Performing Bayesian analysis in Stata using WinBUGS

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Outline

The Bayesian approach

Bayes Theorem

$$Posterior \propto Likelihood \times prior$$

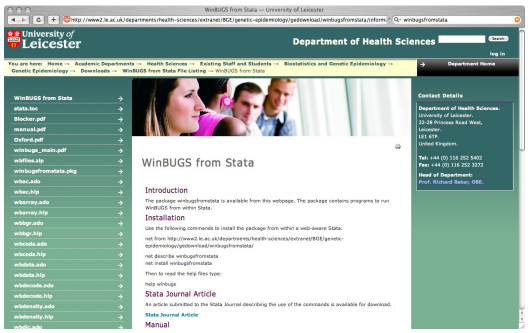
- Direct probability statements - not frequentist - subjective
- Complex posterior marginal distributions - estimation via simulation
- Markov chain Monte Carlo (MCMC) methods

WinBUGS

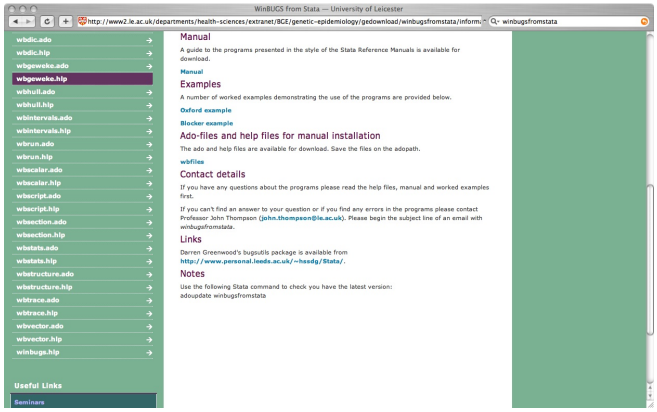
- Bayesian statistics using Gibbs sampling
- MRC Biostatistics unit
  `http://www.mrc-bsu.cam.ac.uk/bugs`
- Health Economics, Medical Statistics
- Disadvantages: data management, post-processing of results, graphics

The winbugsfromstata package

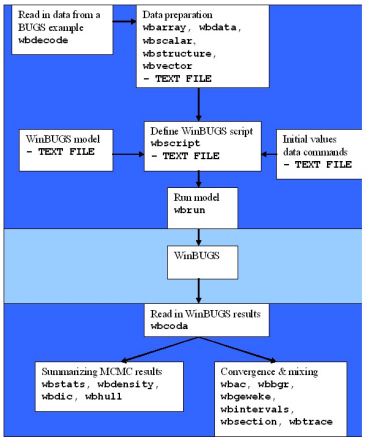
- Stata interface to WinBUGS [Thompson et al., 2006]
  `http://www2.le.ac.uk/departments/health-sciences/extranet/BGE/genetic-epidemiology/gedownload/information`



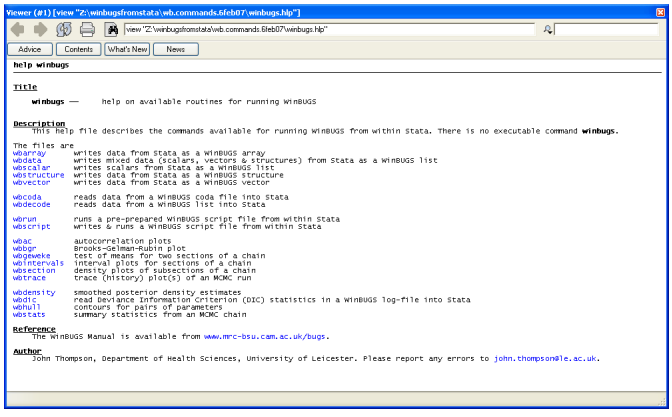
The winbugsfromstata package



How to run an analysis



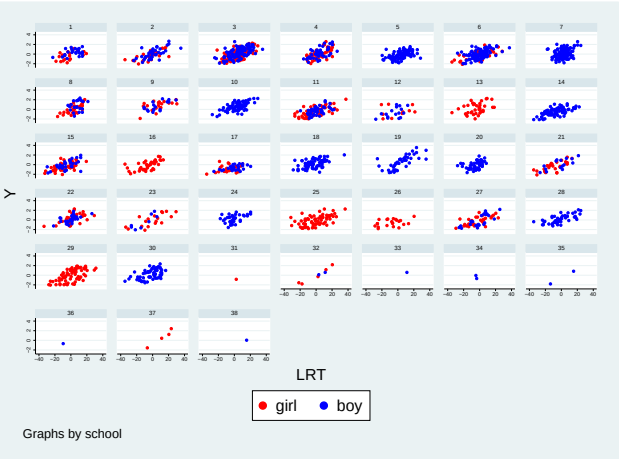
help winbugs



Example analysis: Schools

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

- Hierarchical model; specified the mean and variance
- Model:

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

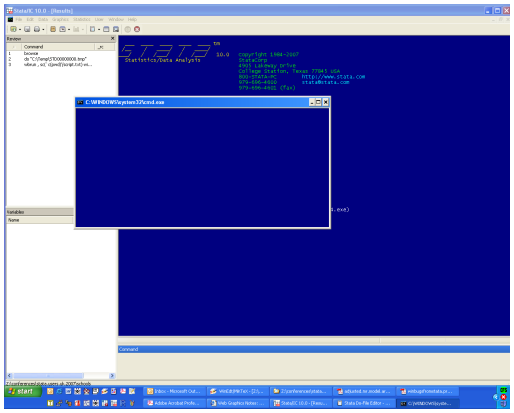
WinBUGS model statement

```
 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)
}
```

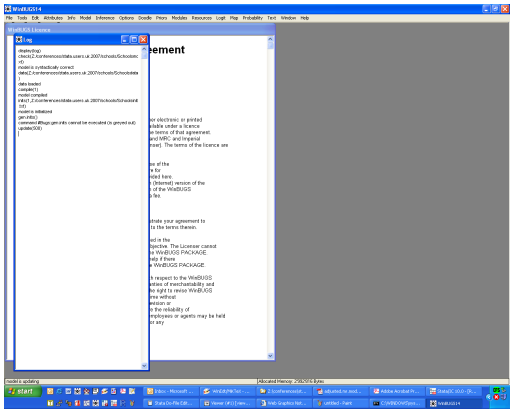
Do-file for the example

```
 // 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 )
```

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

Stata output

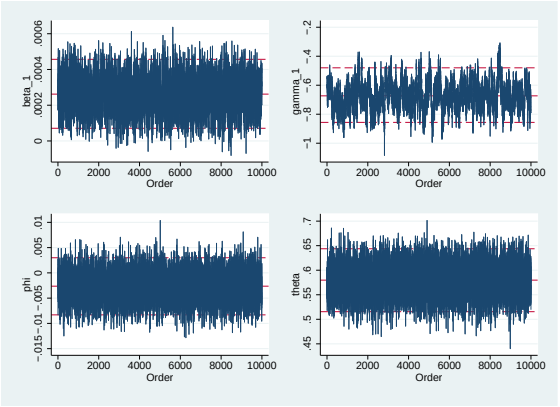
wbgeweke output

```
. 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
```

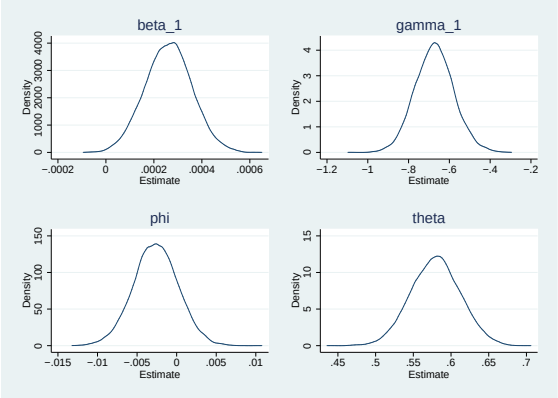
wbdic output

```
. 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
```

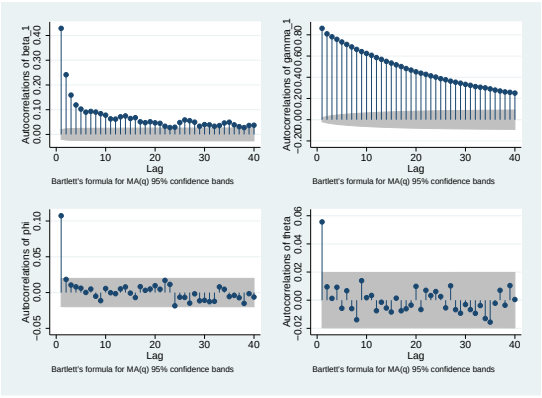

wbtrace output



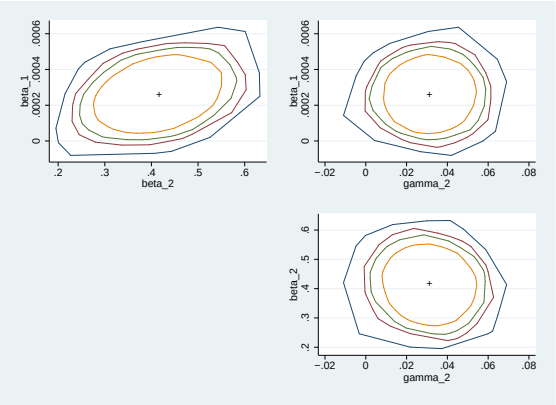
wbdensity output



wbac output



`wbhull` output



Summary

- WinBUGS - easy & flexible
- `winbugsfromstata` - data preparation, analysis of MCMC output, graphics
- Prior distributions - *controversial*
- Check complex Stata models - *vague* prior distributions
- Fit complex models not possible in Stata

Developments

- Bayesian residuals and model checking [Lu et al., 2007]
- Automate WinBUGS model statement
- Mac users: WinBUGS runs under Darwine
- OpenBUGS (version 3.0.1), WinBUGS (version 1.4.2)
  `http://mathstat.helsinki.fi/openbugs/`

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