta, \delta)$$

and the covariate x is correlated with the error. To learn about the causal effect parameter β, we suppose that two instruments, z_1 and z_2, are available. We also suppose that w is uncorrelated with ε.

The overidentified moment restrictions in this example are

$$\begin{aligned}\mathbb{E}^P\left[(y_i - \alpha - x_i\beta - w_i\delta)\right] &= 0 \\ \mathbb{E}^P\left[(y_i - \alpha - x_i\beta - w_i\delta)\, z_{1i}\right] &= 0 \\ \mathbb{E}^P\left[(y_i - \alpha - x_i\beta - w_i\delta)\, z_{2i}\right] &= 0 \\ \mathbb{E}^P\left[(y_i - \alpha - x_i\beta - w_i\delta)\, w_i\right] &= 0, \qquad (i \le n)\end{aligned}$$

For the purpose of this package, one can view these moments in the following way. Let $\boldsymbol{\varepsilon}(\boldsymbol{\theta}) = (\varepsilon_1, ..., \varepsilon_n)$ denote the n vector of errors, where $\varepsilon_i(\boldsymbol{\theta}) = y_i - \alpha - x_i\beta - w_i\delta$. Let $\boldsymbol{Z} = (\mathbf{1}, \boldsymbol{w}, \boldsymbol{z}_1, \boldsymbol{z}_2)$ denote the $n \times 4$ matrix of data. Then, the moments for all n observations take the form

$$\mathbb{E}^P\left[\boldsymbol{\varepsilon} \circ \mathbf{1}, \boldsymbol{\varepsilon} \circ \boldsymbol{w}, \boldsymbol{\varepsilon} \circ \boldsymbol{z}_1, \boldsymbol{\varepsilon} \circ \boldsymbol{z}_2\right] = 0$$

where $\circ$ is the Hadamard (element by element multiplication) operator.

We now calculate $\boldsymbol{\varepsilon}(\boldsymbol{\theta})$ in a cppXPtr object and sent it out as an arma::field object. The data on $(\mathbf{1}, \boldsymbol{w}, \boldsymbol{z}_1, \boldsymbol{z}_2)$ is put into a list object. Inside the package, for each value of the parameters $\boldsymbol{\theta}$, the $n \times 4$ matrix

$$\left[\boldsymbol{\varepsilon} \circ \mathbf{1}, \boldsymbol{\varepsilon} \circ \boldsymbol{w}, \boldsymbol{\varepsilon} \circ \boldsymbol{z}_1, \boldsymbol{\varepsilon} \circ \boldsymbol{z}_2\right]$$

is calculated by multiplying the error into each column of the data in the list.

If you also wanted to impose a symmetry condition on the error, then the cppXPtr object would be an arma::field with two elements: the first one for $\boldsymbol{\varepsilon}$ and the second for $\boldsymbol{\varepsilon}^3$. The list would now have length 2, with the first element in the list containing the data $\boldsymbol{Z}$, and the second element of the list containing the data $\mathbf{1}$.

```
rm(list = ls())
library(czzg)
library(RcppXPtrUtils)
library(betel2)
library(nor1mix);

# GENERATE DATA

set.seed(100)
n = 200;

Sigma = matrix(c(1,.7,.7,1),nr = 2)
Cp = t(chol(Sigma));
E = matrix(0,nr = 2,nc = n);

# parameters of the error components
```

```
mue1 = 1/2;
mue2 = -1/2;
sig1 = 0.5;
sig2 = 1.118;
q1 = 0.5;

a = norMix(mu = c(mue1,mue2),
           sigma = c(sig1,sig2),
           w = c(q1,1-q1));
for (i in 1:n) {
    ei = Cp%*%rnorm(2);
    u = pnorm(ei[1]);
    v = pnorm(ei[2]);
    e1i = qnorMix(u,a);
    e2i = qnorm(v);
    E[,i] = c(e1i,e2i);
}
z1 = 0.5 + rnorm(n);
z2 = 0.5 + rnorm(n);
w = runif(n);
e2 = E[2,];
e1 = E[1,]

beta = .5;
x = z1 + z2 + w + e2;
y = 1 + x*beta + .7*w + e1;
dat = cbind(x,w);

# SET UP MOMENT FUNCTIONS in C++ and in a LIST

Rmatptr = cppXPtr('
arma::field<arma::mat> g(const arma::mat theta,
                         const arma::colvec y,
                         const arma::mat dat) {
int n = y.n_rows;
arma::colvec onen = arma::ones<arma::colvec>(n);
arma::mat X = arma::join_horiz(onen,dat);
arma::colvec e = y - X*theta;
arma::field<arma::mat> rhof(1,1);
rhof(0,0) = e;
return rhof;
}', depends = "RcppArmadillo");

# list for data on the instruments

Z = cbind(rep(1,n),w,z1,z2);
qZls = vector("list",1);
```

```r
qZls[[1]] = Z;

# PRIOR AND STARTING VALUES

k = 3;  # number of parameters
d = 4;  # number of moments
lam0 = .5*rnorm(d);
psi0 = lm(y~x+w)$coefficients;
psi0_ = as.matrix(psi0);
Psi0_ = 5*rep(1,k);   # prior dispersion

# MODEL ESTIMATION

psim = betel2::bayesetel(rhofunc = Rmatptr,
                         qZls = qZls,
                         y = y,
                         dat = dat,
                         psi0 = psi0,
                         lam0 = lam0,
                         psi0_ = psi0_,
                         Psi0_ = Psi0_,
                         controlpsi = list(maxiterpsi = 1000,
                                           mingrpsi = 1.0e-10),
                         controllam = list(maxiterlam = 50,
                                           mingrlam = 1.0e-7));
```

```
## MCMC estimation has started ...
##
## this is psi0 0.6378344 0.6289491 0.7727952
##
## tailoring step is done
##
##  maxgradient     laststep      stepmax        neval
## 0.0002530333 0.0000000000 1.0000000000 1.0000000000
##
## this is the value  1068.154
##
## this is grad   -4.7459e-06   1.1359e-05   1.1457e-05
##
## this is hessian
##    2.1659e+02   3.1001e+02   1.0378e+02
##    3.1001e+02   1.0430e+03   1.8463e+02
##    1.0378e+02   1.8463e+02   7.2192e+01
##
## this is lam0
##    0.0060  -0.0118   0.0602  -0.0600
##
```

```
##
## this is g 2000
## this is psi
##    0.8604   0.4400   0.7507
## this is the M-H rate 0.8715
##
## this is g 4000
## this is psi
##    0.8089   0.3664   1.2176
## this is the M-H rate 0.86775
##
## this is g 6000
## this is psi
##    0.8240   0.4477   0.9465
## this is the M-H rate 0.867
##
## this is g 8000
## this is psi
##    0.8651   0.4850   0.8290
## this is the M-H rate 0.869
##
## this is g 10000
## this is psi
##    0.9939   0.3313   1.0026
## this is the M-H rate 0.8698
##
## *************************
## *************************
## *************************
## calculating effective prior ...
## Posterior summary ...
##
##       postmean     postsd postmedian     lower     upper    ineff
## [1,] 0.8257763 0.12600911  0.8262736 0.5765834 1.0706707 1.236258
## [2,] 0.4473576 0.04387476  0.4479309 0.3580681 0.5310021 1.469247
## [3,] 0.9369073 0.22185300  0.9403052 0.4903999 1.3612577 1.366139
## logmarg by Chib (1995) and Chib and Jeliazkov (2001) is  -1072.66
```

References

Chib, Siddhartha. 1995. "Marginal Likelihood from the Gibbs Output." *Journal of the American Statistical Association* 90 (432): 1313–21.

Chib, Siddhartha, and Edward Greenberg. 1995. "Understanding the Metropolis-Hastings algorithm." *The American Statistician* 49 (4): 327–35.

Chib, Siddhartha, and Ivan Jeliazkov. 2001. "Marginal likelihood from the Metropolis-Hastings output." *Journal of the American Statistical Association* 96 (453): 270–81.

Chib, Siddhartha, Minchul Shin, and Anna Simoni. 2018. "Bayesian Estimation and Comparison of Moment Condition Models." *Journal of the American Statistical As-*

sociation 113 (524): 1656–68.