Performing Bayesian analysis in Stata using WinBUGS

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Outline

The Bayesian approach

Bayes Theorem

$$Posterior \propto Likelihood \times prior$$

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Bayes Theorem

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- Direct probability statements - not frequentist - subjective
- Complex posterior marginal distributions - estimation via simulation
- Markov chain Monte Carlo (MCMC) methods

WinBUGS

- Bayesian statistics using Gibbs sampling

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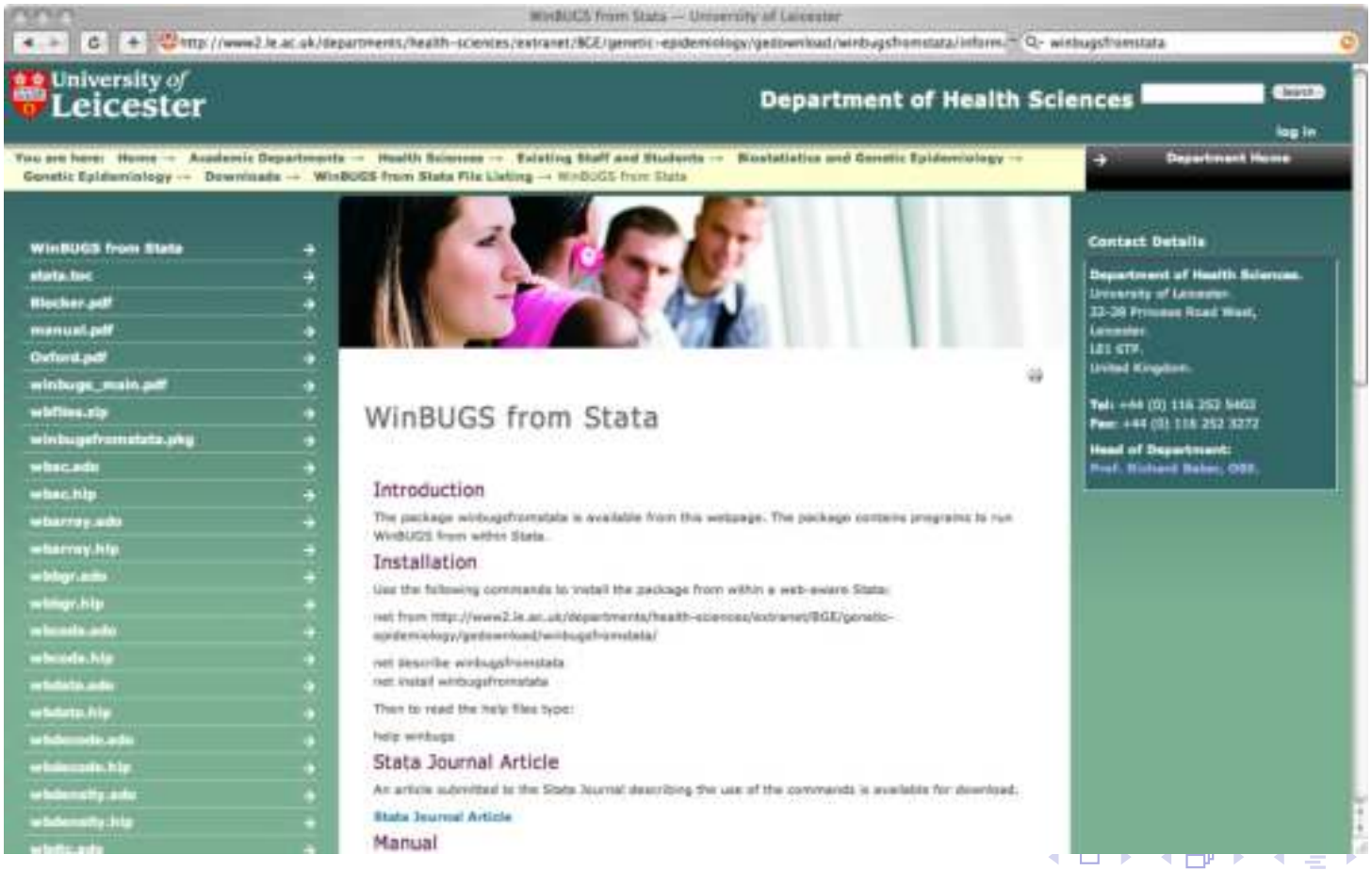
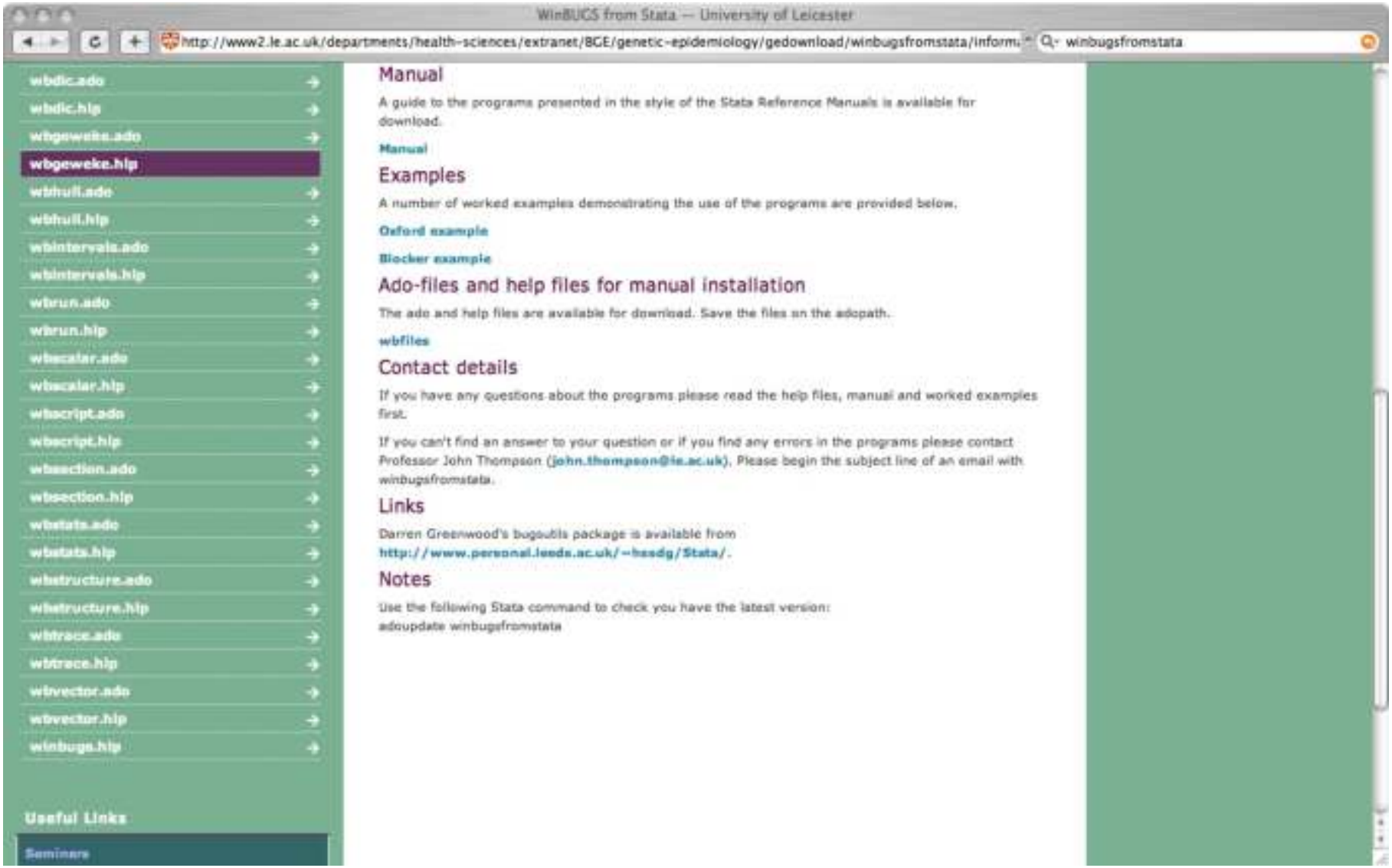
- Health Economics, Medical Statistics
- Disadvantages: data management, post-processing of results, graphics

The winbugsfromstata package

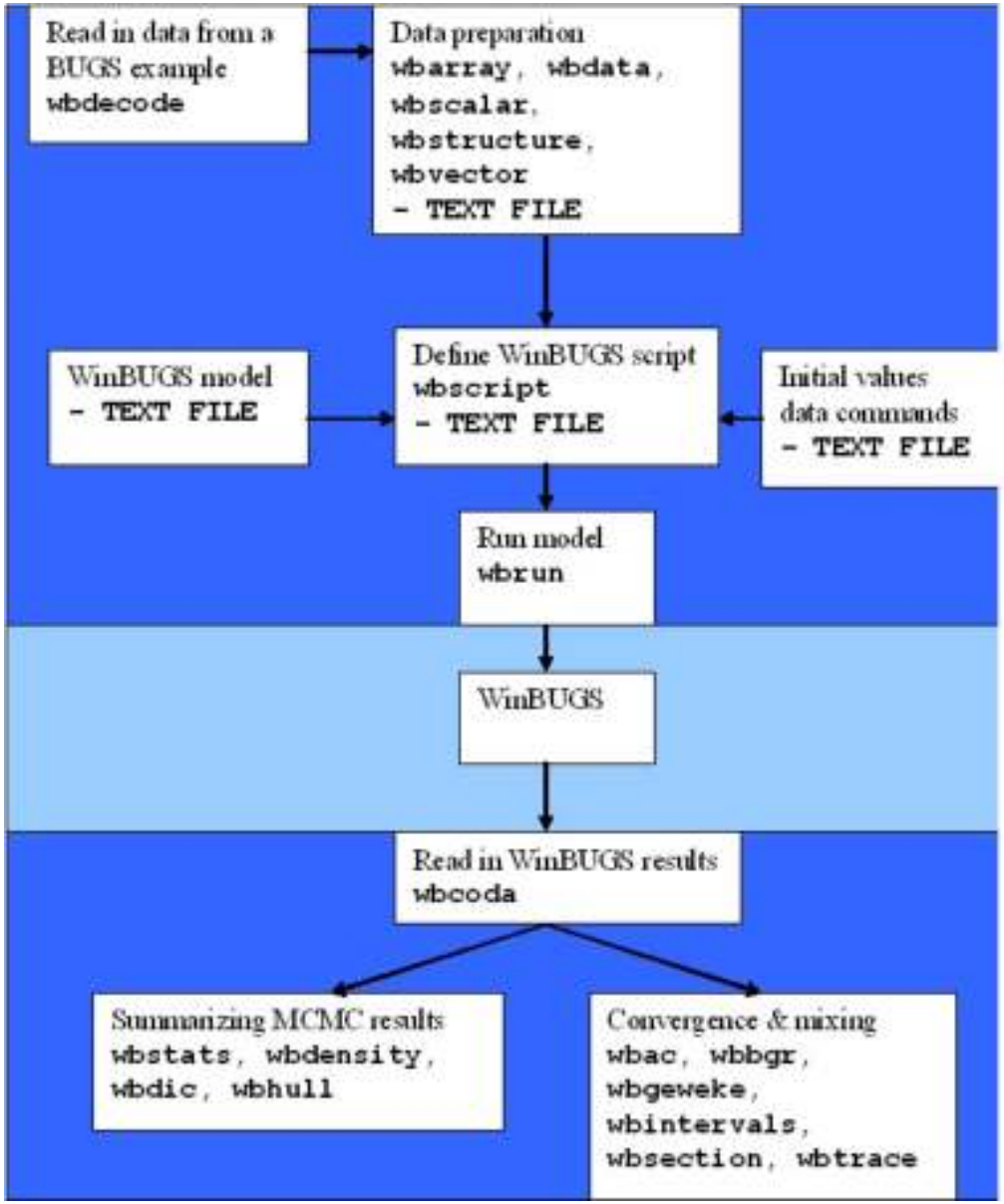
- Stata interface to WinBUGS [Thompson et al., 2006]
  http://www2.le.ac.uk/departments/health-sciences/extranet/BGE/genetic-epidemiology/gedownload/information



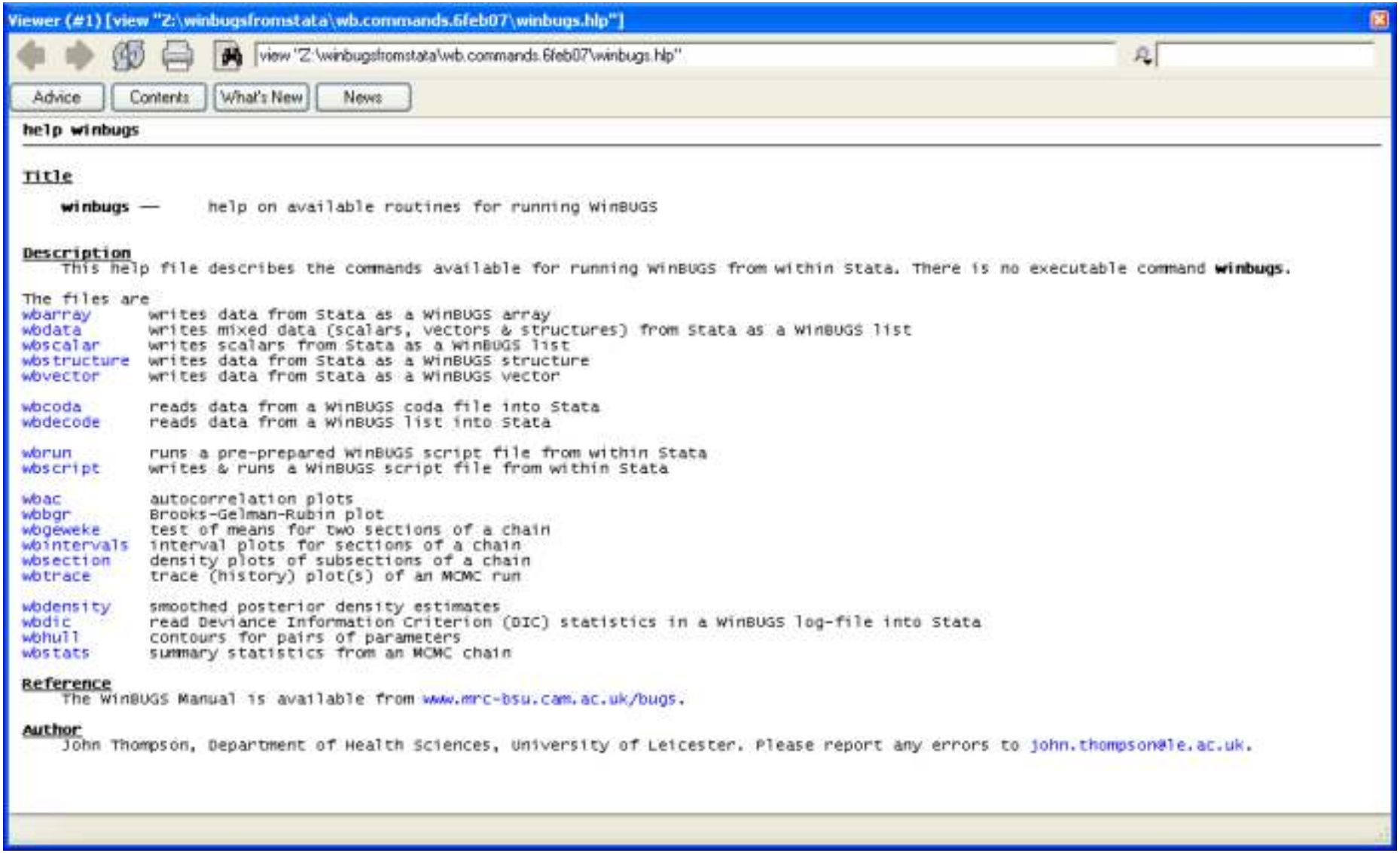
The winbugsfromstata package



How to run an analysis



help winbugs



Example analysis: Schools

- Schools example [Goldstein et al., 1993],[Spiegelhalter et al., 2004]

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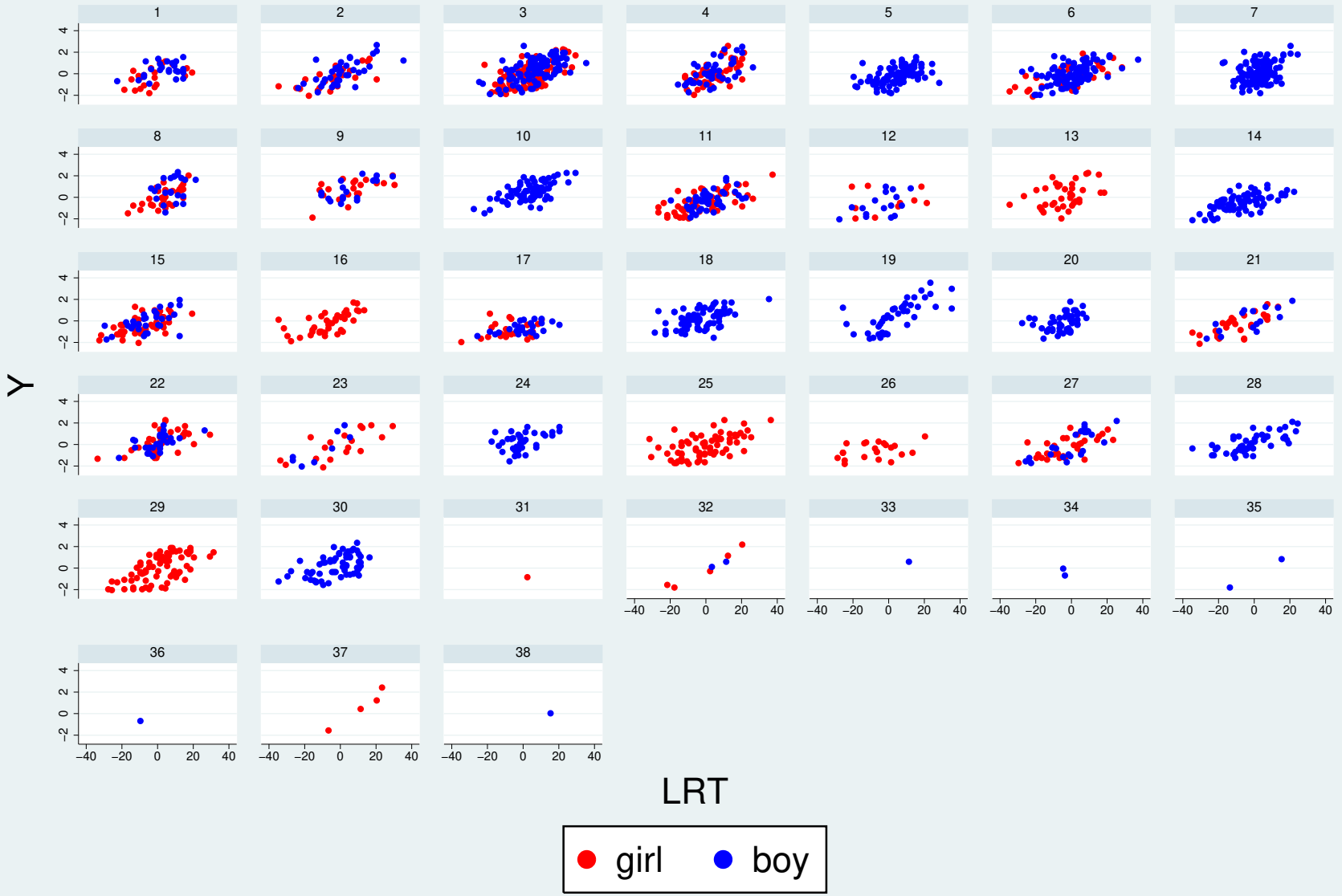
- Between-school variation in exam results from inner London schools
- Standardized mean scores (Y) 1,978 pupils, 38 schools
- LRT: London Reading Test, VR: verbal reasoning, Gender intake of school, denomination of school

Data for the Schools example



The model

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- Model:

$$
\begin{aligned}
Y_{ij} &\sim N(\mu_{ij}, \tau_{ij}) \\
\mu_{ij} &= \gamma_{1j} + \gamma_{2j} LRT_{ij} + \gamma_{3j} VR1_{ij} + \beta_1 LRT_{ij}^2 + \beta_2 VR2_{ij} \\
&\quad + \beta_3 Girl_{ij} + \beta_4 Gsch_j + \beta_5 Bsch_j + \beta_6 CEsch_j + \beta_7 RCsch_j + \beta_8 Osch_j \\
\log \tau_{ij} &= \theta + \phi LRT_{ij}
\end{aligned}
$$

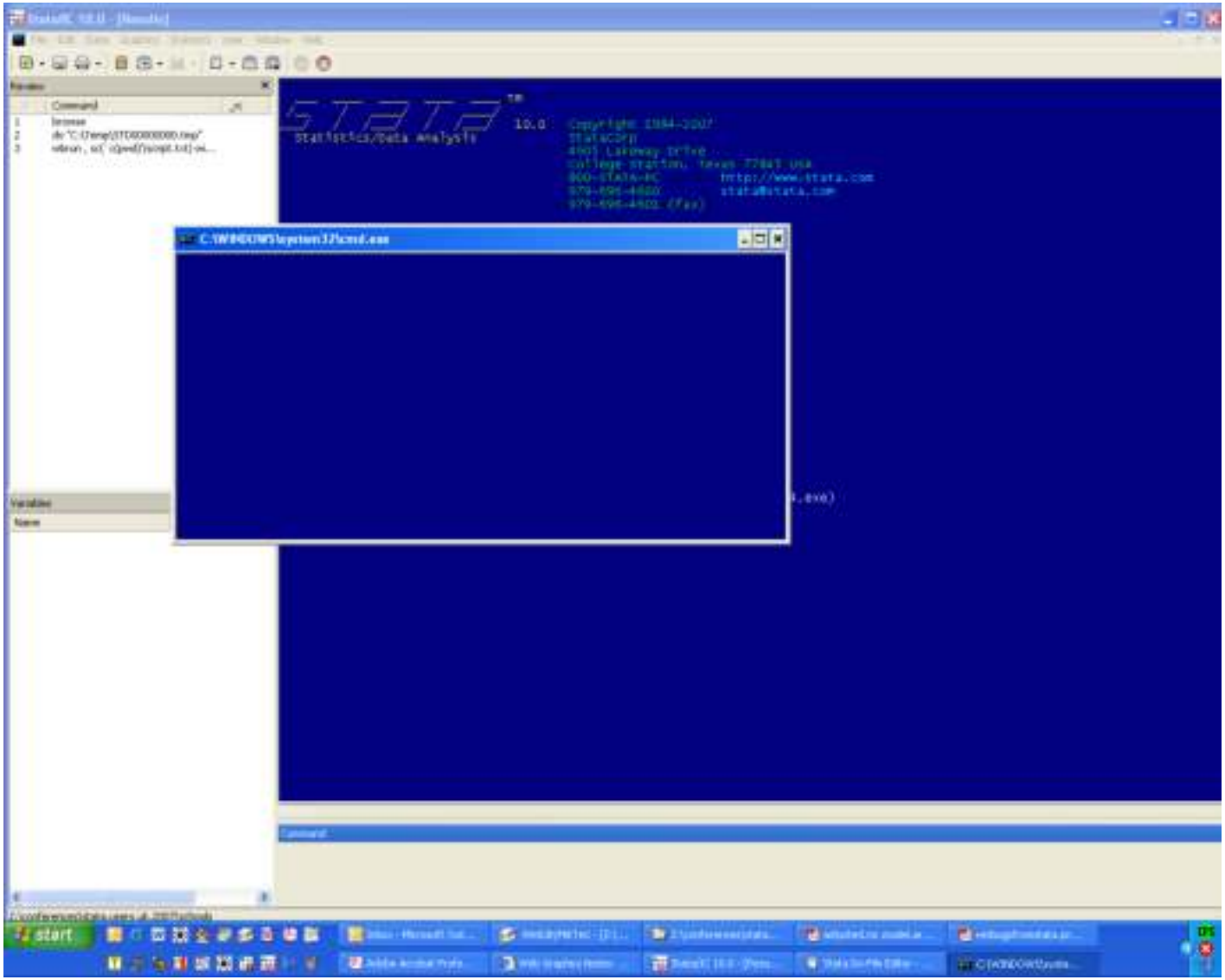
WinBUGS model statement

```
 model{
for(p in 1 : N){
Y[p] ~ dnorm(mu[p], tau[p])
mu[p] <- alpha[school[p], 1] + alpha[school[p], 2] * LRT[p]
      + alpha[school[p], 3] * VR[p, 1] + beta[1] * LRT2[p]
      + beta[2] * VR[p, 2] + beta[3] * Gender[p]
      + beta[4] * School.gender[p, 1] + beta[5] * School.gender[p, 2]
      + beta[6] * School.denom[p, 1] + beta[7] * School.denom[p, 2]
      + beta[8] * School.denom[p, 3]
      log(tau[p]) <- theta + phi * LRT[p]
      sigma2[p] <- 1 /  tau[p]
      LRT2[p] <- LRT[p] * LRT[p]
}
      min.var <- exp(-(theta + phi * (-34.6193))) # lowest LRT score = -34.6193
      max.var <- exp(-(theta + phi * (37.3807)))  # highest LRT score = 37.3807

     # Priors for fixed effects:
        for (k in 1 : 8){
            beta[k] ~ dnorm(0.0, 0.0001)
        }
        theta ~ dnorm(0.0, 0.0001)
        phi ~ dnorm(0.0, 0.0001)

    # Priors for random coefficients:
        for (j in 1 : M) {
            alpha[j, 1 : 3] ~ dmnorm(gamma[1:3 ], T[1:3 ,1:3 ])
            alpha1[j] <- alpha[j,1]
        }

    # Hyper-priors:
        gamma[1 : 3] ~ dmnorm(mn[1:3 ], prec[1:3 ,1:3 ])
        T[1 : 3, 1 : 3 ] ~ dwish(R[1:3 ,1:3 ], 3)
}
```

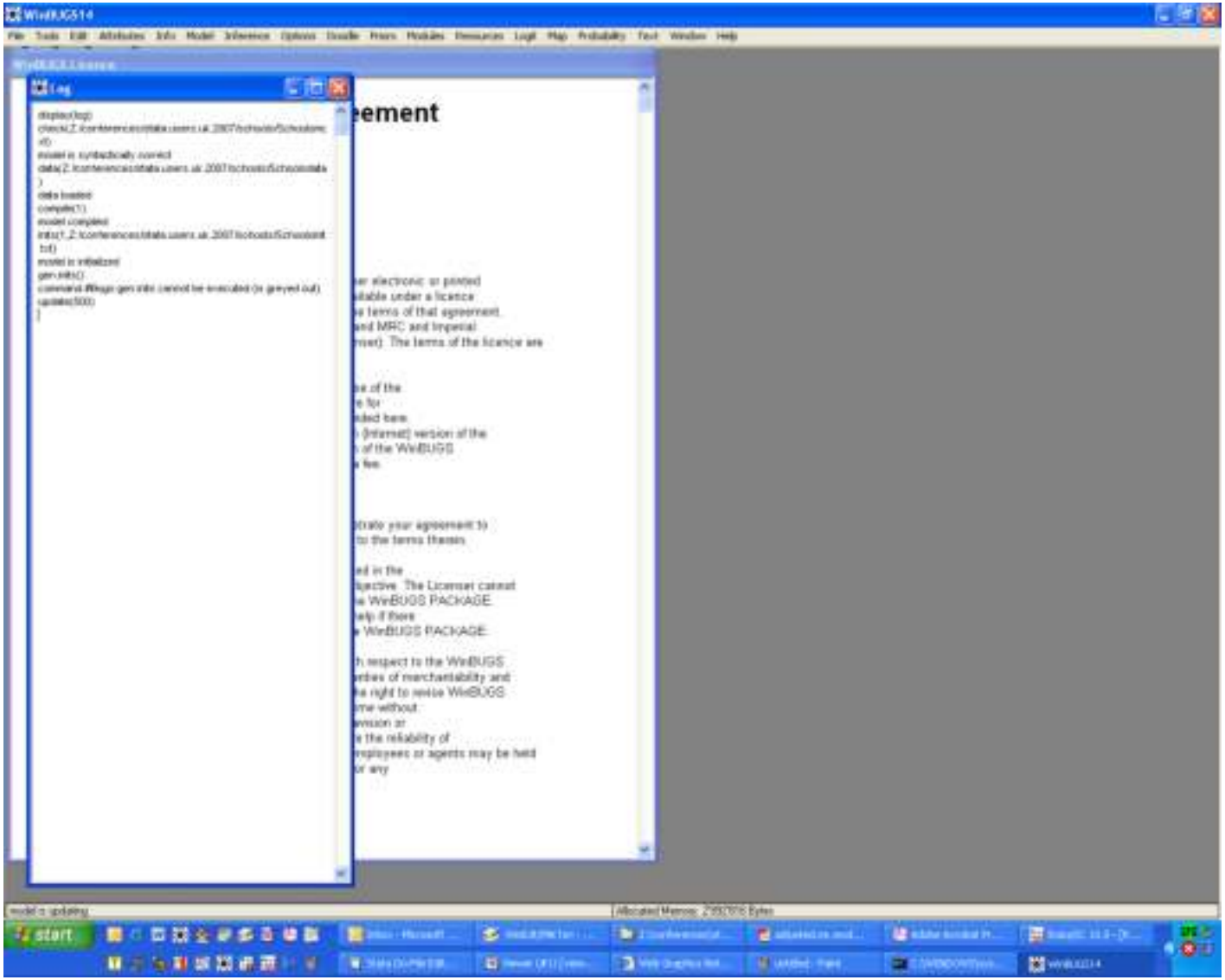
Do-file for the example

```
 // winbugsfromstata demo, 16august2007
cd "Z:/conferences/stata.users.uk.2007/schools"
wbdecode, file(Schoolsdata.txt) clear

wbscript, sav(‘c(pwd)’/script.txt, replace) ///
model(‘c(pwd)’/Schoolsmodel.txt) ///
data(‘c(pwd)’/Schoolsdata.txt) ///
inits(‘c(pwd)’/Schoolsinits.txt) ///
coda(‘c(pwd)’/out) ///
burn(500) update(1000) ///
set(beta gamma phi theta) dic ///
log(‘c(pwd)’/winbugslog.txt) ///
quit

wbrun , sc(‘c(pwd)’/script.txt) ///
win(Z:/winbugs/WinBUGS14/WinBUGS14.exe)

clear
set memory 500m
wbcoda, root(out) clear

wbstats gamma* beta* phi theta

wbtrace beta_1 gamma_1 phi theta
wbdensity beta_1 gamma_1 phi theta
wbac beta_1 gamma_1 phi theta
wbhull beta_1 beta_2 gamma_2, peels(1 5 10 25)

wbgeweke beta_1 gamma_1 phi theta

wbdic using winbugslog.txt
```

wbrun screenshot 1



wbrun screenshot 2



Stata output

wbstats output

```
. wbstats gamma* beta* phi theta
Parameter        n    mean      sd     sem  median          95% CrI
gamma_1        500  -0.715   0.103  0.0179  -0.715 (  -0.951,  -0.523 )
gamma_2        500   0.031   0.010  0.0005   0.031 (   0.010,   0.052 )
gamma_3        500   0.967   0.105  0.0225   0.972 (   0.750,   1.168 )
beta_1         500   0.000   0.000  0.0000   0.000 (   0.000,   0.000 )
beta_2         500   0.433   0.072  0.0099   0.435 (   0.284,   0.576 )
beta_3         500   0.173   0.048  0.0031   0.172 (   0.085,   0.271 )
beta_4         500   0.151   0.141  0.0230   0.164 (  -0.156,   0.392 )
beta_5         500   0.091   0.105  0.0150   0.087 (  -0.094,   0.318 )
beta_6         500  -0.279   0.183  0.0279  -0.290 (  -0.618,   0.108 )
beta_7         500   0.170   0.105  0.0158   0.169 (  -0.029,   0.380 )
beta_8         500  -0.109   0.209  0.0376  -0.124 (  -0.485,   0.357 )
phi            500  -0.003   0.003  0.0002  -0.003 (  -0.009,   0.003 )
theta          500   0.579   0.032  0.0016   0.579 (   0.513,   0.649 )
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```

- `regress` γ_2: 0.030, 95% C.I. (0.026, 0.034)

Stata output

wbgeweke output

```
 . wbgeweke beta_1
Parameter: beta_1 first 10.0% (n=50) vs last 50.0% (n=250)
Means (se)      0.0003 (    0.0000)    0.0003 (    0.0000)
Autocorrelations  0.3736   0.4114
Mean Difference (se)    0.0000 (    0.0000) z =  1.030 p =  0.3031
```

Stata output

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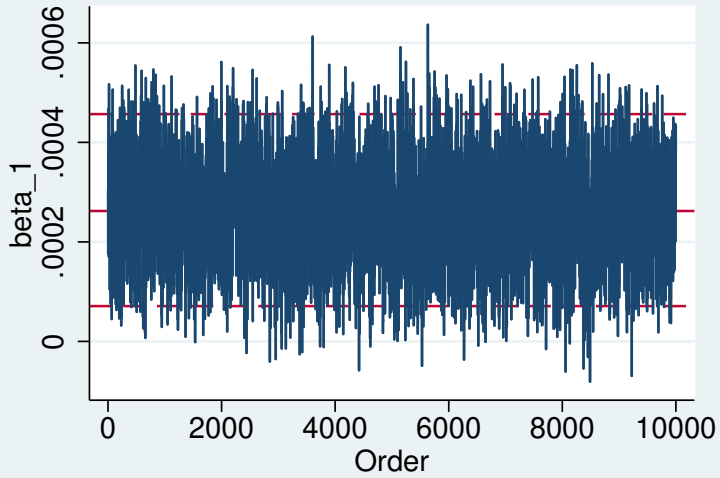
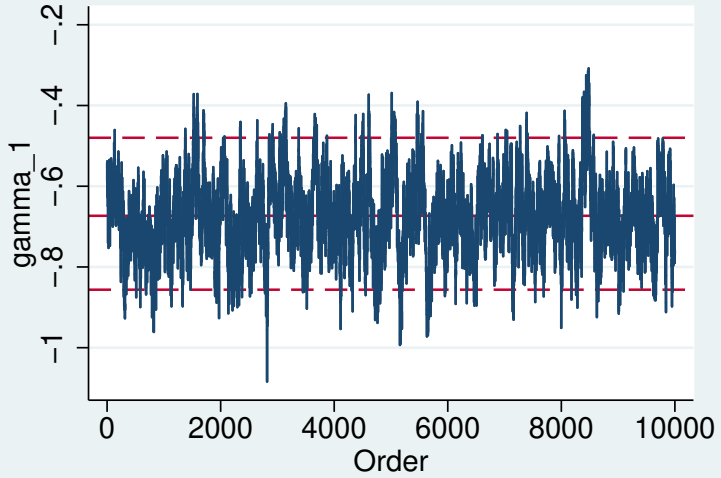
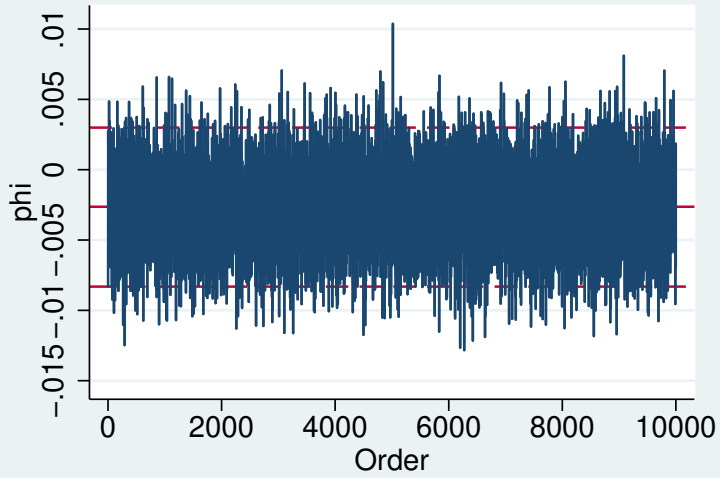
wbdic output

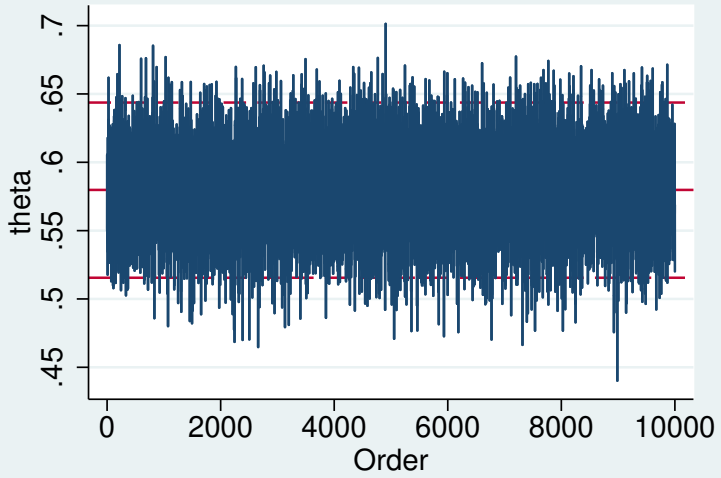
```
 . wbdic using winbugslog.txt
DIC statistics 1
DIC
Dbar = post.mean of -2logL; Dhat = -2LogL at post.mean of stochastic nodes
        Dbar    Dhat    pD      DIC
Y       4466.330        4393.470        72.861  4539.190
total   4466.330        4393.470        72.861  4539.190
```

wbtrace output

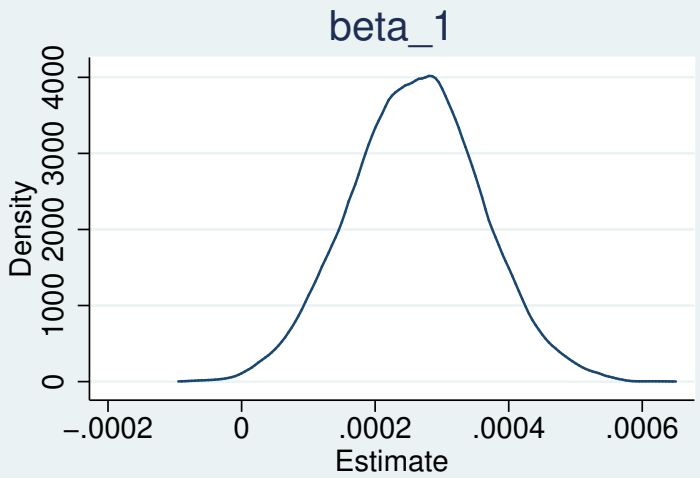


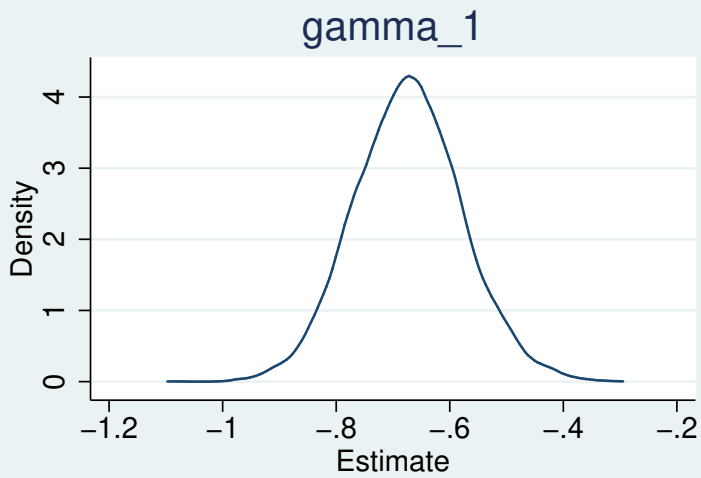


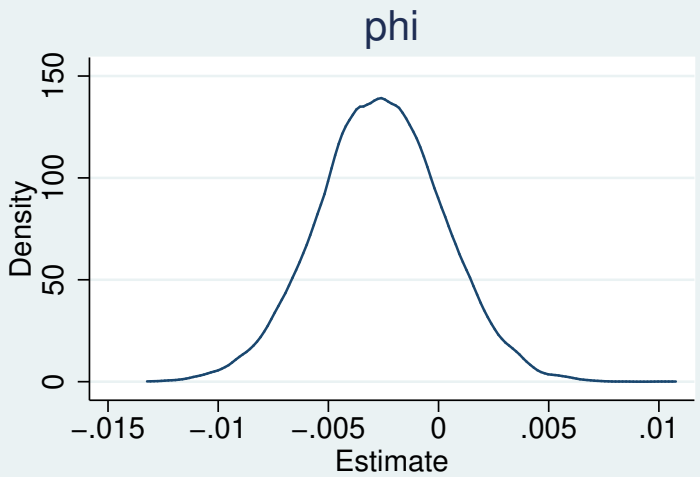


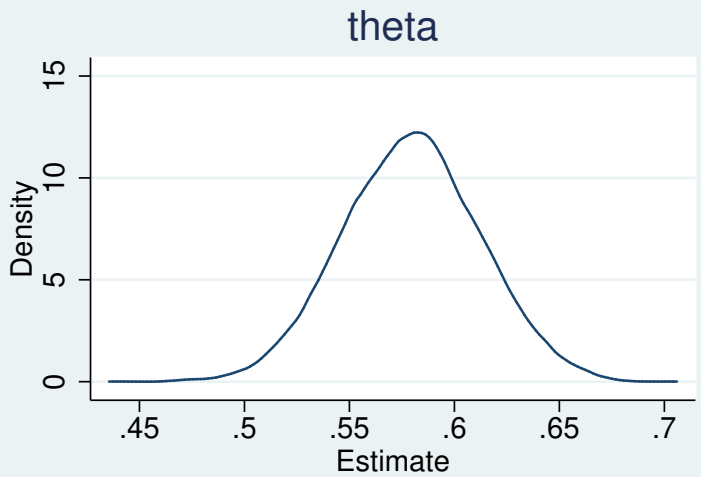


wbdensity output

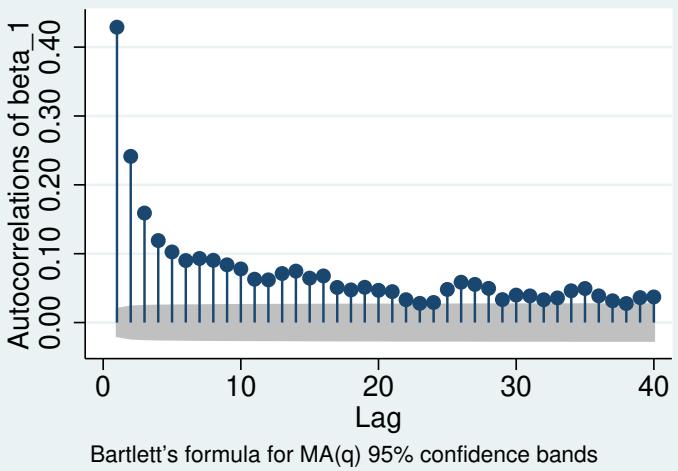


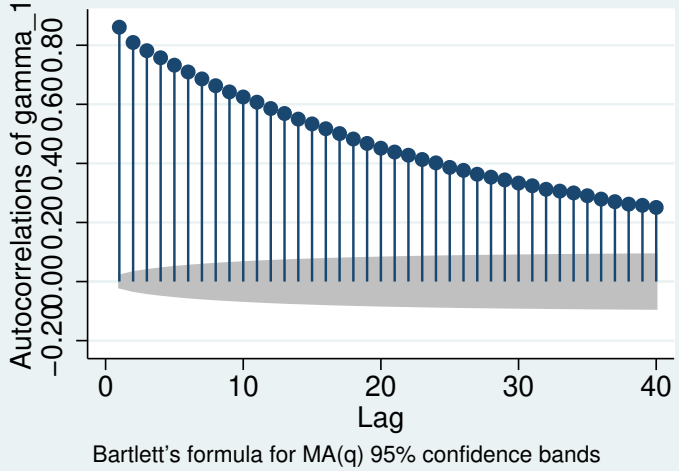






wbac output


Autocorrelations of beta_1
0.00 0.10 0.20 0.30 0.40
0 10 20 30 40
Lag
Bartlett's formula for MA(q) 95% confidence bands


Autocorrelations of gamma_1
−0.20 0.00 0.20 0.40 0.60 0.80
0 10 20 30 40
Lag
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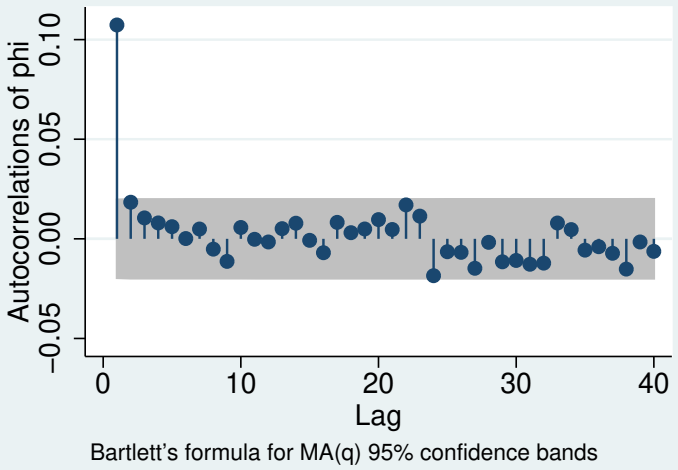
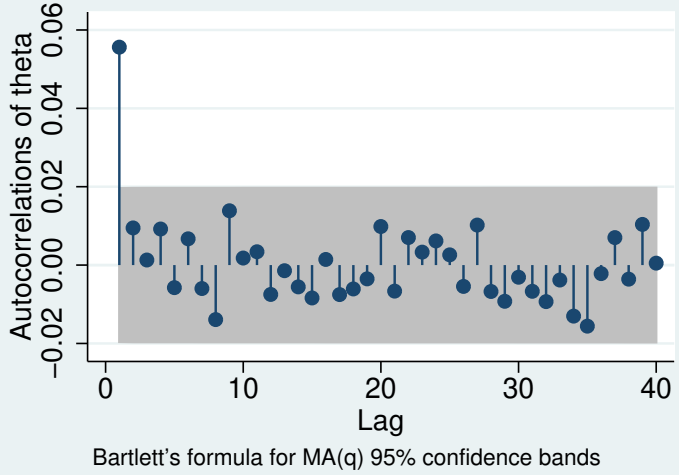
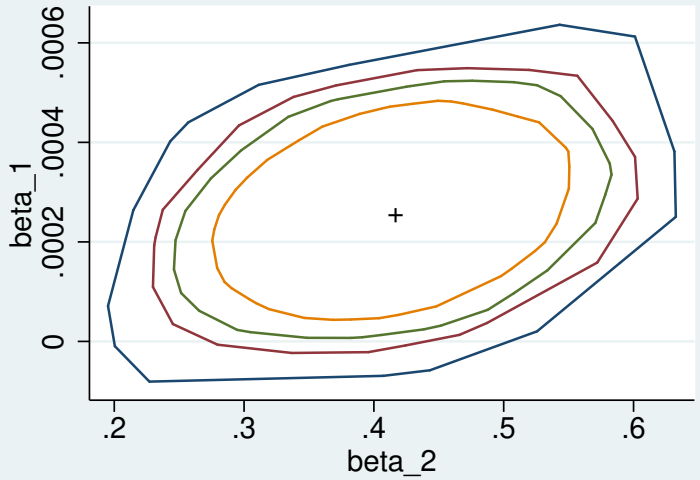
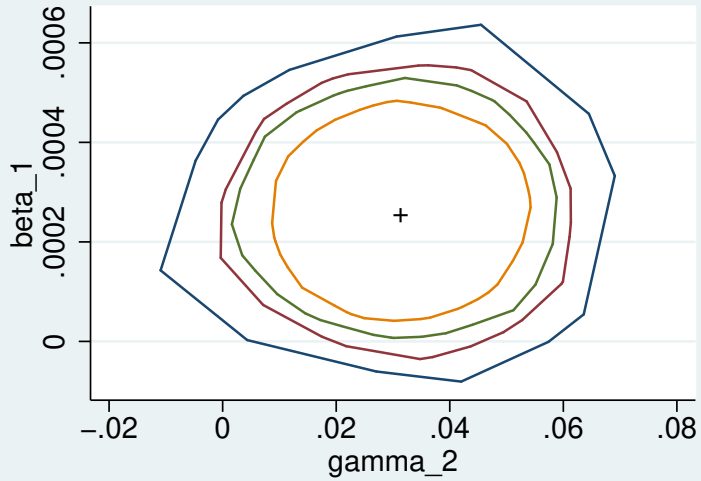
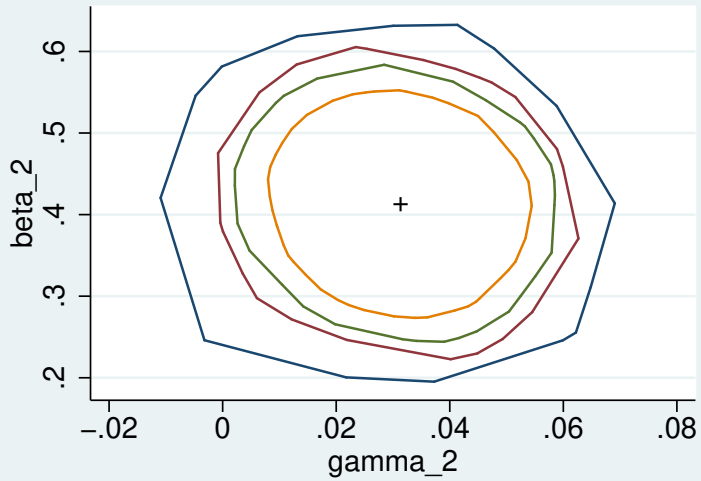

Autocorrelations of phi
−0.05 0.00 0.05 0.10
0 10 20 30 40
Lag
Bartlett's formula for MA(q) 95% confidence bands


Autocorrelations of theta
−0.02 0.00 0.02 0.04 0.06
0 10 20 30 40
Lag
Bartlett's formula for MA(q) 95% confidence bands

wbhull output







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- Prior distributions - *controversial*
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- Fit complex models not possible in Stata

Developments

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- OpenBUGS (version 3.0.1), WinBUGS (version 1.4.2)
  `http://mathstat.helsinki.fi/openbugs/`

References

Goldstein, H., Rasbash, J., Yang, M., Woodhouse, G., Pan, H., Nuttall, D., and Thomas, S. (1993).
A multilevel analysis of school examination results.
Oxford Review of Education, 19(4):425–433.

Lu, G., Ades, A. E., Sutton, A. J., Cooper, N. J., Briggs, A. H., and Caldwell, D. M. (2007).
Meta-analysis of mixed treatment comparisons at multiple follow-up times.
Statistics in Medicine.
in press.

Spiegelhalter, D. J., Thomas, A., Best, N., and Lunn, D. (2004).
WinBUGS User Manual, version 1.4.1.
MRC Biostatistics Unit, Cambridge, UK.

Thompson, J., Palmer, T., and Moreno, S. (2006).
Bayesian Analysis in Stata using WinBUGS.
The Stata Journal, 6(4):530–549.

Acknowledgements

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