Econometria Bayesiana - Aula 11

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Abstract

Neste aula abordaremos a estimação bayesiana de modelos de equilíbrio geral dinâmicas e estocásticos (DSGE no acrônimo em inglês).

Keywords: DSGE

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1 Modelos DSGE com estimativa bayesiana

O exercício desta aula foi retirado de `http://gecon.r-forge.r-project.org/` e replicado fielmente.

Nele é abordado um modelo da classe de RBC com governo e utilização da capacidade instalada.

```
library(gEcon)
library(gEcon.estimation)


file.copy(from = file.path(system.file("examples", package = "gEcon.estimation"),
                           "dsge_model.gcn"), to = getwd())
```

```
## [1] FALSE
```

```
dsge_model <- make_model("dsge_model.gcn")
```

```
## (gEcon model info): model has 5 blocks: CONSUMER, FIRM, EQUILIBRIUM, GOVERNMENT, EXOG
## (gEcon model info): model is dynamic, stochastic
## (gEcon model info): model has 20 equations with 20 variables
## (gEcon model info): model has 0 calibrating equations and 0 non-free (calibrated) parameters
## (gEcon model info): after reduction the model has 12 equations with 12 variables
## (gEcon info): R code written to 'C:/Users/jcfil/Documents/2020 1 Bayesian Econometrics/Aulas/Au
## (gEcon info): LaTeX documentation written to 'C:/Users/jcfil/Documents/2020 1 Bayesian Economet
## model parsed in 0.01s
## model loaded in 0.03s
```

O arquivo \textit{dsge_model.gcn} contém o modelo:

```
# ############################################################################
# This file is a part of gEcon.estimation                                    #
#                                                                            #
# (c) Chancellery of the Prime Minister of the Republic of Poland 2012-2015  #
# (c) Grzegorz Klima, Karol Podemski 2015-2016                               #
# License terms can be found in the file 'LICENCE'                           #
```

```
#                                                                             #
# Authors: Karol Podemski                                                     #
# ############################################################################
# RBC model with variable capacity utilization and government
# ############################################################################


options
{
    output logfile = TRUE;
    output LaTeX = TRUE;
    verbose = TRUE;
    output R long = TRUE;
}

tryreduce
{
    H_d[], PI[], lambda_U[], lambda_c[], T[], P[];
};

block CONSUMER
{
    definitions
    {
        u[] = log(C[]) + psi * log(1 - H[]);
    }
    controls
    {
        C[], H[];
```

```
    }
    objective
    {
        U[] = u[] + beta * E[][U[1]]     : lambda_U[];
    }
    constraints
    {
         C[] + T[] = W[] * H[] + PI[]       : lambda_c[];
    }
    calibration
    {
        beta = 0.99;
        psi = 1.75;
    }
}



block FIRM
{
    controls
    {
        K[], H_d[], Y[], I[], PI[], CapUt[];
    };
    objective
    {
        SPI[] = PI[] + E[][lambda_U[1] * lambda_c[1] / lambda_c[] * SPI[1]];
    };
    constraints
    {
```

```
        Y[] = exp(Z[]) ^ (1 - alpha) * (K[-1] * CapUt[])^alpha * (H_d[] )^(1 - alpha);

        K[] = (1 - delta * CapUt[] ^ omega) * K[-1]  + I[];

        PI[] = P[] * Y[] - H_d[] * W[] - I[];

    };

    identities

    {

        K_ut[] = CapUt[] * K[-1];

    };

    calibration

    {

        alpha = 0.33;

        omega = 1.45;

        delta = 0.0265;

    }

}



block EQUILIBRIUM

{

    identities

    {

        P[] = 1;

        H[] = H_d[];

    };

};


block GOVERNMENT

{

    identities
```

```
    {
        T[] = G[];
        G[] = phi_G * G[-1] + epsilon_G[];
    };
    shocks
    {
        epsilon_G[];
    };
    calibration
    {
        phi_G = 0.9;
    };
};

block EXOG
{
    identities
    {
        Z[] = phi_Z * Z[-1]  + epsilon_Z[];
    }
    shocks
    {
        epsilon_Z[];
    }
    calibration
    {
        phi_Z = 0.9;
    }
};
```

A partir dele, podemos resolver o modelo utilizando o pacote *gEcon*. A estimativa bayesiana, via MCMC, utiliza o pactoe *gEcon.estimation*.

```
# solve the model
dsge_model <- steady_state(dsge_model)
```

```
## Steady state has been FOUND
```

```
dsge_model <- solve_pert(dsge_model, loglin = TRUE)
```

```
## Model has been SOLVED
```

```
# set the stochastic shocks distribution parameters
dsge_model <- set_shock_distr_par(dsge_model,
                                  distr_par = list("sd( epsilon_G )" = 0.01,
                                                   "sd( epsilon_Z )" = 0.01))
shock_info(model = dsge_model, all = TRUE)
```

```
## Incidence info:
##
##       epsilon_G epsilon_Z
## Eq. 7         X         .
## Eq. 8         .         X
##
## ----------------------------------------------------------
##
## Covariance matrix of shocks:
##
##           epsilon_G epsilon_Z
## epsilon_G     1e-04     0e+00
## epsilon_Z     0e+00     1e-04
```

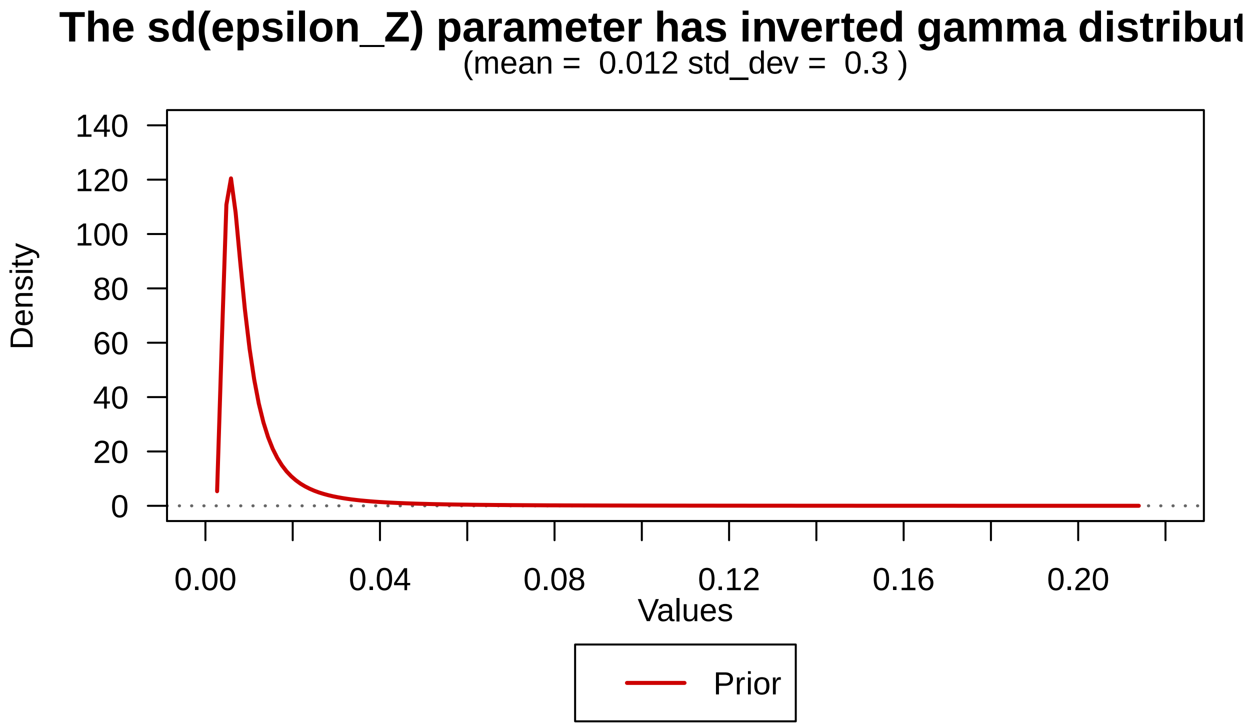
A base de dados será criada a partir de simulações do modelo:

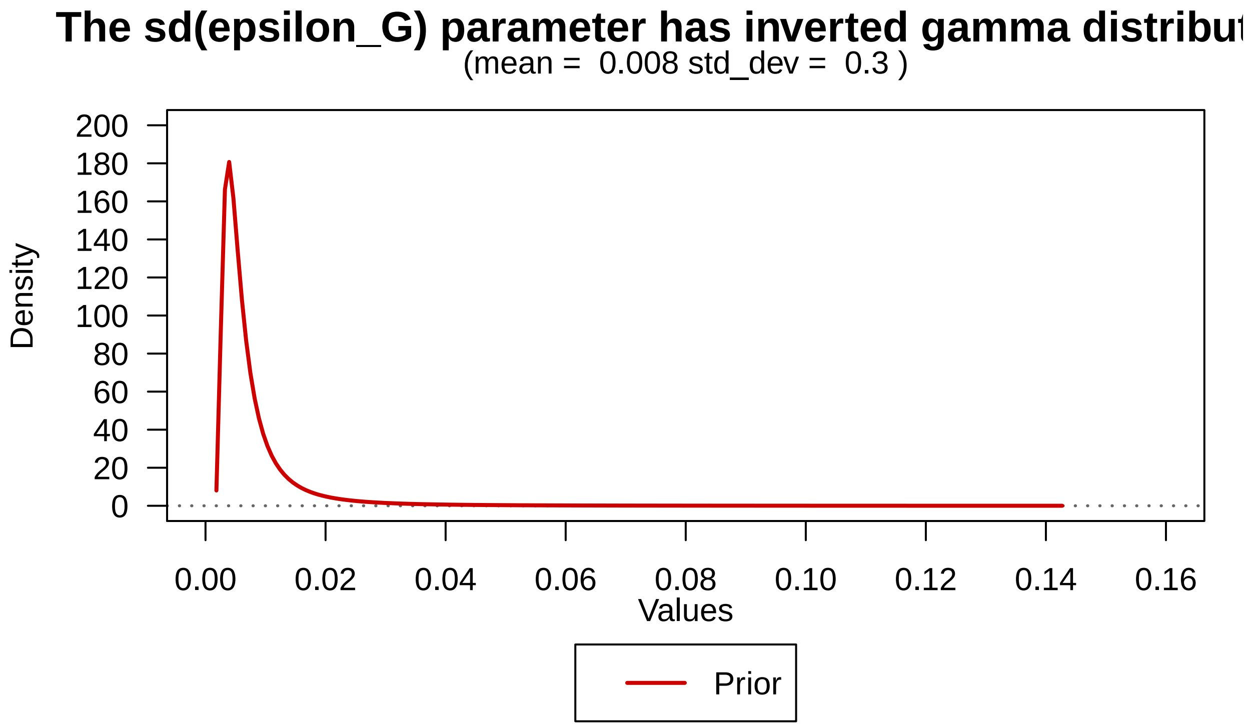
```
# ######################################################################
# 2. simulate the model to obtain data for the estimation
# choose variables of interest
set.seed(1301)
series_length <- 150
observables <- c("Y", "G")
# simulate random path
dsge_simulation <- random_path(model = dsge_model,
                               sim_length = series_length,
                               variables = observables)
model_data <- get_simulation_results(dsge_simulation)

# create data set to be used for estimation (ts object)
estimation_data <- ts(data = t(model_data)[, observables],
                      start = c(1973, 1),
                      frequency = 4, names = observables)
# remove mean from the data series
mean_var <- matrix(apply(estimation_data, 2, mean),
                   byrow = TRUE,
                   nrow = nrow(estimation_data),
                   ncol = ncol(estimation_data))
estimation_data <- estimation_data - mean_var
```

Para os parâmetros estimados, é necessário declarar a prior:

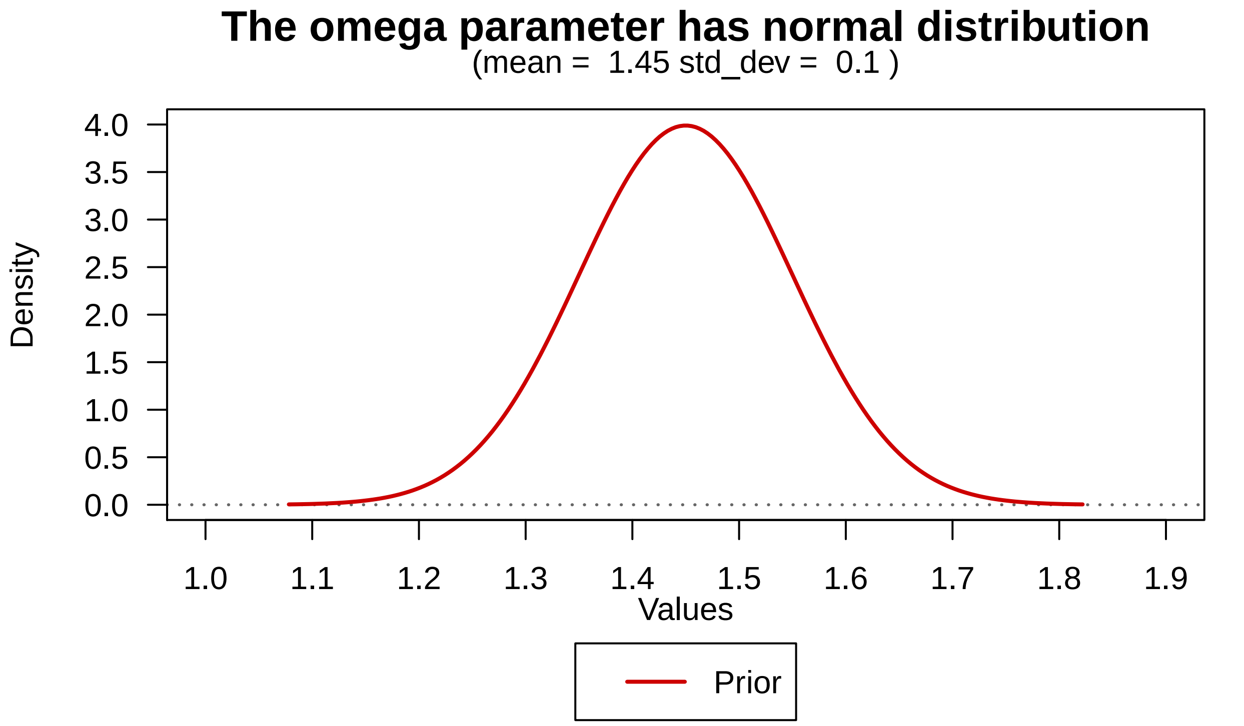
```
# ######################################################################
# 3. declare prior distribution
dsge_prior <- gecon_prior(
  prior_list = list(
```

```
    list(par = "sd(epsilon_Z)", type = "inv_gamma",
         mean = 0.012, sd = 0.3, lower_bound = 0.0001,
         upper_bound = 0.9, initial = 0.0012),
    list(par = "sd(epsilon_G)", type = "inv_gamma",
         mean = 0.008, sd = 0.3, lower_bound = 0.0001,
         upper_bound = 0.9, initial = 0.006),
    list(par = "omega", type = "normal",mean = 1.45, sd = 0.1, lower_bound = 1,
         upper_bound = 2, initial = 1.5),
    list(par = "phi_G", type = "beta",
         mean = 0.88, sd = 0.03, lower_bound = 0.5,
         upper_bound = 0.999, initial = 0.95),
    list(par = "phi_Z", type = "beta",
         mean = 0.92, sd = 0.03, lower_bound = 0.5,
         upper_bound = 0.999, initial = 0.95)),
  model = dsge_model)
plot_prior(dsge_prior)
```

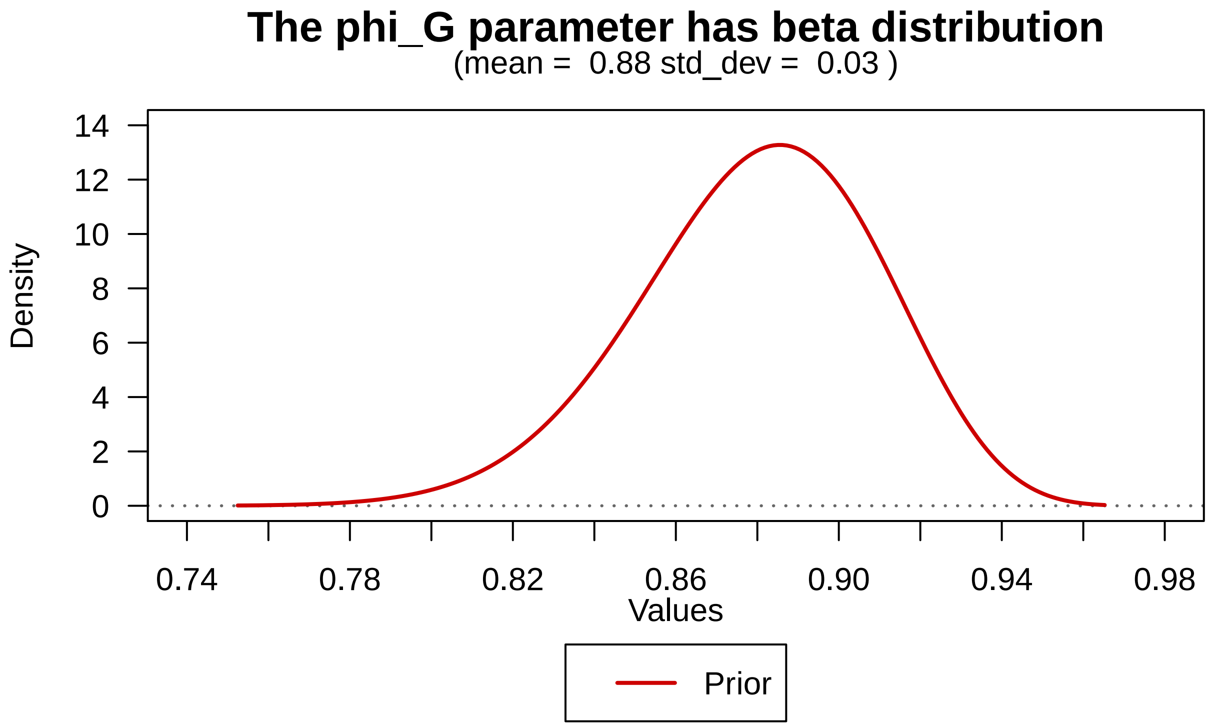


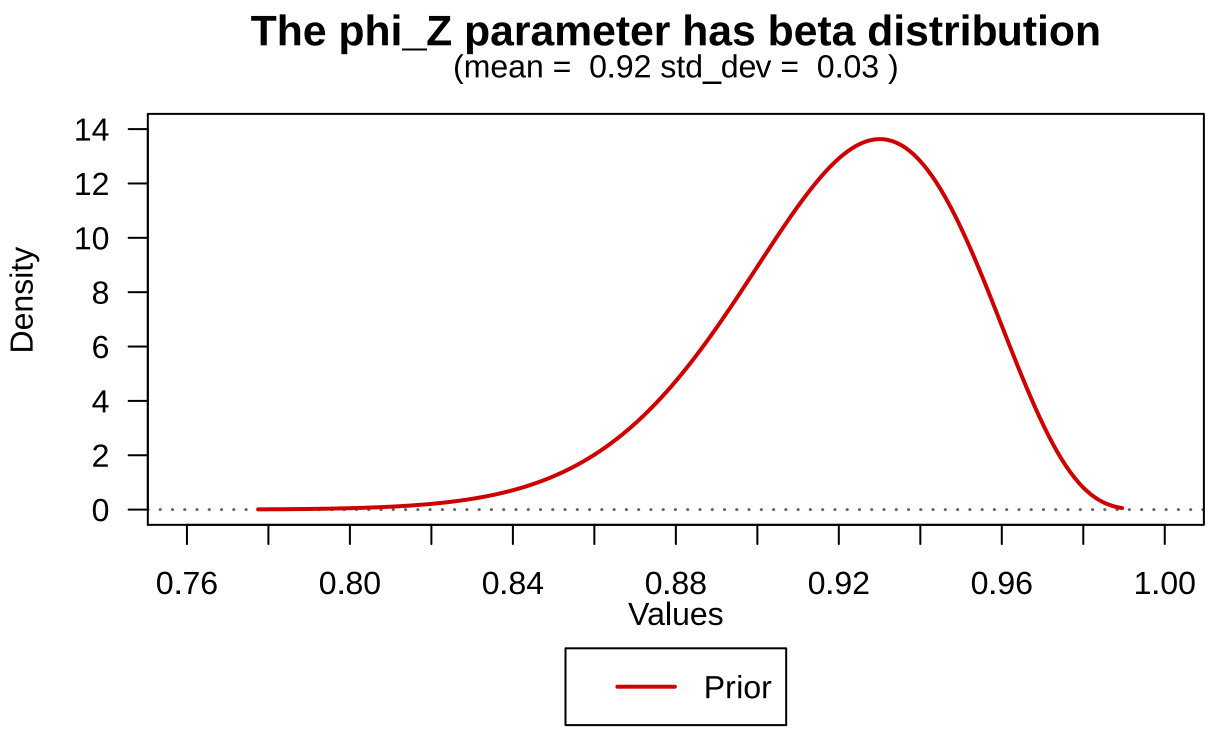


The sd(epsilon_G) parameter has inverted gamma distribut
(mean = 0.008 std_dev = 0.3)
Density
200
180
160
140
120
100
80
60
40
20
0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
Values
Prior



The omega parameter has normal distribution
(mean = 1.45 std_dev = 0.1)
Density
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
Values
Prior


The phi_G parameter has beta distribution
(mean = 0.88 std_dev = 0.03)
Density
0
2
4
6
8
10
12
14
0.74
0.78
0.82
0.86
0.90
0.94
0.98
Values
Prior


The phi_Z parameter has beta distribution
(mean = 0.92 std_dev = 0.03)
Density
0
2
4
6
8
10
12
14
0.76
0.80
0.84
0.88
0.92
0.96
1.00
Values
Prior

```r
# ####################################################################
# 4. estimate the model (Bayesian estimation)
estimation_result <- bayesian_estimation(data_set = estimation_data,
                     optim_options_list = list(solver = "csminwel"),
                     mcmc_options_list = list(chain_length = 1000,
                     burn = 200, cores = 2, chains = 2, scale = rep(0.5, 5)),
                     observables = observables, model = dsge_model,
                     prior = dsge_prior)
```

```
##
## Finding the posterior kernel mode...
## Moments of the distributions specified for model parameters
##
## ----------------------------------------------------------
##
##
## Parameters of the distributions specified for model parameters
##              Distribution type 1st parameter 2nd parameter Lower bound Upper bound
## sd(epsilon_Z)         inv_gamma      2.001018  9.180268e-05       1e-04       0.900
## sd(epsilon_G)         inv_gamma      2.000453  4.076923e-05       1e-04       0.900
## omega                    normal      1.450000  1.000000e-01       1e+00       2.000
## phi_G                      beta     37.500779  1.174367e+01       5e-01       0.999
## phi_Z                      beta     30.188377  5.678290e+00       5e-01       0.999
##
## ----------------------------------------------------------
##
##
## Initial values of parameters for estimation
##               Initial value
## sd(epsilon_Z)        0.0012
```

```
## sd(epsilon_G)        0.0060
## omega                1.5000
## phi_G                0.9500
## phi_Z                0.9500
##
## Initial values of the parameters:
## sd(epsilon_Z) sd(epsilon_G)         omega         phi_G         phi_Z
##        0.0012        0.0060        1.5000        0.9500        0.9500
## ----------------
## ----------------
## f at the beginning of new iteration,      4178.7185568636
## x =
## sd(epsilon_Z) sd(epsilon_G)         omega         phi_G         phi_Z
##        0.0012        0.0060        1.5000        0.9500        0.9500
## Predicted improvement           = 3952890071.063458443
## lambda =          1; f =                 Inf
## lambda =    0.33333; f =                 Inf
## lambda =    0.11111; f =                 Inf
## lambda =   0.037037; f =                 Inf
## lambda =   0.012346; f =                 Inf
## lambda =  0.0041152; f =                 Inf
## lambda =  0.0013717; f =                 Inf
## lambda = 0.00045725; f =         -393.5121068
## lambda = 0.00015242; f =         -537.3110320
## lambda = 5.0805e-05; f =         -685.4196998
## Norm of dx     889.14
## ----
## Improvement on iteration        1 =     4864.138256708
## ----------------
## ----------------
```

```
## f at the beginning of new iteration,      -685.4196998443
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.04637236808803 0.00622118752743 1.49999075162238 0.94998149932255 0.94983311453703
## Predicted improvement            =    69740.486512142
## lambda =          1; f =                 Inf
## lambda =    0.33333; f =                 Inf
## lambda =    0.11111; f =         -235.6910904
## lambda =   0.037037; f =         -397.3360515
## lambda =   0.012346; f =         -549.8577104
## lambda =  0.0041152; f =         -671.8414608
## lambda =  0.0013717; f =         -728.2831073
## Norm of dx     3.7347
## ----
## Improvement on iteration        2 =       42.863407499
## -----------------
## -----------------
## f at the beginning of new iteration,      -728.2831073428
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0463689423677 0.0113439928884 1.4999934934136 0.9499507919232 0.9498796189698
## Predicted improvement            =        8.038462707
## lambda =          1; f =         -749.8583104
## lambda =     1.9332; f =                 Inf
## lambda =     1.3017; f =         -759.5351605
## lambda =     1.6503; f =                 Inf
## lambda =     1.4313; f =         -757.8016483
## lambda =      1.559; f =                 Inf
## lambda =     1.4811; f =                 Inf
## lambda =     1.4071; f =         -760.3490790
```

```
## lambda =      1.451; f =                  Inf
## lambda =     1.4245; f =         -758.9420167
## lambda =     1.4403; f =         -754.7739277
## lambda =     1.4564; f =                  Inf
## Norm of dx   0.038318
## Cliff.  Perturbing search direction.
## Predicted improvement            =        5.939755488
## lambda =          1; f =         -744.9186091
## lambda =     1.9332; f =                  Inf
## lambda =     1.3017; f =         -752.8886106
## lambda =     1.6503; f =                  Inf
## lambda =     1.4313; f =         -756.5507177
## lambda =      1.559; f =         -758.2688900
## lambda =      1.698; f =                  Inf
## lambda =     1.6131; f =         -750.2299772
## lambda =     1.6635; f =                  Inf
## lambda =     1.6331; f =                  Inf
## lambda =     1.6033; f =         -754.5427655
## lambda =     1.6211; f =                  Inf
## Norm of dx   0.030625
## Cliff again.  Try traversing
## Predicted improvement            =    10563.999600240
## lambda =          1; f =                  Inf
## lambda =    0.33333; f =                  Inf
## lambda =    0.11111; f =                  Inf
## lambda =   0.037037; f =                  Inf
## lambda =   0.012346; f =                  Inf
## lambda =  0.0041152; f =                  Inf
## lambda =  0.0013717; f =         -713.7832665
## lambda = 0.00045725; f =         -734.6939098
```

```
## Norm of dx     145.35
## ----
## Improvement on iteration        3 =        6.410802468
## -----------------
## -----------------
## f at the beginning of new iteration,      -734.6939098113
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega            phi_G            phi_Z
## 0.0463329994349 0.0105920926752 1.5071921508929 0.8838996895649 0.9513643195135
## Predicted improvement            =        6.383925458
## lambda =          1; f =        -754.6039091
## lambda =     1.9332; f =                 Inf
## lambda =     1.3017; f =        -762.5670698
## lambda =     1.6503; f =                 Inf
## lambda =     1.4313; f =                 Inf
## lambda =     1.3141; f =        -762.3155396
## lambda =     1.3832; f =                 Inf
## lambda =     1.3413; f =        -760.1919361
## lambda =     1.3663; f =                 Inf
## lambda =     1.3513; f =        -757.7300879
## Norm of dx   0.035095
## Cliff.  Perturbing search direction.
## Predicted improvement            =        2.598507791
## lambda =          1; f =        -740.7213914
## lambda =     1.9332; f =        -748.6102565
## lambda =     3.7372; f =                 Inf
## lambda =     2.5164; f =        -755.2408232
## lambda =     3.1904; f =        -758.8074716
## lambda =     4.0448; f =                 Inf
## lambda =      3.508; f =                 Inf
```

```
## lambda =     3.2208; f =        -755.6552392
## lambda =     3.3902; f =                 Inf
## lambda =     3.2875; f =                 Inf
## lambda =     3.2274; f =        -754.2186718
## lambda =     3.2633; f =                 Inf
## Norm of dx   0.016065
## Cliff again.  Try traversing
## Predicted improvement            =    10394.987299974
## lambda =          1; f =                 Inf
## lambda =    0.33333; f =                 Inf
## lambda =    0.11111; f =                 Inf
## lambda =   0.037037; f =                 Inf
## lambda =   0.012346; f =                 Inf
## lambda =  0.0041152; f =                 Inf
## lambda =  0.0013717; f =                 Inf
## lambda = 0.00045725; f =        -727.6418329
## lambda = 0.00015242; f =        -733.9570609
## lambda = 5.0805e-05; f =        -734.6207559
## lambda = 1.6935e-05; f =        -734.6890967
## lambda =  5.645e-06; f =        -734.6945025
## lambda = 1.8817e-06; f =        -734.6943523
## Norm of dx     144.19
## ----
## Improvement on iteration        4 =        0.000592650
## -----------------
## -----------------
## f at the beginning of new iteration,      -734.6945024613
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0463224709838 0.0106120035984 1.5073969482484 0.8846851695377 0.9513088877282
```

```
## Predicted improvement            =        6.384007617
## lambda =          1; f =        -754.5729751
## lambda =     1.9332; f =                 Inf
## lambda =     1.3017; f =        -762.6236440
## lambda =     1.6503; f =                 Inf
## lambda =     1.4313; f =                 Inf
## lambda =     1.3141; f =        -762.4150575
## lambda =     1.3832; f =                 Inf
## lambda =     1.3413; f =        -760.5714313
## lambda =     1.3663; f =                 Inf
## lambda =     1.3513; f =        -758.5461675
## Norm of dx   0.035103
## Cliff.  Perturbing search direction.
## Predicted improvement            =       16.208706404
## lambda =          1; f =                 Inf
## lambda =    0.33333; f =        -750.5294528
## lambda =    0.64439; f =                 Inf
## lambda =     0.4339; f =        -758.3190780
## lambda =    0.55011; f =                 Inf
## lambda =     0.4771; f =        -761.6421231
## lambda =    0.51965; f =        -759.4044001
## lambda =      0.566; f =                 Inf
## lambda =    0.53772; f =                 Inf
## lambda =    0.51085; f =        -761.8531039
## lambda =     0.5268; f =                 Inf
## lambda =    0.51717; f =        -760.4768846
## lambda =    0.52293; f =        -756.7074549
## lambda =    0.52875; f =                 Inf
## Norm of dx   0.090654
## Cliff again.  Try traversing
```

```
## Predicted improvement            =  1077785.084334856
## lambda =          1; f =                 Inf
## lambda =    0.33333; f =                 Inf
## lambda =    0.11111; f =                 Inf
## lambda =   0.037037; f =                 Inf
## lambda =   0.012346; f =                 Inf
## lambda =  0.0041152; f =                 Inf
## lambda =  0.0013717; f =                 Inf
## lambda = 0.00045725; f =                 Inf
## lambda = 0.00015242; f =         647.2011010
## lambda = 5.0805e-05; f =        -717.2078695
## lambda = 1.6935e-05; f =        -733.5677714
## lambda =  5.645e-06; f =        -734.6584677
## lambda = 1.8817e-06; f =        -734.7158210
## lambda = 6.2723e-07; f =        -734.7051588
## lambda = 2.0908e-07; f =        -734.6984447
## lambda = 6.9692e-08; f =        -734.6958597
## lambda = 2.3231e-08; f =        -734.6949596
## lambda = 7.7435e-09; f =        -734.6946554
## lambda = 2.5812e-09; f =        -734.6945535
## Norm of dx     1468.2
## ----
## Improvement on iteration        5 =        0.021318512
## smallest step still improving too slow
## -----------------
## -----------------
## f at the beginning of new iteration,      -734.7158209729
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0463093758460 0.0105102789254 1.5091381195917 0.8826005800318 0.9508143878485
```

```
## Predicted improvement            =        6.157210693
## lambda =          1; f =         -754.7445388
## lambda =     1.9332; f =                  Inf
## lambda =     1.3017; f =         -757.9185409
## lambda =     1.6503; f =                  Inf
## lambda =     1.4313; f =                  Inf
## lambda =     1.3141; f =         -749.1150042
## Norm of dx   0.039069
## ----
## Improvement on iteration        6 =       23.202719961
## warning: possible inaccuracy in H matrix
## -----------------
## -----------------
## f at the beginning of new iteration,      -757.9185409340
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0464749939924 0.0109657137928 1.5017459333558 0.8987093633317 0.9984791525119
## Predicted improvement            =      163.715963577
## lambda =          1; f =         -738.7346637
## lambda =    0.33333; f =         -752.7341272
## lambda =    0.11111; f =         -760.3939693
## Norm of dx    0.06333
## ----
## Improvement on iteration        7 =        2.475428416
## -----------------
## -----------------
## f at the beginning of new iteration,      -760.3939693496
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0463858585288 0.0108290786241 1.5064366384089 0.8973141848375 0.9934255542139
```

```
## Predicted improvement            =        2.537664682
## lambda =          1; f =         -763.9869053
## Norm of dx   0.036448
## ----
## Improvement on iteration        8 =        3.592935934
## -----------------
## -----------------
## f at the beginning of new iteration,      -763.9869052837
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.04579274687357 0.00975882014223 1.54227652541268 0.89081569181116 0.99390725176815
## Predicted improvement            =        1.954824342
## lambda =          1; f =         -766.9147565
## Norm of dx   0.046707
## ----
## Improvement on iteration        9 =        2.927851182
## -----------------
## -----------------
## f at the beginning of new iteration,      -766.9147564662
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.04480288334342 0.00911257475667 1.58830832338066 0.89857828050576 0.99490101555363
## Predicted improvement            =        3.605662306
## lambda =          1; f =         -771.7619452
## Norm of dx   0.091113
## ----
## Improvement on iteration       10 =        4.847188689
## -----------------
## -----------------
## f at the beginning of new iteration,      -771.7619451553
```

```
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.04265517972214 0.00879982043818 1.67619012631028 0.92241872843960 0.99718363637463
## Predicted improvement            =        2.479509212
## lambda =          1; f =         -775.3485069
## Norm of dx   0.057987
## ----
## Improvement on iteration       11 =        3.586561750
## -----------------
## -----------------
## f at the beginning of new iteration,      -775.3485069057
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.04110781963609 0.00918577310305 1.73362706010088 0.93017574399612 0.99803654075330
## Predicted improvement            =        8.296851517
## lambda =          1; f =         -786.3794232
## Norm of dx    0.14529
## ----
## Improvement on iteration       12 =       11.030916342
## -----------------
## -----------------
## f at the beginning of new iteration,      -786.3794232476
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0370501271853 0.0106894396989 1.8788074922440 0.9336282172397 0.9972732030374
## Predicted improvement            =        8.575324596
## lambda =          1; f =                  Inf
## lambda =    0.33333; f =         -791.5899760
## Norm of dx    0.30367
## ----
```

```
## Improvement on iteration       13 =        5.210552715
## -----------------
## -----------------
## f at the beginning of new iteration,      -791.5899759623
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0343962893307 0.0110010281253 1.9799076993687 0.9293984288694 0.9973504252368
## Predicted improvement            =       13.675801479
## lambda =          1; f =                 Inf
## lambda =    0.33333; f =                 Inf
## lambda =    0.11111; f =                 Inf
## lambda =   0.037037; f =         -792.5872879
## Norm of dx    0.52623
## ----
## Improvement on iteration       14 =        0.997311934
## -----------------
## -----------------
## f at the beginning of new iteration,      -792.5872878961
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0338809617438 0.0110354336197 1.9993743873259 0.9285998635403 0.9973466411754
## Predicted improvement            =       17.274635349
## lambda =          1; f =                 Inf
## lambda =    0.33333; f =                 Inf
## lambda =    0.11111; f =                 Inf
## lambda =   0.037037; f =                 Inf
## lambda =   0.012346; f =                 Inf
## lambda =  0.0041152; f =                 Inf
## lambda =  0.0013717; f =                 Inf
## lambda = 0.00045725; f =         -792.6030825
```

```
## lambda = 0.00088394; f =         -792.6178158
## lambda =  0.0017088; f =                  Inf
## lambda =  0.0011506; f =                  Inf
## lambda = 0.00090756; f =         -792.6186311
## lambda =  0.0010464; f =                  Inf
## lambda = 0.00096075; f =         -792.6204672
## lambda =  0.0010113; f =                  Inf
## lambda = 0.00098065; f =         -792.6211541
## lambda = 0.00099891; f =                  Inf
## lambda = 0.00098791; f =                  Inf
## Norm of dx    0.63408
## Cliff.  Perturbing search direction.
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -793.5725164
## Norm of dx    0.34944
## ----
## Improvement on iteration       15 =        0.985228505
## -----------------
## -----------------
## f at the beginning of new iteration,      -793.5725164015
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0337201011216 0.0109122461979 1.9993723906370 0.9285963141057 0.9972961100271
## Predicted improvement            =       50.565431220
## lambda =          1; f =                  Inf
## lambda =    0.33333; f =                  Inf
## lambda =    0.11111; f =                  Inf
## lambda =   0.037037; f =                  Inf
## lambda =   0.012346; f =                  Inf
```

```
## lambda =  0.0041152; f =                  Inf
## lambda =  0.0013717; f =                  Inf
## lambda = 0.00045725; f =         -793.6187472
## lambda = 0.00088394; f =                  Inf
## lambda =  0.0005952; f =         -793.6326915
## lambda =  0.0007546; f =                  Inf
## lambda = 0.00065446; f =         -793.6386817
## lambda = 0.00071283; f =                  Inf
## lambda = 0.00067721; f =         -793.6409811
## lambda = 0.00069836; f =         -793.6431188
## lambda = 0.00072017; f =                  Inf
## lambda = 0.00070701; f =         -793.6439924
## lambda = 0.00071488; f =                  Inf
## Norm of dx    0.88372
## Cliff.  Perturbing search direction.
## Predicted improvement            =      105.704702547
## lambda =          1; f =                  Inf
## lambda =    0.33333; f =                  Inf
## lambda =    0.11111; f =                  Inf
## lambda =   0.037037; f =                  Inf
## lambda =   0.012346; f =                  Inf
## lambda =  0.0041152; f =                  Inf
## lambda =  0.0013717; f =                  Inf
## lambda = 0.00045725; f =         -793.6691842
## lambda = 0.00088394; f =                  Inf
## lambda =  0.0005952; f =         -793.6983501
## lambda =  0.0007546; f =                  Inf
## lambda = 0.00065446; f =         -793.7108803
## lambda = 0.00071283; f =                  Inf
## lambda = 0.00067721; f =                  Inf
```

```
## lambda =  0.0006567; f =         -793.7113539
## lambda = 0.00066893; f =         -793.7139398
## lambda = 0.00068139; f =                  Inf
## lambda = 0.00067389; f =                  Inf
## Norm of dx    0.93742
## Cliff again.  Try traversing
## Predicted improvement            =  3206327.141996205
## lambda =          1; f =                  Inf
## lambda =    0.33333; f =                  Inf
## lambda =    0.11111; f =                  Inf
## lambda =   0.037037; f =                  Inf
## lambda =   0.012346; f =                  Inf
## lambda =  0.0041152; f =                  Inf
## lambda =  0.0013717; f =                  Inf
## lambda = 0.00045725; f =                  Inf
## lambda = 0.00015242; f =                  Inf
## lambda = 5.0805e-05; f =                  Inf
## lambda = 1.6935e-05; f =                  Inf
## lambda =  5.645e-06; f =                  Inf
## lambda = 1.8817e-06; f =         -811.5725569
## lambda = 3.6376e-06; f =         -829.0600205
## lambda = 7.0322e-06; f =                  Inf
## lambda = 4.7351e-06; f =                  Inf
## lambda = 3.7348e-06; f =         -830.0321231
## lambda = 4.3063e-06; f =                  Inf
## lambda = 3.9537e-06; f =         -832.2170763
## lambda = 4.1616e-06; f =                  Inf
## lambda = 4.0356e-06; f =         -833.0325084
## lambda = 4.1107e-06; f =                  Inf
## lambda = 4.0655e-06; f =         -833.3298251
```

```
## Norm of dx     2532.3
## ----
## Improvement on iteration       16 =       39.757308688
## back and forth on step length never finished
## -----------------
## -----------------
## f at the beginning of new iteration,      -833.3298250899
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0238567123731 0.0104361484073 1.9999943606886 0.9257570328831 0.9974632558779
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -834.3175064
## Norm of dx    0.47551
## ----
## Improvement on iteration       17 =        0.987681263
## -----------------
## -----------------
## f at the beginning of new iteration,      -834.3175063529
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0236745623216 0.0103634047856 1.9999921897023 0.9257537379386 0.9973815058959
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -835.3066923
## Norm of dx    0.58838
## ----
## Improvement on iteration       18 =        0.989185965
## -----------------
## -----------------
```

```
## f at the beginning of new iteration,      -835.3066923176
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0234836081057 0.0102953767671 1.9999899114550 0.9257502806883 0.9973024945416
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -836.2972831
## lambda =     1.9332; f =         -837.2051425
## Norm of dx    0.58451
## ----
## Improvement on iteration       19 =        1.898450142
## -----------------
## -----------------
## f at the beginning of new iteration,      -837.2051424597
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0230990191197 0.0101743848317 1.9999853163083 0.9257433096164 0.9971548459491
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -838.1981804
## lambda =     1.9332; f =         -839.1125735
## Norm of dx    0.57969
## ----
## Improvement on iteration       20 =        1.907431057
## -----------------
## -----------------
## f at the beginning of new iteration,      -839.1125735171
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0226886212561 0.0100770880420 1.9999803933550 0.9257358481003 0.9970165925519
```

```
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -840.1073895
## lambda =     1.9332; f =         -841.0265196
## lambda =     3.7372; f =         -842.7777513
## Norm of dx    0.59047
## ----
## Improvement on iteration       21 =        3.665177734
## -----------------
## -----------------
## f at the beginning of new iteration,      -842.7777512516
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.02185792755226 0.00993473717631 1.99997036931598 0.92572067947845 0.99676572914189
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -843.7741464
## lambda =     1.9332; f =         -844.6973665
## lambda =     3.7372; f =         -846.4627966
## Norm of dx    0.61729
## ----
## Improvement on iteration       22 =        3.685045307
## -----------------
## -----------------
## f at the beginning of new iteration,      -846.4627965587
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.02097872320475 0.00987420329789 1.99995957191012 0.92570441563827 0.99654020983248
## Predicted improvement            =       59.335187752
## lambda =          1; f =         -122.6254048
```

```
## lambda =    0.33333; f =        -871.8562435
## Norm of dx    0.73531
## ----
## Improvement on iteration       23 =       25.393446952
## -----------------
## -----------------
## f at the beginning of new iteration,      -871.8562435107
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.01511010477466 0.00817116003253 1.75501621462895 0.92135827807504 0.99187165381283
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =        -872.8111603
## Norm of dx   0.089156
## ----
## Improvement on iteration       24 =        0.954916833
## -----------------
## -----------------
## f at the beginning of new iteration,      -872.8111603440
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.01507935598126 0.00828057669377 1.75501585855759 0.92135746345566 0.99186721403861
## Predicted improvement            =        9.205190532
## lambda =          1; f =        -882.6959019
## Norm of dx    0.20082
## ----
## Improvement on iteration       25 =        9.884741546
## -----------------
## -----------------
## f at the beginning of new iteration,      -882.6959018903
```

```
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0148862952073 0.0094482082848 1.5547108997700 0.9094825870201 0.9839219149907
## H unused
## Predicted improvement            =        0.500000000
## lambda =          1; f =         -883.6600036
## Norm of dx    0.20376
## ----
## Improvement on iteration       26 =        0.964101749
## -----------------
## -----------------
## f at the beginning of new iteration,      -883.6600036393
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.01464616792161 0.00954110876507 1.55471057967161 0.90948075135027 0.98392718244172
## Predicted improvement            =        7.926362770
## lambda =          1; f =         -889.1479770
## Norm of dx   0.031204
## ----
## Improvement on iteration       27 =        5.487973373
## -----------------
## -----------------
## f at the beginning of new iteration,      -889.1479770127
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0104134378474 0.0106982062748 1.5250814741610 0.9031850881647 0.9778503464840
## Predicted improvement            =        3.275863548
## lambda =          1; f =         -891.3684522
## Norm of dx   0.055325
## ----
```

```
## Improvement on iteration       28 =        2.220475209
## -----------------
## -----------------
## f at the beginning of new iteration,      -891.3684522219
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0119051674017 0.0103121481403 1.4698731005164 0.9001710300962 0.9766595740125
## Predicted improvement            =        0.751749575
## lambda =          1; f =         -892.6809610
## Norm of dx   0.019895
## ----
## Improvement on iteration       29 =        1.312508797
## -----------------
## -----------------
## f at the beginning of new iteration,      -892.6809610184
## x =
##   sd(epsilon_Z)   sd(epsilon_G)           omega           phi_G           phi_Z
## 0.0112455493104 0.0103040545459 1.4506666282013 0.8968613847770 0.9727167679411
## Predicted improvement            =        2.138741559
## lambda =          1; f =         -894.1563150
## Norm of dx    0.05537
## ----
## Improvement on iteration       30 =        1.475353974
## -----------------
## -----------------
## f at the beginning of new iteration,      -894.1563149922
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00929476611824 0.00994596820673 1.39824565707777 0.88821650821512 0.95725086050849
## Predicted improvement            =        0.951551073
```

```
## lambda =           1; f =         -895.1470629
## Norm of dx  0.0024772
## ----
## Improvement on iteration       31 =        0.990747945
## -----------------
## -----------------
## f at the beginning of new iteration,      -895.1470629374
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00999738036049 0.00981089713705 1.39810983820807 0.89023014528865 0.95849646928212
## Predicted improvement            =        0.243317905
## lambda =           1; f =         -895.5119192
## Norm of dx   0.012746
## ----
## Improvement on iteration       32 =        0.364856262
## -----------------
## -----------------
## f at the beginning of new iteration,      -895.5119191998
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00987223335746 0.00960388529381 1.38613056881245 0.89091845084976 0.95420350499469
## Predicted improvement            =        0.229982580
## lambda =           1; f =         -895.8404633
## Norm of dx   0.015442
## ----
## Improvement on iteration       33 =        0.328544072
## -----------------
## -----------------
## f at the beginning of new iteration,      -895.8404632719
## x =
```

```
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00964150326575 0.00942836136127 1.37208242771161 0.89314613973793 0.94819983201983
## Predicted improvement            =        0.230725865
## lambda =          1; f =         -896.2169310
## Norm of dx    0.01085
## ----
## Improvement on iteration       34 =        0.376467707
## -----------------
## -----------------
## f at the beginning of new iteration,      -896.2169309793
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00941395930217 0.00935457342360 1.36394519621116 0.89579715015202 0.94153441047964
## Predicted improvement            =        0.566148783
## lambda =          1; f =         -897.0643735
## Norm of dx   0.015681
## ----
## Improvement on iteration       35 =        0.847442546
## -----------------
## -----------------
## f at the beginning of new iteration,      -897.0643735248
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00902379292214 0.00935961124042 1.36441898532173 0.90040879582974 0.92655975559764
## Predicted improvement            =        0.630673562
## lambda =          1; f =         -897.9689687
## Norm of dx   0.028269
## ----
## Improvement on iteration       36 =        0.904595132
## -----------------
```

```
## -----------------
## f at the beginning of new iteration,      -897.9689686571
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00880526933345 0.00952679912980 1.38643736156858 0.90303956944163 0.90902945186438
## Predicted improvement            =        0.367172261
## lambda =          1; f =         -898.4254648
## Norm of dx   0.032195
## ----
## Improvement on iteration       37 =        0.456496136
## -----------------
## -----------------
## f at the beginning of new iteration,      -898.4254647930
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00884465030593 0.00974795868987 1.41609170147484 0.90160776603376 0.89657798254267
## Predicted improvement            =        0.041670237
## lambda =          1; f =         -898.4726186
## Norm of dx   0.011644
## ----
## Improvement on iteration       38 =        0.047153815
## -----------------
## -----------------
## f at the beginning of new iteration,      -898.4726186084
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00885267701848 0.00983748098237 1.42682862861279 0.89941731319654 0.89264044415818
## Predicted improvement            =        0.001613451
## lambda =          1; f =         -898.4744242
## Norm of dx 0.00073768
```

```
## ----
## Improvement on iteration       39 =        0.001805579
## -----------------
## -----------------
## f at the beginning of new iteration,      -898.4744241874
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00886723135473 0.00985543047356 1.42712375575694 0.89874433224872 0.89258010707982
## Predicted improvement            =        0.000119601
## lambda =          1; f =         -898.4745615
## Norm of dx 0.00023931
## ----
## Improvement on iteration       40 =        0.000137334
## -----------------
## -----------------
## f at the beginning of new iteration,      -898.4745615212
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00886443906194 0.00985782851119 1.42711012610656 0.89852493531279 0.89267462834690
## Predicted improvement            =        0.000020199
## lambda =          1; f =         -898.4745892
## Norm of dx 0.00018587
## ----
## Improvement on iteration       41 =        0.000027722
## -----------------
## -----------------
## f at the beginning of new iteration,      -898.4745892432
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00886560395217 0.00985813574894 1.42701627466330 0.89848966905616 0.89283113388589
```

```
## Predicted improvement            =        0.000004059
## lambda =          1; f =         -898.4745960
## Norm of dx 8.8308e-05
## ----
## Improvement on iteration       42 =        0.000006712
## -----------------
## -----------------
## f at the beginning of new iteration,      -898.4745959554
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00886606256094 0.00985843043840 1.42707786085718 0.89850360423300 0.89289286638953
## Predicted improvement            =        0.000000990
## lambda =          1; f =         -898.4745981
## lambda =     1.9332; f =         -898.4745987
## Norm of dx 6.8509e-05
## ----
## Improvement on iteration       43 =        0.000002706
## -----------------
## -----------------
## f at the beginning of new iteration,      -898.4745986613
## x =
##    sd(epsilon_Z)    sd(epsilon_G)            omega            phi_G            phi_Z
## 0.00886651900406 0.00985910431259 1.42720318699852 0.89853401924212 0.89292300140767
## Predicted improvement            =        0.000000504
## lambda =          1; f =         -898.4745984
## lambda =    0.33333; f =         -898.4745987
## Norm of dx 4.7692e-05
## ih = 1
## ----
## Improvement on iteration       44 =        0.000000026
```

```
## improvement < crit termination
##
## The solver has stopped searching for the solution.
##
##
## Computes inverse Hessian of the posterior kernel at the mode: DONE.
##
##
## Maximisation routine solution:
## sd(epsilon_Z) sd(epsilon_G)         omega         phi_G         phi_Z
##   0.008866451   0.009859030   1.427188881   0.898530299   0.892917151
##
## Candidate for posterior mode FOUND
##
## Computing marginal density (Laplace approximation)
## (Log-)marginal density
##               878.2836
##
## Running burn-in phase ...
##
## Progress:  400/2400( 17% )
## Time consumed:  00h 00m 57s
## Estimated time left:  00h 01m 27s
## Acceptance rate:  60%
## Steady state failures:  0
## Perturbation failures:  0
##
## Burn-in phase DONE.
##
## Running proper phase of MCMC ...
```

```
##
## Progress:  900/2400( 38% )
## Time consumed:  00h 01m 16s
## Estimated time left:  00h 01m 01s
## Acceptance rate:  58%
## Steady state failures:  0
## Perturbation failures:  0
##
## Current estimates:
##
##                  Mean       Std. dev.
## sd(epsilon_Z)   0.008931   0.0006765
## sd(epsilon_G)   0.010072   0.0005731
## omega           1.396506   0.0834375
## phi_G           0.895451   0.0165865
## phi_Z           0.894022   0.0277492
##
##
## Progress:  1400/2400( 58% )
## Time consumed:  00h 01m 36s
## Estimated time left:  00h 00m 41s
## Acceptance rate:  58%
## Steady state failures:  0
## Perturbation failures:  0
##
## Current estimates:
##
##                  Mean       Std. dev.
## sd(epsilon_Z)   0.009179   0.0007903
## sd(epsilon_G)   0.010089   0.0005727
```

```
## omega           1.427278   0.0979651
## phi_G           0.898266   0.0168379
## phi_Z           0.902131   0.0295521
##
##
## Progress:  1900/2400( 79% )
## Time consumed:  00h 01m 56s
## Estimated time left:  00h 00m 20s
## Acceptance rate:  58%
## Steady state failures:  0
## Perturbation failures:  0
##
## Current estimates:
##
##                 Mean       Std. dev.
## sd(epsilon_Z)   0.009027   0.0007940
## sd(epsilon_G)   0.010029   0.0005561
## omega           1.411469   0.1008320
## phi_G           0.897257   0.0182132
## phi_Z           0.894715   0.0308442
##
##
## Progress:  2400/2400( 100% )
## Time consumed:  00h 02m 16s
## Estimated time left:  00h 00m 00s
## Acceptance rate:  59%
## Steady state failures:  0
## Perturbation failures:  0
##
## Current estimates:
```

```
##
##                  Mean       Std. dev.
## sd(epsilon_Z)    0.008962   0.0007563
## sd(epsilon_G)    0.009977   0.0005647
## omega            1.410502   0.0970033
## phi_G            0.897292   0.0182773
## phi_Z            0.892733   0.0310480
##
##
## Estimation is DONE. Total time elapsed:  00h 02m 16s
```

```r
plot_posterior(estimation_result)



# csminwel: http://sims.princeton.edu/yftp/optimize/


# retrieve estimates
# true model parameters were:
# sd(epsilon_Z) 0.01
# sd(epsilon_G) 0.01
# omega 1.45
# phi_G 0.9
# phi_Z 0.9
est_par <- get_estimated_par(estimation_result)
```

```
## Estimated parameter values:
##                    Values:
## sd(epsilon_Z) 0.009006809
## sd(epsilon_G) 0.009898204
## omega         1.412736976
## phi_G         0.897513530
```

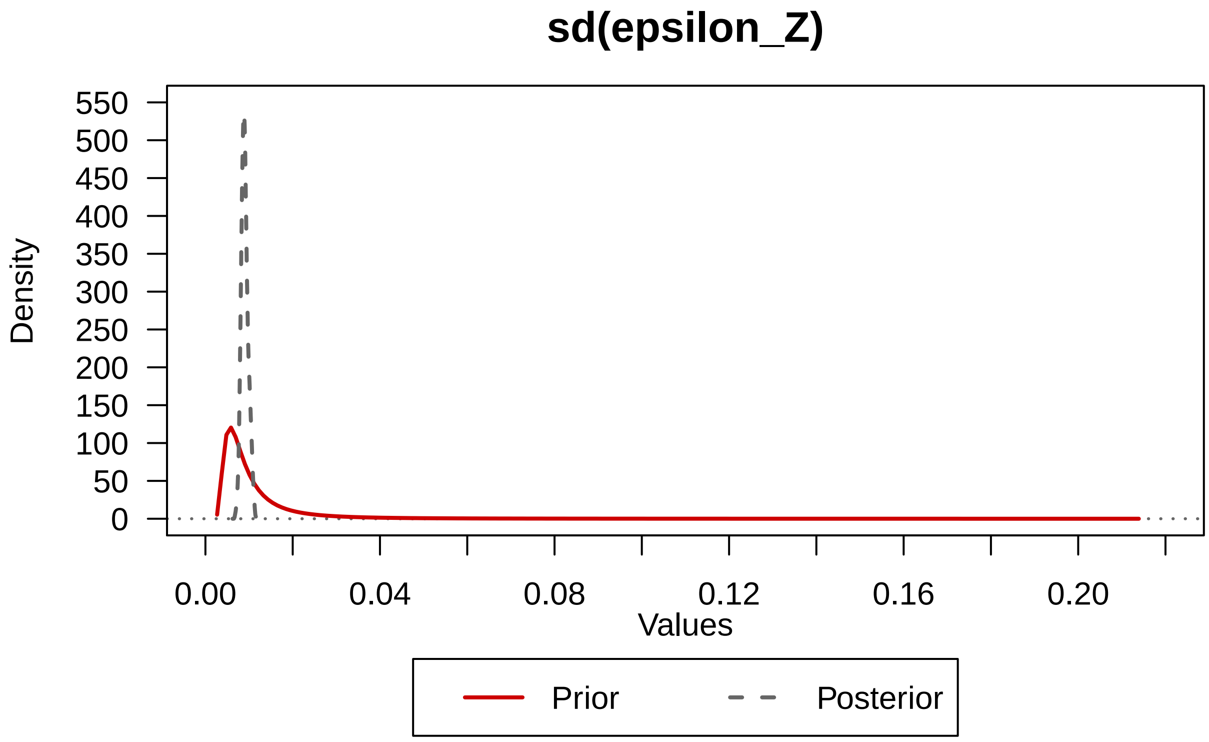
```
## phi_Z         0.892903359
```

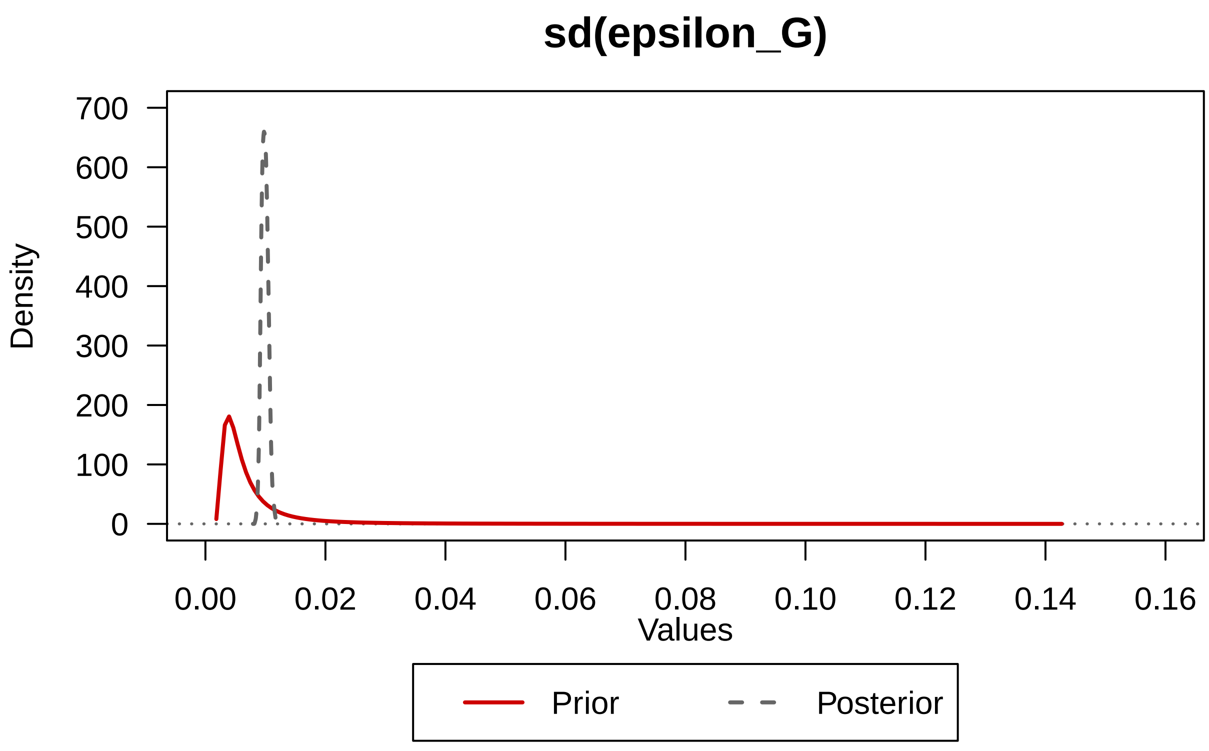
```r
free_par <- est_par$free_par
shock_distr_par <- est_par$shock_distr_par
estimated_dsge_model <- set_free_par(dsge_model, free_par = free_par)
estimated_dsge_model <- set_shock_distr_par(estimated_dsge_model, distr_par = shock_distr_par)
estimated_dsge_model <- steady_state(estimated_dsge_model)
```

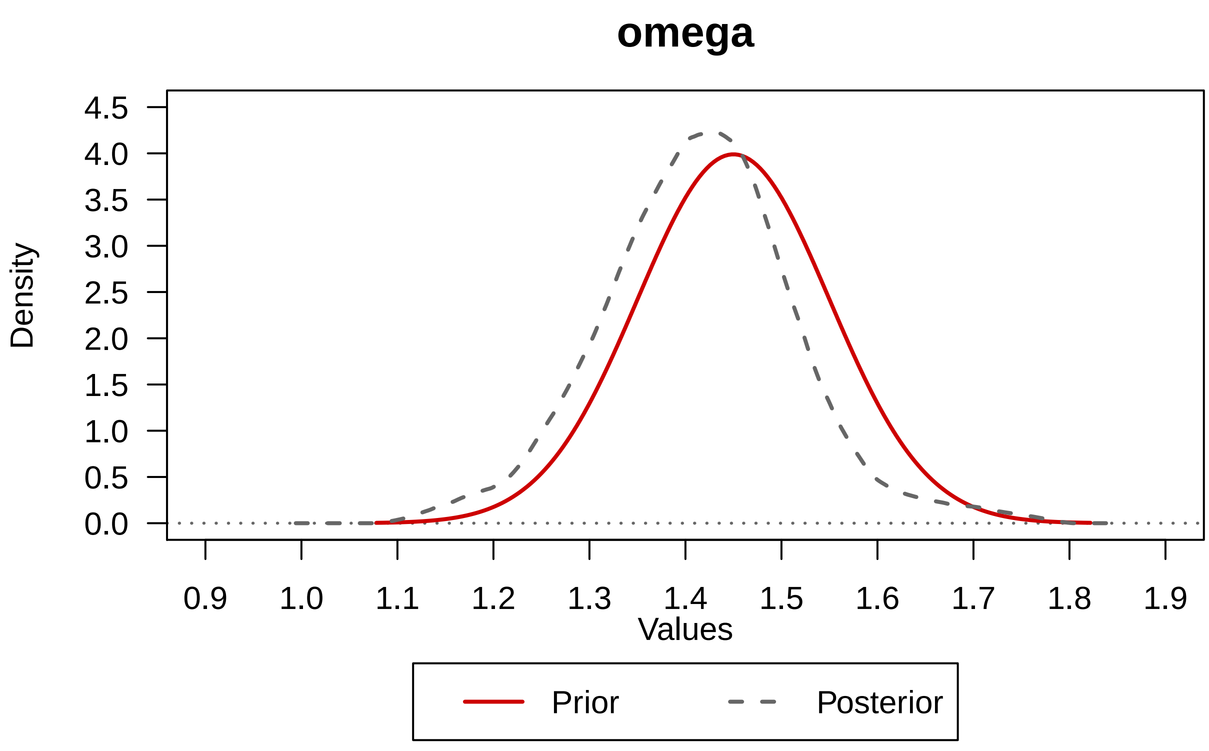
```
## Steady state has been FOUND
```

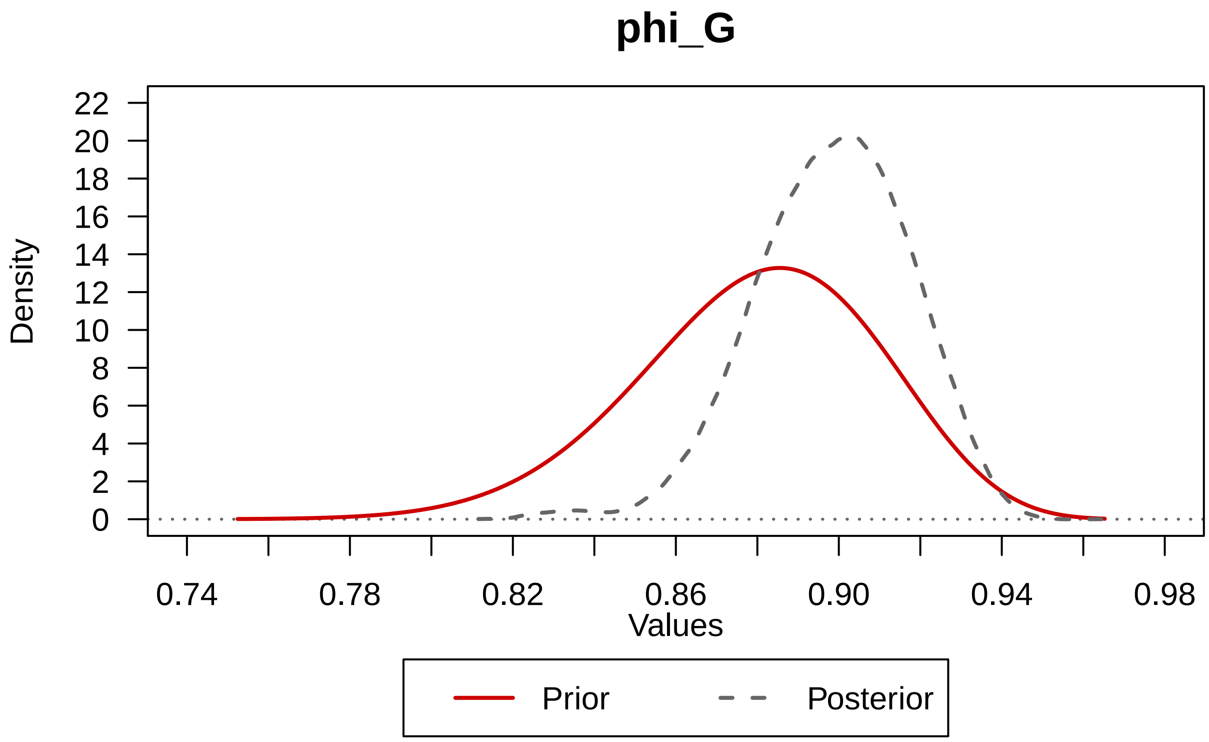
```r
estimated_dsge_model <- solve_pert(estimated_dsge_model, loglin = TRUE)
```

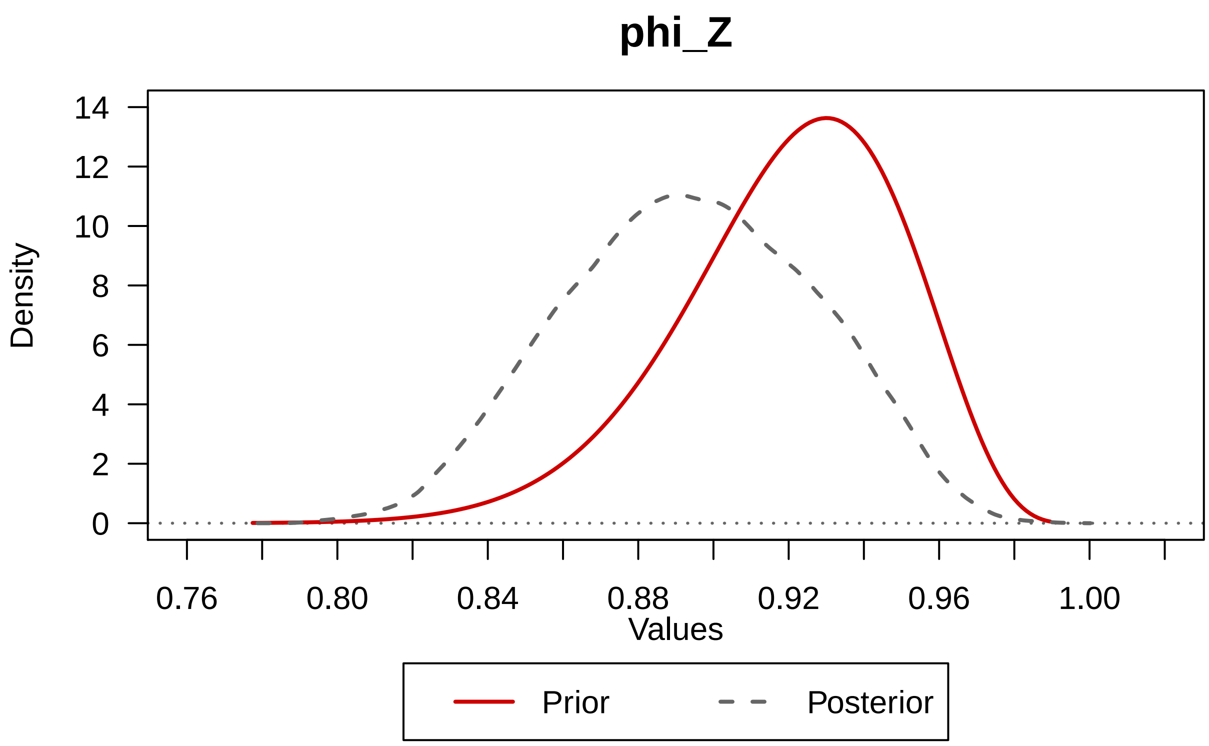
```
## Model has been SOLVED
```




sd(epsilon_G)
Density
700
600
500
400
300
200
100
0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
Values
Prior
Posterior


omega
Density
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
Values
Prior
Posterior


phi_G
Density
22
20
18
16
14
12
10
8
6
4
2
0
0.74
0.78
0.82
0.86
0.90
0.94
0.98
Values
Prior
Posterior


phi_Z
Density
14
12
10
8
6
4
2
0
0.76
0.80
0.84
0.88
0.92
0.96
1.00
Values
Prior
Posterior

```r
# ####################################################################
# 5. historical shock decomposition and variable smoothing
# find historical shock decomposition
dsge_shock_decomp <- shock_decomposition(model = estimated_dsge_model,
                                         data_set = window(estimation_data,
                                                           start = c(2004, 1),
                                                           end = c(2010, 1),
                                                           frequency = 4),
                                         observables = observables,
                                         variables = observables)
plot_shock_decomposition(dsge_shock_decomp)
# use Kalman smoother to obtain smoothed variables' values
dsge_smoothed_variables <- smoother(model = estimated_dsge_model,
                                    data_set = estimation_data,
                                    observables = c("Y", "G"),
                                    variables = c("K", "I", "C"))


# print smoothed shocks' values
dsge_smoothed_variables$smoothed_shock
```

```
##             epsilon_G     epsilon_Z
## 1973 Q1 -0.0002923913 -2.448697e-04
## 1973 Q2  0.0031686164  7.536763e-03
## 1973 Q3 -0.0166798010  4.905527e-03
## 1973 Q4 -0.0091035494 -9.090039e-03
## 1974 Q1  0.0052054438 -1.340887e-02
## 1974 Q2  0.0122654738  7.204123e-03
## 1974 Q3  0.0030997676  3.255889e-03
## 1974 Q4 -0.0119168365 -4.263854e-03
```

```
## 1975 Q1 -0.0048166851  1.293068e-02
## 1975 Q2  0.0104857062 -1.032784e-02
## 1975 Q3 -0.0052861871  1.464332e-03
## 1975 Q4 -0.0005310195 -8.421220e-03
## 1976 Q1 -0.0053723199 -1.347343e-03
## 1976 Q2 -0.0018302907 -1.039950e-02
## 1976 Q3 -0.0146729430  1.474396e-02
## 1976 Q4 -0.0019110631  3.727916e-03
## 1977 Q1 -0.0057856572 -1.149017e-03
## 1977 Q2  0.0087908549  6.891102e-03
## 1977 Q3  0.0135204287 -7.591692e-03
## 1977 Q4 -0.0107544712 -3.749390e-03
## 1978 Q1  0.0037051230 -3.783189e-04
## 1978 Q2 -0.0097975293  3.936227e-03
## 1978 Q3 -0.0005587253 -1.189989e-02
## 1978 Q4  0.0083779110 -2.964147e-03
## 1979 Q1  0.0021505550 -5.759420e-03
## 1979 Q2 -0.0115163234  9.178243e-04
## 1979 Q3  0.0028071378  8.050321e-03
## 1979 Q4  0.0068683272  1.513153e-03
## 1980 Q1  0.0012939604  1.600904e-03
## 1980 Q2 -0.0006765656 -3.851386e-03
## 1980 Q3  0.0036643613 -3.216176e-03
## 1980 Q4 -0.0018602373 -1.194890e-02
## 1981 Q1  0.0144005034  3.343980e-03
## 1981 Q2 -0.0035015712  5.534297e-03
## 1981 Q3 -0.0139687742 -2.126177e-02
## 1981 Q4  0.0006920075 -6.436612e-03
## 1982 Q1 -0.0079392977  4.362571e-03
## 1982 Q2  0.0047216067 -9.742803e-03
```

```
## 1982 Q3  0.0025227201  9.443316e-03
## 1982 Q4  0.0048745325 -3.320005e-04
## 1983 Q1  0.0102345066 -4.608775e-03
## 1983 Q2  0.0068896585 -8.011131e-04
## 1983 Q3  0.0210179712  1.788043e-02
## 1983 Q4  0.0117187788 -5.344215e-03
## 1984 Q1 -0.0087478318 -7.354002e-03
## 1984 Q2 -0.0048063341  3.032926e-03
## 1984 Q3  0.0153715304  1.250000e-02
## 1984 Q4  0.0219651192 -8.993457e-03
## 1985 Q1  0.0079193245 -6.669265e-03
## 1985 Q2  0.0123389638 -5.997566e-03
## 1985 Q3 -0.0088410918  8.222220e-03
## 1985 Q4  0.0123761588  4.159277e-04
## 1986 Q1 -0.0023518507  1.277412e-02
## 1986 Q2  0.0066443359  5.593540e-03
## 1986 Q3  0.0112312880  7.706126e-03
## 1986 Q4  0.0043430385  8.543798e-03
## 1987 Q1  0.0006818738 -2.523524e-04
## 1987 Q2  0.0008334159 -3.920095e-05
## 1987 Q3  0.0116779179 -1.216870e-02
## 1987 Q4 -0.0006409225  1.239544e-02
## 1988 Q1 -0.0090151013  1.675041e-02
## 1988 Q2 -0.0111465354  5.966612e-03
## 1988 Q3  0.0124059813  3.430640e-03
## 1988 Q4  0.0209617570  1.941460e-02
## 1989 Q1  0.0065041646 -6.866563e-03
## 1989 Q2 -0.0104949622 -3.018784e-03
## 1989 Q3 -0.0032816112 -1.335257e-03
## 1989 Q4  0.0090566266 -1.076578e-02
```

```
## 1990 Q1 -0.0013291079 -2.102884e-02
## 1990 Q2 -0.0121351405  1.162007e-02
## 1990 Q3 -0.0104675843 -4.982244e-03
## 1990 Q4  0.0075075759  1.260137e-03
## 1991 Q1  0.0054500051 -3.035212e-03
## 1991 Q2  0.0003759029  1.663826e-03
## 1991 Q3  0.0149625712  3.692725e-03
## 1991 Q4 -0.0043073403 -1.498971e-02
## 1992 Q1 -0.0092816012  2.265488e-02
## 1992 Q2 -0.0255057541 -1.750413e-02
## 1992 Q3 -0.0038744106  3.319955e-03
## 1992 Q4 -0.0131626539 -1.090373e-02
## 1993 Q1 -0.0070382726  6.681225e-03
## 1993 Q2  0.0221476981 -6.601633e-03
## 1993 Q3 -0.0123074529  1.069848e-02
## 1993 Q4  0.0051804336  3.241285e-03
## 1994 Q1  0.0158082622  5.141563e-03
## 1994 Q2  0.0095610373 -1.127800e-02
## 1994 Q3 -0.0043763999 -1.385336e-02
## 1994 Q4 -0.0068112620  1.217365e-02
## 1995 Q1 -0.0089696496 -7.062405e-03
## 1995 Q2  0.0007511999  2.516485e-03
## 1995 Q3  0.0045573809 -2.691161e-03
## 1995 Q4  0.0015514217 -9.283217e-04
## 1996 Q1 -0.0168305127  3.980786e-03
## 1996 Q2 -0.0071000319 -2.048397e-04
## 1996 Q3 -0.0080906802  1.995237e-02
## 1996 Q4 -0.0161718006  1.130563e-03
## 1997 Q1  0.0100103020 -2.580200e-03
## 1997 Q2 -0.0032395971 -1.523517e-02
```

```
## 1997 Q3 -0.0038717991 -5.981981e-03
## 1997 Q4  0.0114406752  7.191923e-03
## 1998 Q1  0.0043295040  6.921274e-03
## 1998 Q2 -0.0062559966  8.679511e-03
## 1998 Q3  0.0038422089 -6.190460e-03
## 1998 Q4 -0.0041522076  1.116054e-02
## 1999 Q1 -0.0053255025 -1.683899e-02
## 1999 Q2 -0.0021871765 -3.933895e-03
## 1999 Q3 -0.0190671091 -1.315710e-03
## 1999 Q4  0.0026902914 -4.961590e-03
## 2000 Q1  0.0065627361 -1.237080e-02
## 2000 Q2  0.0138112812  9.306412e-03
## 2000 Q3 -0.0088631552 -3.359310e-03
## 2000 Q4  0.0120208538 -1.122340e-02
## 2001 Q1 -0.0049057011 -1.706266e-03
## 2001 Q2  0.0171613524  4.800149e-03
## 2001 Q3  0.0127004121  1.604417e-03
## 2001 Q4 -0.0033426605 -2.297636e-03
## 2002 Q1 -0.0131458326  6.523209e-03
## 2002 Q2 -0.0001478813  7.868010e-03
## 2002 Q3 -0.0086025586 -2.871695e-03
## 2002 Q4 -0.0031182651 -2.211389e-04
## 2003 Q1  0.0191191920  5.650920e-03
## 2003 Q2  0.0164972465  1.262432e-02
## 2003 Q3 -0.0143695221 -5.654344e-03
## 2003 Q4 -0.0118690773  1.722847e-03
## 2004 Q1  0.0070244778  9.987707e-03
## 2004 Q2 -0.0097096453  4.644059e-03
## 2004 Q3 -0.0030950696 -1.466496e-02
## 2004 Q4  0.0029975441  6.370864e-04
```

```
## 2005 Q1 -0.0088640158 -2.919460e-03
## 2005 Q2  0.0033863230  1.800327e-02
## 2005 Q3 -0.0129905398  5.963736e-03
## 2005 Q4  0.0032244849  8.226262e-04
## 2006 Q1  0.0021969760 -1.076971e-02
## 2006 Q2 -0.0074942364 -1.847155e-03
## 2006 Q3 -0.0041825431  1.768727e-03
## 2006 Q4 -0.0282713920  2.078331e-02
## 2007 Q1  0.0108198147 -5.558412e-03
## 2007 Q2 -0.0015235474 -8.787866e-03
## 2007 Q3 -0.0104334253 -4.728317e-03
## 2007 Q4  0.0044603913  5.608480e-03
## 2008 Q1 -0.0063404381  9.195251e-03
## 2008 Q2 -0.0100512687 -1.326091e-02
## 2008 Q3 -0.0150943119  7.019759e-03
## 2008 Q4 -0.0046154013 -8.102353e-03
## 2009 Q1  0.0168440473 -3.583513e-03
## 2009 Q2  0.0100923870 -9.258323e-03
## 2009 Q3  0.0101219432 -1.212852e-02
## 2009 Q4 -0.0130432583 -1.326514e-02
## 2010 Q1 -0.0083365655 -6.156235e-04
## 2010 Q2 -0.0013234762 -1.459335e-02
```

```
# print smoothed variables' values
dsge_smoothed_variables$smoothed_var
```

```
##                     K             I            C
## 1973 Q1  0.0014592099 -0.0041948580 6.694447e-04
## 1973 Q2  0.0021547284  0.0408231230 1.619754e-03
## 1973 Q3  0.0044113274  0.1066681749 6.563920e-03
## 1973 Q4  0.0057818402  0.0495114862 6.645191e-03
```

```
## 1974 Q1  0.0049430044 -0.0625932875  2.335691e-03
## 1974 Q2  0.0043319811 -0.0335557545  8.978732e-04
## 1974 Q3  0.0040008210 -0.0144172368  8.142475e-04
## 1974 Q4  0.0039195118 -0.0154700687  2.485685e-03
## 1975 Q1  0.0057575273  0.0857168654  6.333289e-03
## 1975 Q2  0.0053705550 -0.0217513722  1.682875e-03
## 1975 Q3  0.0055342706  0.0023000308  3.094445e-03
## 1975 Q4  0.0046377184 -0.0558288331  1.221365e-03
## 1976 Q1  0.0040207718 -0.0464078268  1.908565e-03
## 1976 Q2  0.0022936097 -0.1086044424 -2.518373e-04
## 1976 Q3  0.0035694957  0.0399794682  6.008018e-03
## 1976 Q4  0.0052490120  0.0635784415  7.130932e-03
## 1977 Q1  0.0069048870  0.0589822591  8.072617e-03
## 1977 Q2  0.0086194187  0.0770180275  7.498062e-03
## 1977 Q3  0.0082662765 -0.0178318514  2.719970e-03
## 1977 Q4  0.0081417206 -0.0182637098  4.180151e-03
## 1978 Q1  0.0077259271 -0.0283786236  3.061485e-03
## 1978 Q2  0.0084510471  0.0233221739  5.971817e-03
## 1978 Q3  0.0075967219 -0.0621400838  3.273913e-03
## 1978 Q4  0.0059371182 -0.0948029785  4.027486e-04
## 1979 Q1  0.0036311283 -0.1278052786 -1.677539e-03
## 1979 Q2  0.0024735295 -0.0790558107  7.850658e-04
## 1979 Q3  0.0022997097 -0.0201528548  1.659652e-03
## 1979 Q4  0.0018994765 -0.0231774163  3.161141e-04
## 1980 Q1  0.0016663573 -0.0123418046  3.059809e-04
## 1980 Q2  0.0010207634 -0.0359642935 -4.511743e-04
## 1980 Q3 -0.0001722038 -0.0618216298 -2.094884e-03
## 1980 Q4 -0.0025756561 -0.1316081128 -4.481628e-03
## 1981 Q1 -0.0051278288 -0.1233066545 -7.236187e-03
## 1981 Q2 -0.0063986532 -0.0597636277 -5.316787e-03
```

```
## 1981 Q3 -0.0092469113 -0.1653956292 -6.968110e-03
## 1981 Q4 -0.0125119877 -0.1879732912 -8.914227e-03
## 1982 Q1 -0.0142297434 -0.1130802021 -6.502651e-03
## 1982 Q2 -0.0171678750 -0.1738417558 -9.995918e-03
## 1982 Q3 -0.0186115940 -0.0888286968 -8.738968e-03
## 1982 Q4 -0.0201334410 -0.0874600356 -9.986024e-03
## 1983 Q1 -0.0225911471 -0.1275234301 -1.334550e-02
## 1983 Q2 -0.0251616341 -0.1278706202 -1.508520e-02
## 1983 Q3 -0.0263788366 -0.0309908389 -1.572981e-02
## 1983 Q4 -0.0287462264 -0.0852678943 -1.913219e-02
## 1984 Q1 -0.0310566615 -0.0992766385 -1.842415e-02
## 1984 Q2 -0.0322563547 -0.0487282630 -1.638553e-02
## 1984 Q3 -0.0325833810  0.0146234016 -1.669531e-02
## 1984 Q4 -0.0352632554 -0.0930826832 -2.307959e-02
## 1985 Q1 -0.0387878010 -0.1378621767 -2.585472e-02
## 1985 Q2 -0.0432224004 -0.1814769638 -2.952738e-02
## 1985 Q3 -0.0453119476 -0.0725464930 -2.524517e-02
## 1985 Q4 -0.0476841434 -0.0798923931 -2.735754e-02
## 1986 Q1 -0.0478188932  0.0327466728 -2.331205e-02
## 1986 Q2 -0.0474887064  0.0604535886 -2.271904e-02
## 1986 Q3 -0.0467854107  0.0886248832 -2.260782e-02
## 1986 Q4 -0.0452255947  0.1344468961 -2.065089e-02
## 1987 Q1 -0.0438014487  0.1216237600 -1.977215e-02
## 1987 Q2 -0.0424810632  0.1113002796 -1.895884e-02
## 1987 Q3 -0.0434541588 -0.0060565966 -2.338415e-02
## 1987 Q4 -0.0425540162  0.0895517516 -1.970446e-02
## 1988 Q1 -0.0389690289  0.2211671900 -1.300172e-02
## 1988 Q2 -0.0342937958  0.2650161629 -8.092764e-03
## 1988 Q3 -0.0304968078  0.2311793387 -9.106821e-03
## 1988 Q4 -0.0260166588  0.2921520706 -8.463573e-03
```

```
## 1989 Q1 -0.0233413900  0.1964416941 -1.023966e-02
## 1989 Q2 -0.0206773722  0.1780582294 -7.547245e-03
## 1989 Q3 -0.0182736815  0.1566254053 -6.285062e-03
## 1989 Q4 -0.0180587836  0.0446161336 -1.004239e-02
## 1990 Q1 -0.0203586746 -0.0995830124 -1.397697e-02
## 1990 Q2 -0.0200528109  0.0249687768 -8.471049e-03
## 1990 Q3 -0.0196789905  0.0145068042 -6.924772e-03
## 1990 Q4 -0.0195994921  0.0074007753 -8.137018e-03
## 1991 Q1 -0.0201827931 -0.0235433534 -9.810500e-03
## 1991 Q2 -0.0204286184 -0.0063340441 -9.312143e-03
## 1991 Q3 -0.0210499715 -0.0104621084 -1.160450e-02
## 1991 Q4 -0.0231142795 -0.0986746101 -1.366448e-02
## 1992 Q1 -0.0213937460  0.0955421235 -6.364977e-03
## 1992 Q2 -0.0204099539  0.0236438744 -4.131505e-03
## 1992 Q3 -0.0188205045  0.0550042465 -2.454658e-03
## 1992 Q4 -0.0179056762  0.0049890581 -1.850722e-03
## 1993 Q1 -0.0157615381  0.0684758928  1.127858e-03
## 1993 Q2 -0.0160679655 -0.0344854718 -5.353957e-03
## 1993 Q3 -0.0141544949  0.0740092897 -2.092998e-04
## 1993 Q4 -0.0123687049  0.0765866957 -5.405129e-04
## 1994 Q1 -0.0111353411  0.0677007835 -2.782000e-03
## 1994 Q2 -0.0120447922 -0.0387778596 -7.206507e-03
## 1994 Q3 -0.0142411321 -0.1169501458 -9.233869e-03
## 1994 Q4 -0.0141300823  0.0002554895 -5.055827e-03
## 1995 Q1 -0.0142970634 -0.0258638165 -4.524586e-03
## 1995 Q2 -0.0141171205 -0.0047243967 -4.151669e-03
## 1995 Q3 -0.0145305543 -0.0308731749 -5.747768e-03
## 1995 Q4 -0.0150450488 -0.0344237339 -6.282813e-03
## 1996 Q1 -0.0138711679  0.0380695196 -1.567686e-03
## 1996 Q2 -0.0123798527  0.0495349540  3.354388e-05
```

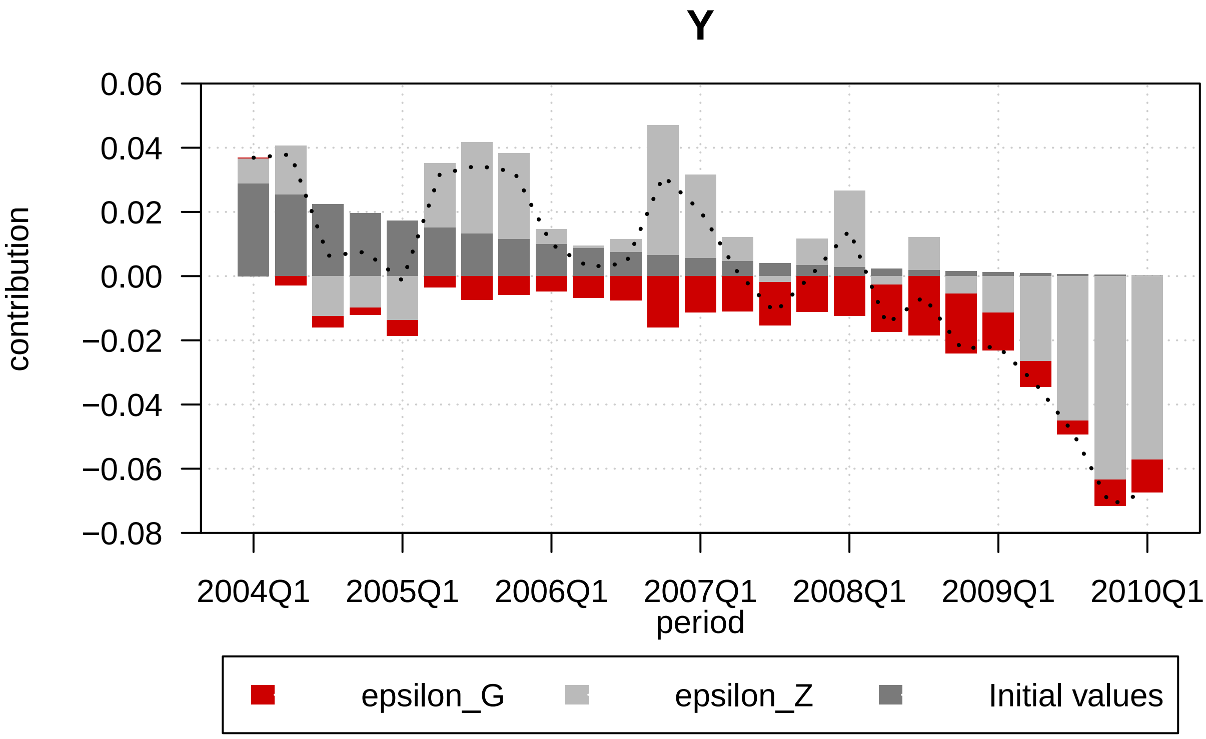
```
## 1996 Q3 -0.0080378781  0.2002030964  6.368998e-03
## 1996 Q4 -0.0030967589  0.2187398361  1.053998e-02
## 1997 Q1  0.0002289025  0.1488853184  7.883012e-03
## 1997 Q2  0.0014015390  0.0309301047  5.289255e-03
## 1997 Q3  0.0019114169 -0.0064018789  4.644882e-03
## 1997 Q4  0.0025281361  0.0171613796  3.428432e-03
## 1998 Q1  0.0036455275  0.0520429797  3.915476e-03
## 1998 Q2  0.0060763234  0.1183276460  7.296068e-03
## 1998 Q3  0.0071351970  0.0500264080  5.142627e-03
## 1998 Q4  0.0096796173  0.1283439533  8.576987e-03
## 1999 Q1  0.0100703891  0.0056128476  6.097984e-03
## 1999 Q2  0.0100201533 -0.0192031721  5.508481e-03
## 1999 Q3  0.0109832910  0.0155446085  9.245139e-03
## 1999 Q4  0.0109914843 -0.0292329971  7.196939e-03
## 2000 Q1  0.0090049448 -0.1277421765  2.558646e-03
## 2000 Q2  0.0075559570 -0.0797902526  1.043867e-03
## 2000 Q3  0.0064198659 -0.0735121063  2.021629e-03
## 2000 Q4  0.0032588740 -0.1695383465 -3.515621e-03
## 2001 Q1  0.0006196654 -0.1481501266 -3.186598e-03
## 2001 Q2 -0.0021388609 -0.1344682518 -6.327903e-03
## 2001 Q3 -0.0051125076 -0.1337060194 -8.991783e-03
## 2001 Q4 -0.0077381612 -0.1228694650 -8.810872e-03
## 2002 Q1 -0.0083312374 -0.0302177258 -4.442517e-03
## 2002 Q2 -0.0078194206  0.0297316402 -2.605178e-03
## 2002 Q3 -0.0071657963  0.0268165482 -1.159945e-03
## 2002 Q4 -0.0064049323  0.0298289866 -4.357053e-04
## 2003 Q1 -0.0062240776  0.0223312770 -3.409794e-03
## 2003 Q2 -0.0055124115  0.0701797087 -4.079671e-03
## 2003 Q3 -0.0046858198  0.0559174962 -1.699355e-03
## 2003 Q4 -0.0029944035  0.0882053816  1.602327e-03
```

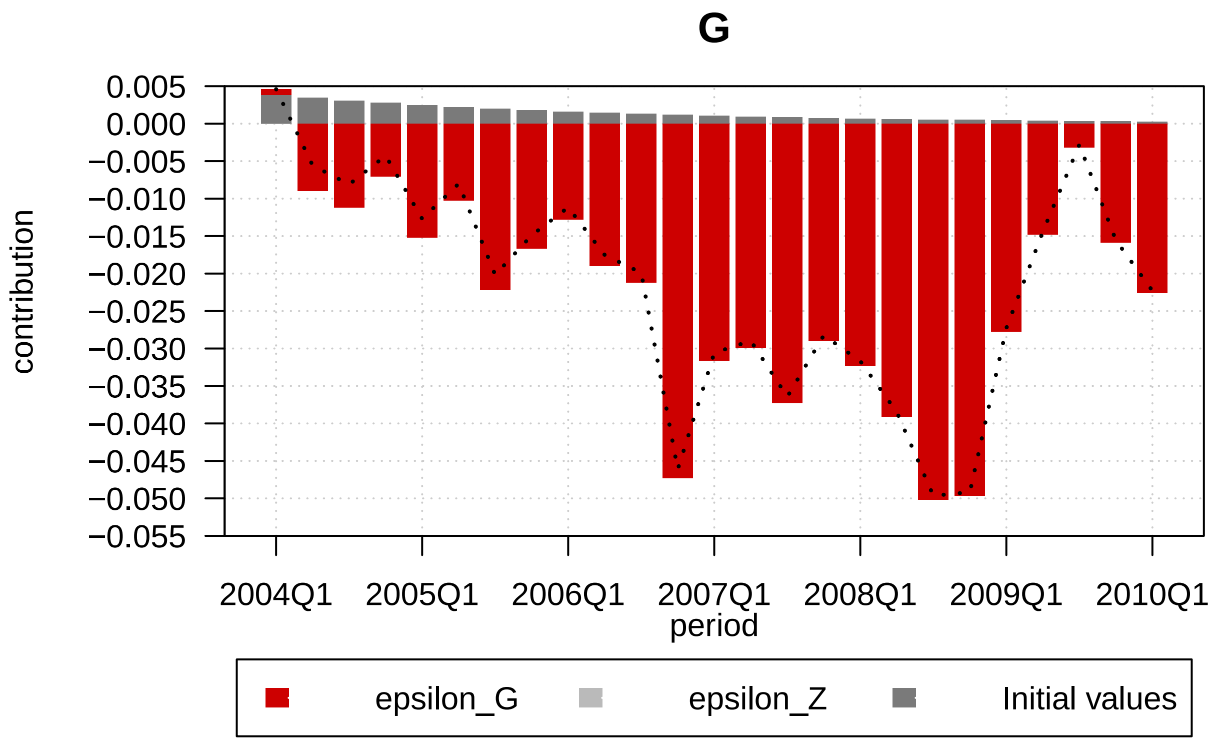
```
## 2004 Q1 -0.0007208061  0.1297907692  2.471194e-03
## 2004 Q2  0.0024323889  0.1667537386  6.034965e-03
## 2004 Q3  0.0035039138  0.0501279079  3.737791e-03
## 2004 Q4  0.0043063896  0.0403467193  3.226943e-03
## 2005 Q1  0.0051774552  0.0341928208  4.585545e-03
## 2005 Q2  0.0079477296  0.1448900622  7.813079e-03
## 2005 Q3  0.0118717223  0.1947325534  1.227689e-02
## 2005 Q4  0.0151120548  0.1649413048  1.191892e-02
## 2006 Q1  0.0163660425  0.0611880847  9.132266e-03
## 2006 Q2  0.0176299788  0.0544917577  1.032281e-02
## 2006 Q3  0.0191422911  0.0657530283  1.150675e-02
## 2006 Q4  0.0247604190  0.2607601137  2.238529e-02
## 2007 Q1  0.0281420263  0.1584655502  1.872031e-02
## 2007 Q2  0.0299555840  0.0752557090  1.697490e-02
## 2007 Q3  0.0314809158  0.0509804903  1.796019e-02
## 2007 Q4  0.0331056681  0.0669813530  1.779761e-02
## 2008 Q1  0.0359376579  0.1299416580  2.096205e-02
## 2008 Q2  0.0372281220  0.0377694482  1.999426e-02
## 2008 Q3  0.0400404165  0.1085889013  2.445686e-02
## 2008 Q4  0.0416050229  0.0414412786  2.320328e-02
## 2009 Q1  0.0412985907 -0.0345251815  1.798287e-02
## 2009 Q2  0.0390924208 -0.1236943634  1.301250e-02
## 2009 Q3  0.0348938943 -0.2202447734  7.310665e-03
## 2009 Q4  0.0303122080 -0.2584204950  6.472218e-03
## 2010 Q1  0.0267049593 -0.2146078356  7.270265e-03
## 2010 Q2  0.0217632966 -0.2883332841  3.413676e-03
```

```
# print the MSE matrix
dsge_smoothed_variables$MSE
```

```
##                  G             K             Z
```

```
## G  9.797445e-05 -6.185833e-06 -2.715225e-21
## K -6.185833e-06  2.146475e-06  1.017048e-05
## Z -2.715225e-21  1.017048e-05  8.112493e-05
```

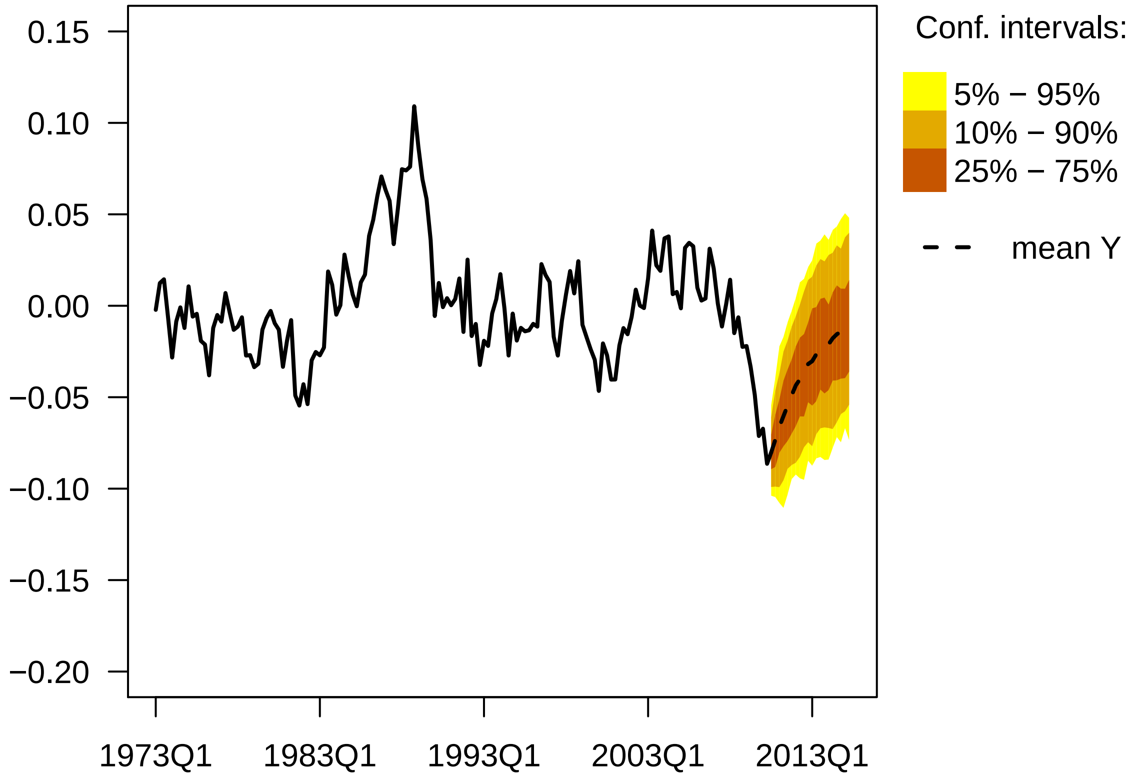


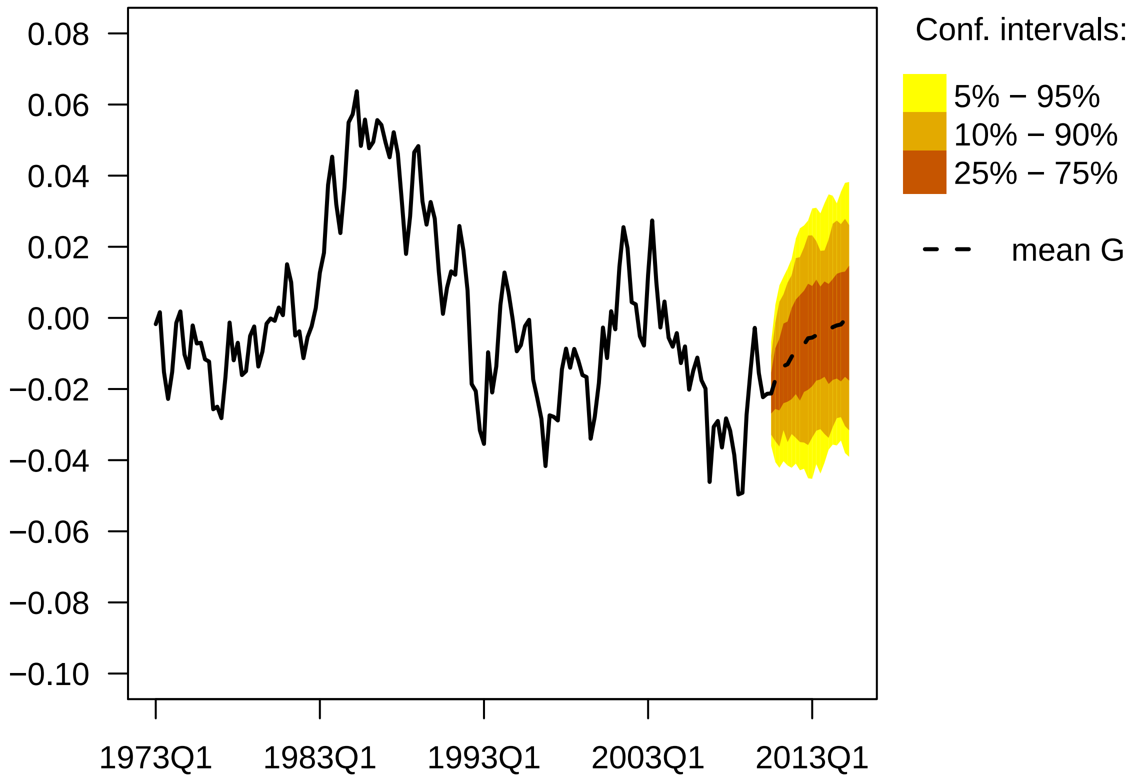


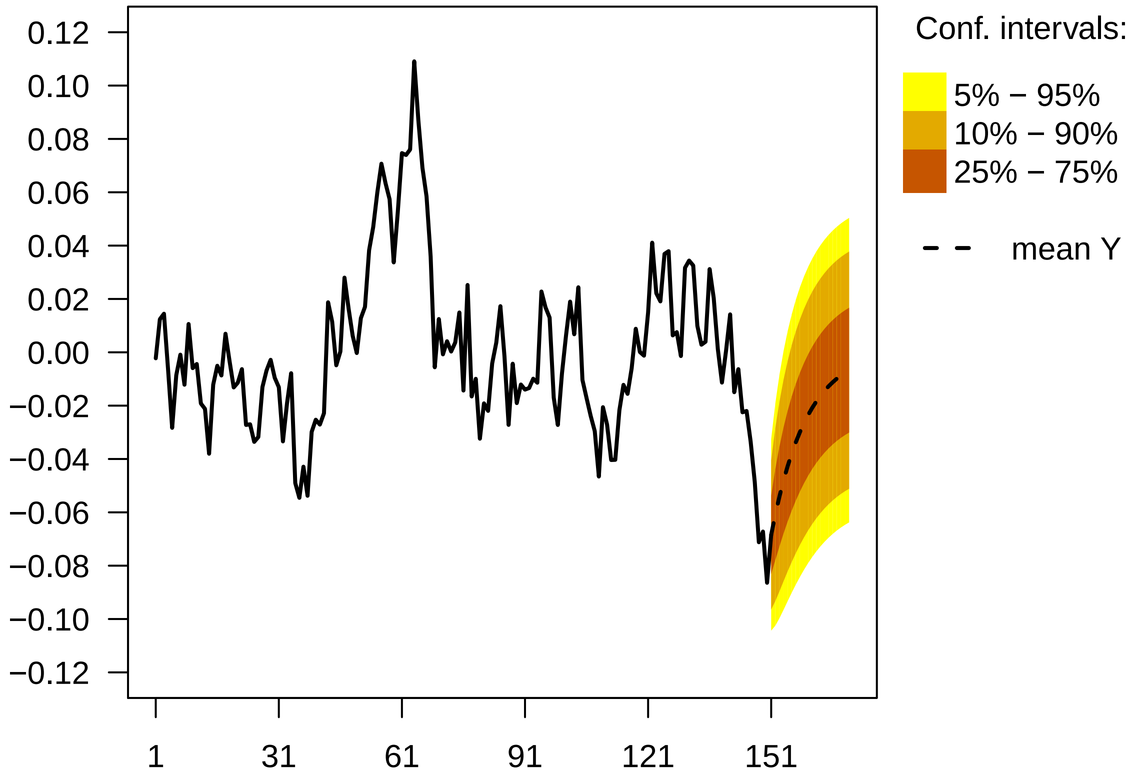

```
# #####################################################################
# 6. forecast using the model
# forecast using point estimates of parameters
fc_res <- forecast(model = estimated_dsge_model,
                   data_set = estimation_data,
                   observables = observables,
                   variables = c("Y", "G"),
                   horizon = 20)

# forecast using posterior distribution
fc_res_post <- forecast_posterior(est_results = estimation_result,
                                  data_set = estimation_data,
                                  observables = observables,
                                  variables = c("Y", "G"),
                                  horizon = 20)
```

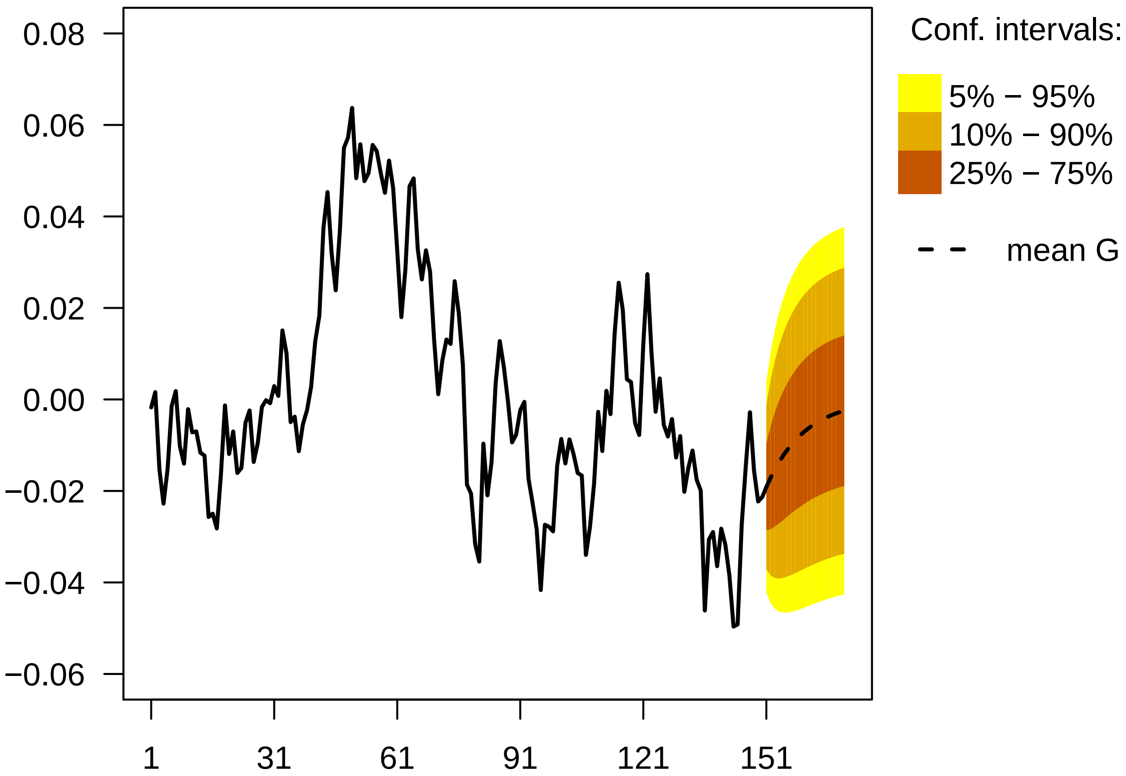
```
## The 250 parameter samples will be drawn from the posterior distribution
##
## 50 parameter samples (20 percent) have been already drawn from the posterior.
## 100 parameter samples (40 percent) have been already drawn from the posterior.
## 150 parameter samples (60 percent) have been already drawn from the posterior.
## 200 parameter samples (80 percent) have been already drawn from the posterior.
## 250 parameter samples (100 percent) have been already drawn from the posterior.
```

```
#"The forecast_posterior function allows to create forecasts by sampling parameter values from

# plot forecasts
plot_forecast(fc_res_post)
plot_forecast(fc_res)
```




0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
1973Q1
1983Q1
1993Q1
2003Q1
2013Q1
Conf. intervals:
5% − 95%
10% − 90%
25% − 75%
mean G


0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
1
31
61
91
121
151
Conf. intervals:
5% − 95%
10% − 90%
25% − 75%
mean Y


0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
1
31
61
91
121
151
Conf. intervals:
5% − 95%
10% − 90%
25% − 75%
mean G