NCRM National Centre for Research Methods

Introduction to the Stat-JR software package

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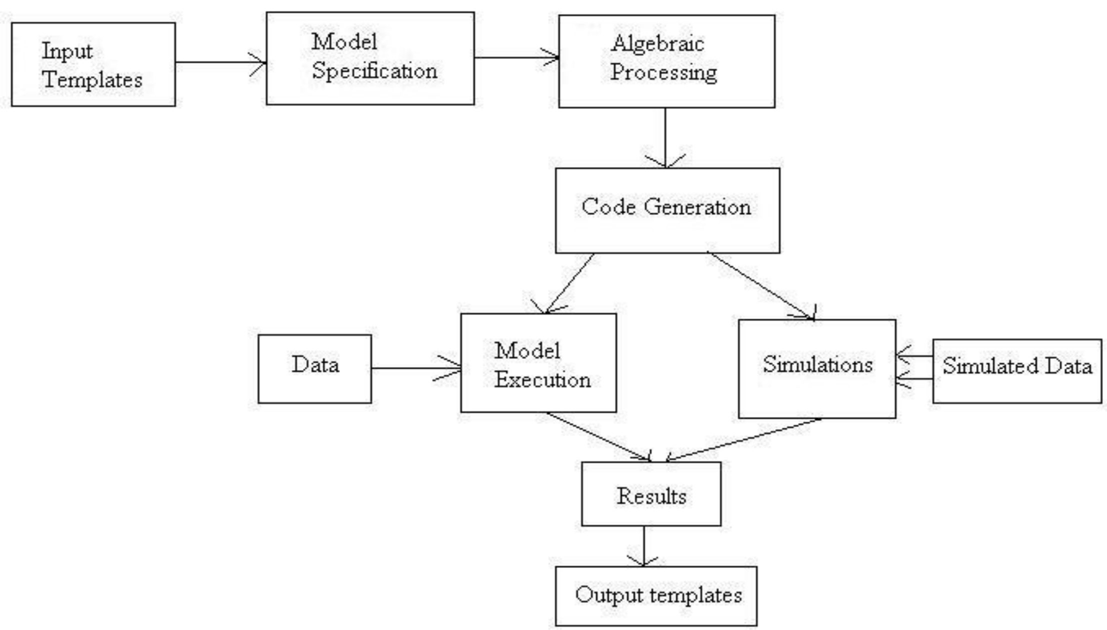
Video 1 What is StatJR

- A statistical software package written in Python and first released in 2013.
- Named after our former colleague Jon Rasbash and pronounced “Stature”.
- Stat-JR is meant to appeal to novice users, expert users and other algorithm developers
- It has its own MCMC estimation engine built into the software but also allows interoperability with other software packages (this talk).
- Has several interfaces including an electronic book interface including “statistical analysis assistant” features (talk 2).
- Can also be used to create “bespoke” training materials in combination with the SPSS software package (talk 3).

StatJR component based approach

Below is an early diagram of how we envisioned the system. Here you will see boxes representing components some of which are built into the STAT-JR system. The system is written in Python with a VB.net algebra processing system. A team of coders have worked together on the system.



Templates

Backbone of Stat-JR.

Consist of a set of code sections for advanced users to write. A bit like R packages.

For a model template it consists of at least:

- an *inputs* method which specifies inputs and types
- A *model* method that creates (BUGS like) model code for the algebra system
- An (optional) *latex* method can be used for outputting LaTeX code for the model.

Other optional functions required for more complex templates

Regression 1 Example

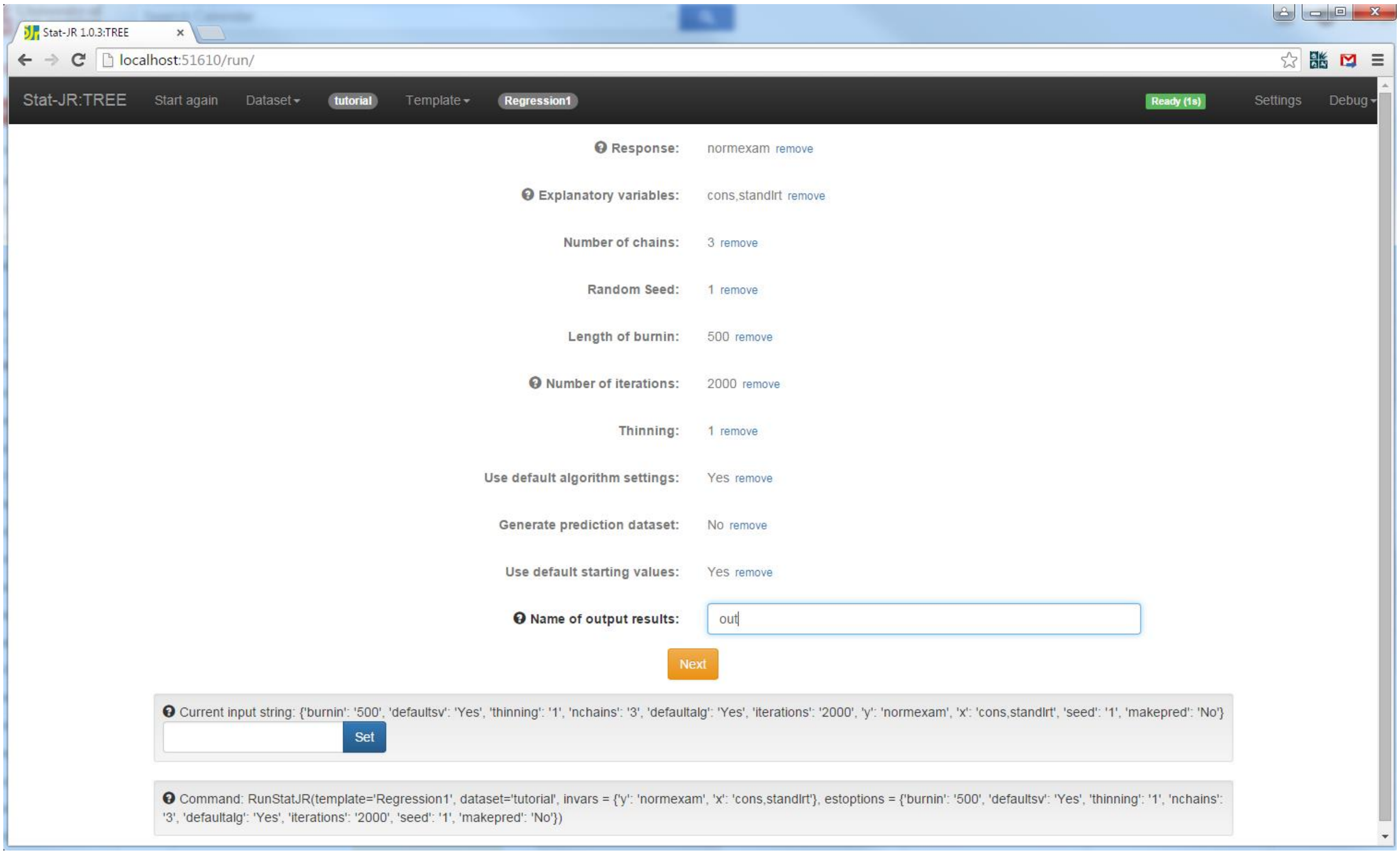
```
from EStat.Templating import *

class Regression1(Template):
    'A model template for fitting 1 level Normal multiple regression model
        in eStat only.‘
 tags = [ 'Model', '1-Level', 'eStat', 'Normal' ]
 engines = ['eStat']
 inputs = '''
y = DataVector('Response: ')
x = DataMatrix('Explanatory variables: ', allow_cat=True, help=
        'predictor variables')
beta = ParamVector(parents=[x], as_scalar=True)
tau = ParamScalar()
sigma = ParamScalar(modelled = False)
sigma2 = ParamScalar(modelled = False)
deviance = ParamScalar(modelled = False)
'''
```

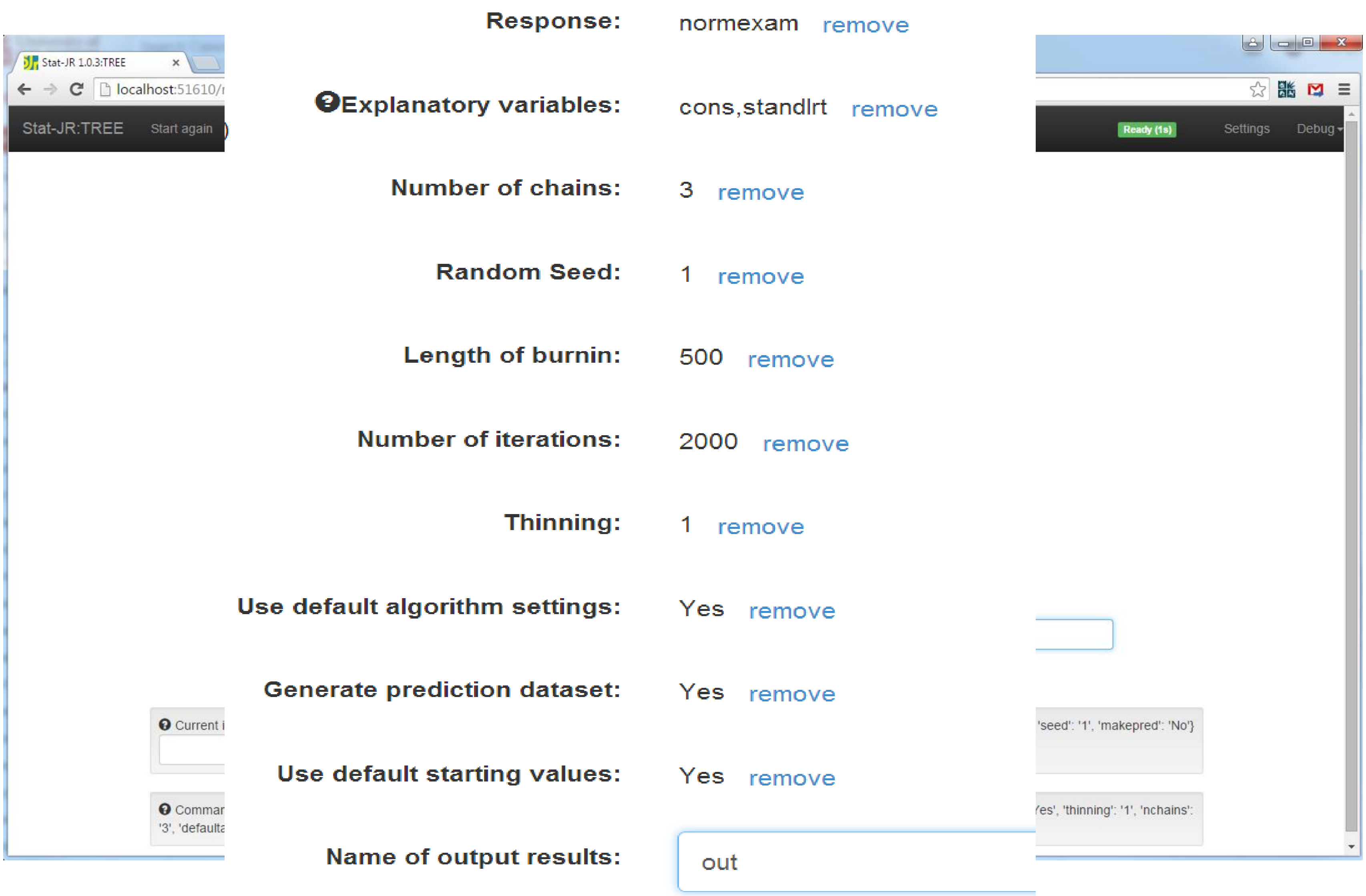
```
model = '''
model{
    for (i in 1:length(${y})) {
        ${y}[i] ~ dnorm(mu[i], tau)
        mu[i] <- ${mmult(x, 'beta', 'i')}
    }

    # Priors
    % for i in range(0, x.ncols()):
    beta${i} ~ dflat()
    % endfor
    tau ~ dgamma(0.001000, 0.001000)
    sigma2 <- 1 / tau
    sigma <- 1 / sqrt(tau)
}
'''
      latex = r'''
\begin{aligned}
 \mbox{${y}}_i & \sim \mbox{N}(\mu_i, \sigma^2) \\
\mu_i & =
  ${mmulttex(x, r'\beta', 'i')} \\
%for i in range(0, len(x)):
\beta_${i} & \propto 1 \\
%endfor
\tau & \sim \Gamma (0.001,0.001) \\
\sigma^2 & = 1 / \tau
\end{aligned}
'''
```

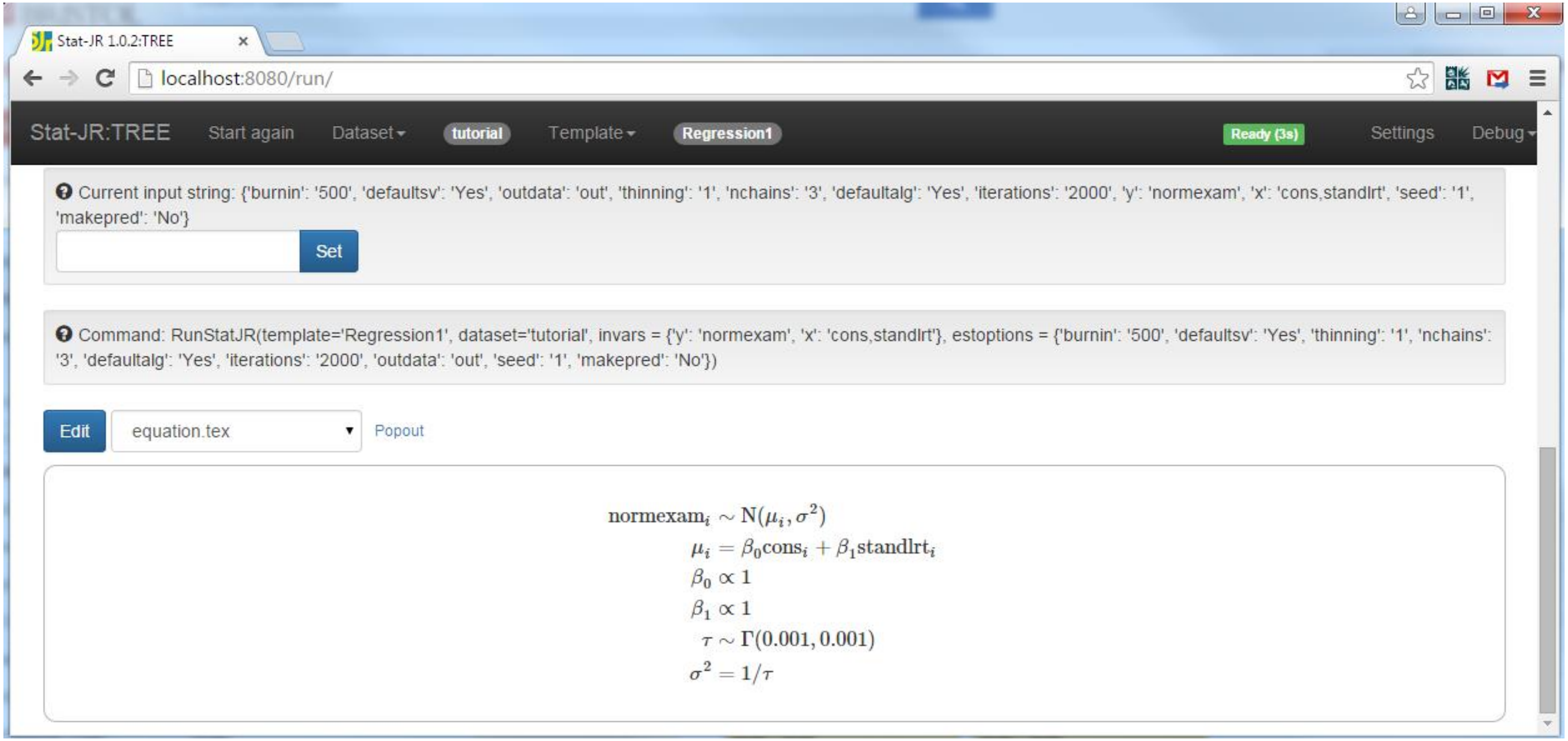
An example of STAT-JR – setting up a model



An example of STAT-JR – setting up a model



Equations for model



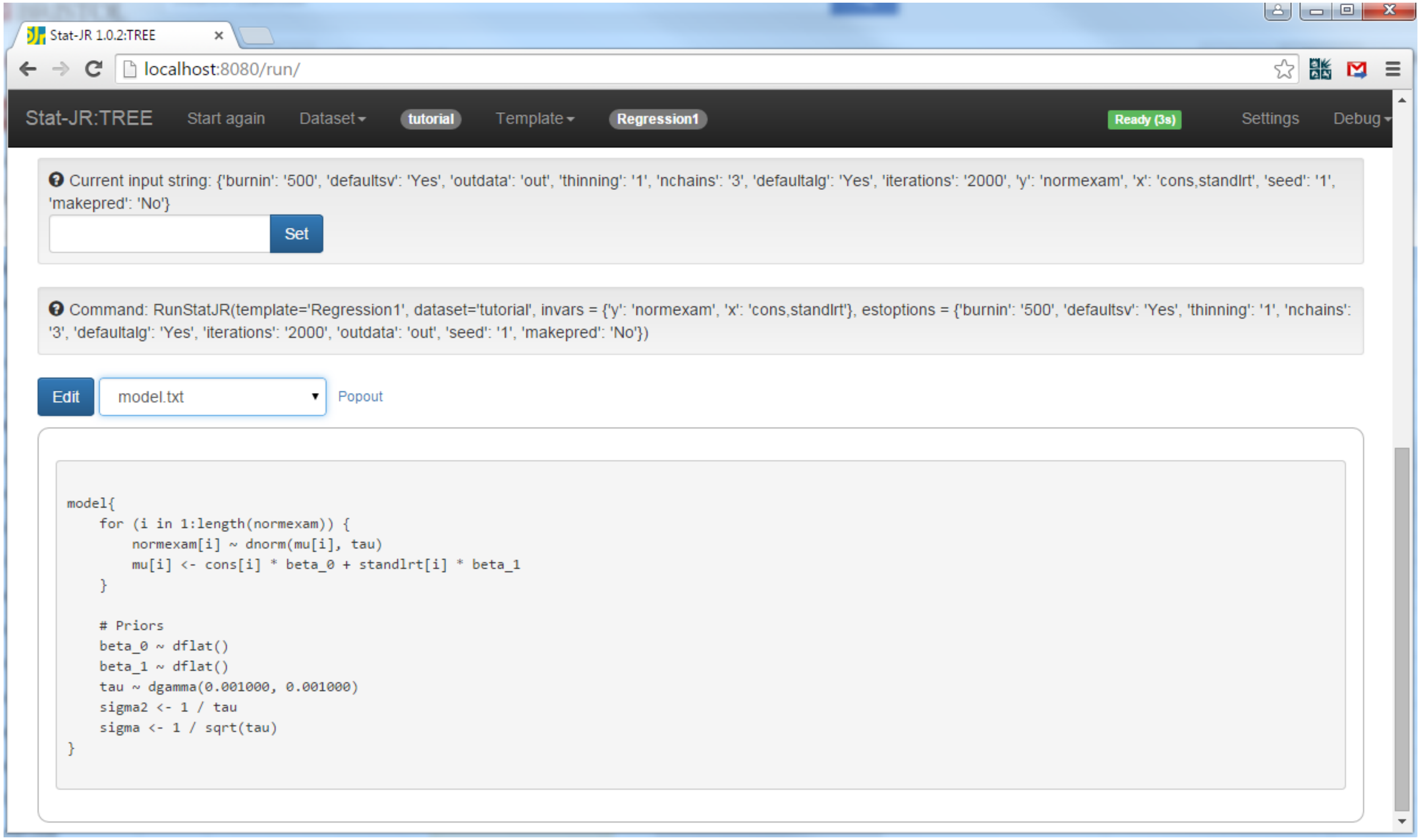
– All objects created available from one pull down and can be popped out to separate tabs in browser.

Equations for model

$$\begin{aligned}
\text{normexam}_i &\sim \mathrm{N}(\mu_i, \sigma^2) \\
\mu_i &= \beta_0 \text{cons}_i + \beta_1 \text{standlrt}_i \\
\beta_0 &\propto 1 \\
\beta_1 &\propto 1 \\
\tau &\sim \Gamma(0.001, 0.001) \\
\sigma^2 &= 1/\tau
\end{aligned}$$

- Note: Equations use MATHJAX and so underlying LaTeX can be copied and paste. The model code is based around the WinBUGS language with some variation.

Model code



- All objects created available from one pull down and can be popped out to separate tabs in browser.

Model code in detail

```
model{
   for (i in 1:length(normexam)) {
      normexam[i] ~ dnorm(mu[i], tau)
      mu[i] <- cons[i] * beta0 + standlrt[i] * beta1
 }
# Priors
   beta0 ~ dflat()
   beta1 ~ dflat()
   tau ~ dgamma(0.001000, 0.001000)
   sigma2 <- 1 / tau
   sigma <- 1/sqrt(tau)
}
```

For this template the code is, aside from the length function, standard WinBUGS model code.

Algebra system steps

localhost:8080/output/node_beta_0.xml

Stat-JR:TREE

Log posterior $\tau\left(\sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i(\text{normexam}_i - \text{beta\_}_1\text{standlrt}_i)\right)\text{beta\_}_0 - \frac{\tau\left(\sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i{}^2\right)\text{beta\_}_0{}^2}{2}$

Distribution dnorm

Match $A = \tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i(\text{normexam}_i - \text{beta\_}_1\text{standlrt}_i)$

Match $B = -\left(\frac{\tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i{}^2}{2}\right)$

Sampling parameter $\mu = \frac{\tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i(\text{normexam}_i - \text{beta\_}_1\text{standlrt}_i)}{\tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i{}^2}$

Sampling parameter $\tau = \tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i{}^2$

Sampling distribution $\text{beta\_}_0 \sim \text{dnorm}\left(\frac{\tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i(\text{normexam}_i - \text{beta\_}_1\text{standlrt}_i)}{\tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i{}^2}, \tau \sum_{i=1}^{\text{length}(\text{normexam})} \text{cons}_i{}^2\right)$

Algebra system steps

Stat-JR 1.0.2:TREE | Stat-JR 1.0.2:TREE | Stat-JR 1.0.2:TREE

localhost:8080/output/algorithm.tex

Stat-JR:TREE

LaTeX version of algorithm

Conditional posterior for tau for Gibbs sampling

$$\tau \sim \Gamma\left(0.001 + 0.5 \times \mathrm{length(normexam)}, 0.001000 + \frac{\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \left(\mathrm{normexam_i} - \mathrm{beta\_0} \times \mathrm{cons_i} - \mathrm{beta\_1} \times \mathrm{standlrt_i}\right)^2}{2}\right)$$

Deviance Function

$$\mathrm{deviance} = 2 \times \left(\frac{\tau \times \left(\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \left(\mathrm{normexam_i} - \mathrm{beta\_0} \times \mathrm{cons_i} - \mathrm{beta\_1} \times \mathrm{standlrt_i}\right)^2\right)}{2} + 0.5 \times (\ln(\pi) - \ln(\tau)) \times \mathrm{length(normexam)} + 0.346573590279973 \times \mathrm{length(normexam)}\right)$$

Conditional posterior for beta_0 for Gibbs sampling

$$\mathrm{beta\_0} \sim \mathrm{N}\left(\frac{\tau \times \left(\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \mathrm{cons_i} \times \left(\mathrm{normexam_i} - \mathrm{beta\_1} \times \mathrm{standlrt_i}\right)\right)}{\tau \times \left(\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \mathrm{cons_i}^2\right)}, \tau \times \left(\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \mathrm{cons_i}^2\right)\right)$$

Conditional posterior for beta_1 for Gibbs sampling

$$\mathrm{beta\_1} \sim \mathrm{N}\left(\frac{\tau \times \left(\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \mathrm{standlrt_i} \times \left(\mathrm{normexam_i} - \mathrm{beta\_0} \times \mathrm{cons_i}\right)\right)}{\tau \times \left(\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \mathrm{standlrt_i}^2\right)}, \tau \times \left(\sum_{\mathrm{i}=1}^{\mathrm{length(normexam)}} \mathrm{standlrt_i}^2\right)\right)$$

Deterministic formula for parameter sigma

$$\sigma = \frac{1}{\mathrm{sqrt}(\tau)}$$

Deterministic formula for parameter sigma2

$$\sigma_2 = \frac{1}{\tau}$$

Algebra system steps

Use Gibbs sampling from conditional posterior for beta1:

$$\beta_1 \sim \mathrm{N}\left(\frac{\tau\times\left(\sum_{i=1}^{\mathrm{length(normexam)}} \mathrm{standlrt}_i \times \left(\mathrm{normexam}_i - \beta_0 \times \mathrm{cons}_i\right)\right)}{\tau\times\left(\sum_{i=1}^{\mathrm{length(normexam)}} \mathrm{standlrt}_i^{\,2}\right)}, \tau \times \left(\sum_{i=1}^{\mathrm{length(normexam)}} \mathrm{standlrt}_i^{\,2}\right)\right)$$

$$\beta_1 \sim \mathrm{N}(0.000249799765395 \times (2382.12631198 + \beta_0 \times (-7.34783096611)), 4003.20632175 \times \tau)$$

- Here the first line is what is returned by the algebra system – which works solely on the model code.
- The second line is what can be calculated when values are added for constants and data etc.
- System then constructs C code and fits model

Output of generated C++ code

```
void iterate() {
// Update tau
    {
                    double sum0=0;
            for(int i=0; i<length(normexam); i++) {
                    double sel0 = double(normexam[int(i)]);
                    double sel1 = double(cons[int(i)]);
                    double sel2 = double(standlrt[int(i)]);
                    double sel5 = double(school[int(i)]);
                    double sel4 = double(u[int(sel5)]);
                    sum0+=pow((((sel0-(beta0*sel1))-(beta1*sel2))-(sel1*sel4)),2);
            }


        std::tr1::gamma_distribution<double> gamma((0.001+(0.5*length(normexam))));
        tau = (1.0 / (0.001000+(sum0/2))) * gamma(eng);

    }
// Update sigma_u
    {


        sigma_u = (1/sqrt(tau_u));
    }
// Update u
for(int j=0; j<length(u); j++){
    {
                    double sum0=0;
            double sum1=0;
            for(int id_i=0; id_i<length(idmap_school[j]); id_i++) {          int i = idmap_school[j][id_i];
                    double sel0 = double(cons[int(i)]);
                    double sel1 = double(normexam[int(i)]);
                    double sel3 = double(standlrt[int(i)]);
                    sum0+=(sel0*((-sel1)+(beta0*sel0)+(beta1*sel3)));
            }
            for(int id_i=0; id_i<length(idmap_school[j]); id_i++) { int i = idmap_school[j][id_i];
                    double sel4 = double(cons[int(i)]);
                    sum1+=pow(sel4,2);
            }


        std::tr1::normal_distribution<double> normal((-((tau*sum0)/(2*((tau_u/2)+((tau*sum1)/2))))), 1/sqrt((2*((tau_u/2)+((tau*sum1)/2)))));

        u[j] = normal(eng);

    }}

// Update beta1
    {
                    double sum0=0;
            double sum1=0;
            for(int i=0; i<length(normexam); i++) {
                    double sel0 = double(standlrt[int(i)]);
```

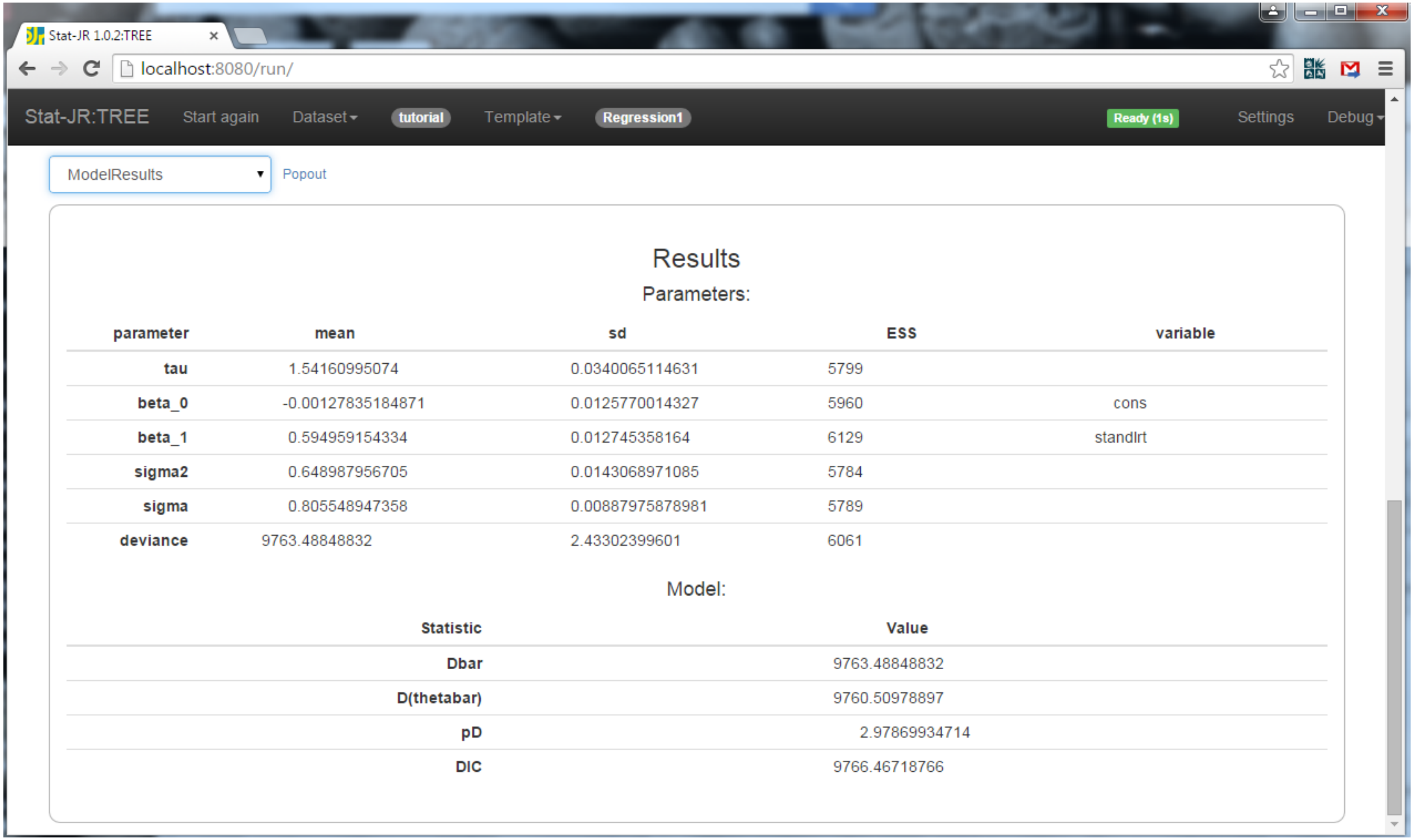
- The package can output C++ code that can then be taken away by software developers and modified.

Output of generated C++ code

```
// Update beta1
{
beta1 = dnorm((0.000249799765395*(2382.12631198+(beta0*(-
    7.34783096611)))),(4003.20632175*tau));
}
// Update beta0
{
beta0 = dnorm((((-0.462375992909)+((-
    7.34783096611)*beta1))*0.000246366100025),(tau*4059.0));
}
```

- Note now that the code includes the actual data in place of constants and so looks less like the familiar algebraic expressions

Output from the E-STAT engine

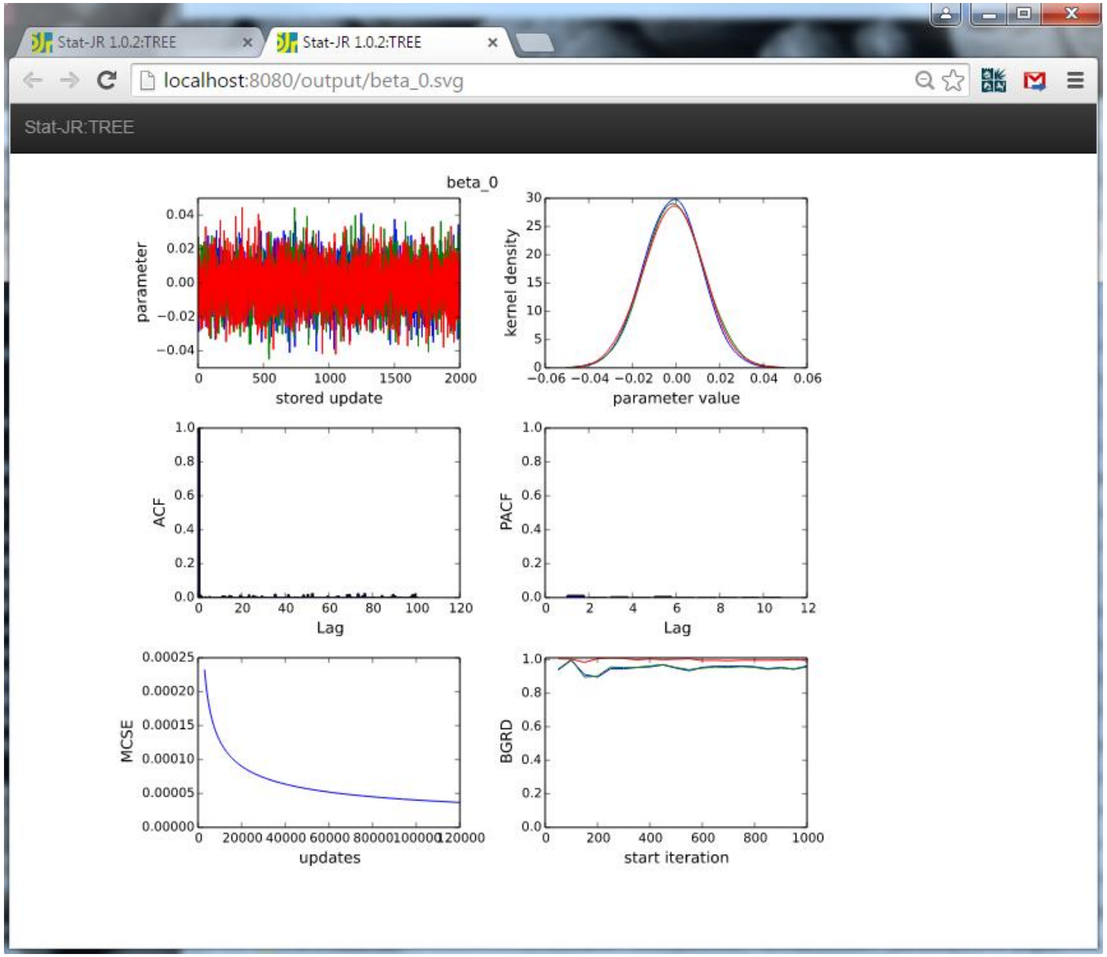


parameter	mean	sd	ESS	variable
tau	1.54160995074	0.0340065114631	5799	
beta_0	-0.00127835184871	0.0125770014327	5960	cons
beta_1	0.594959154334	0.012745358164	6129	standlrt
sigma2	0.648987956705	0.0143068971085	5784	
sigma	0.805548947358	0.00887975878981	5789	
deviance	9763.48848832	2.43302399601	6061	

Statistic	Value
Dbar	9763.48848832
D(thetabar)	9760.50978897
pD	2.97869934714
DIC	9766.46718766

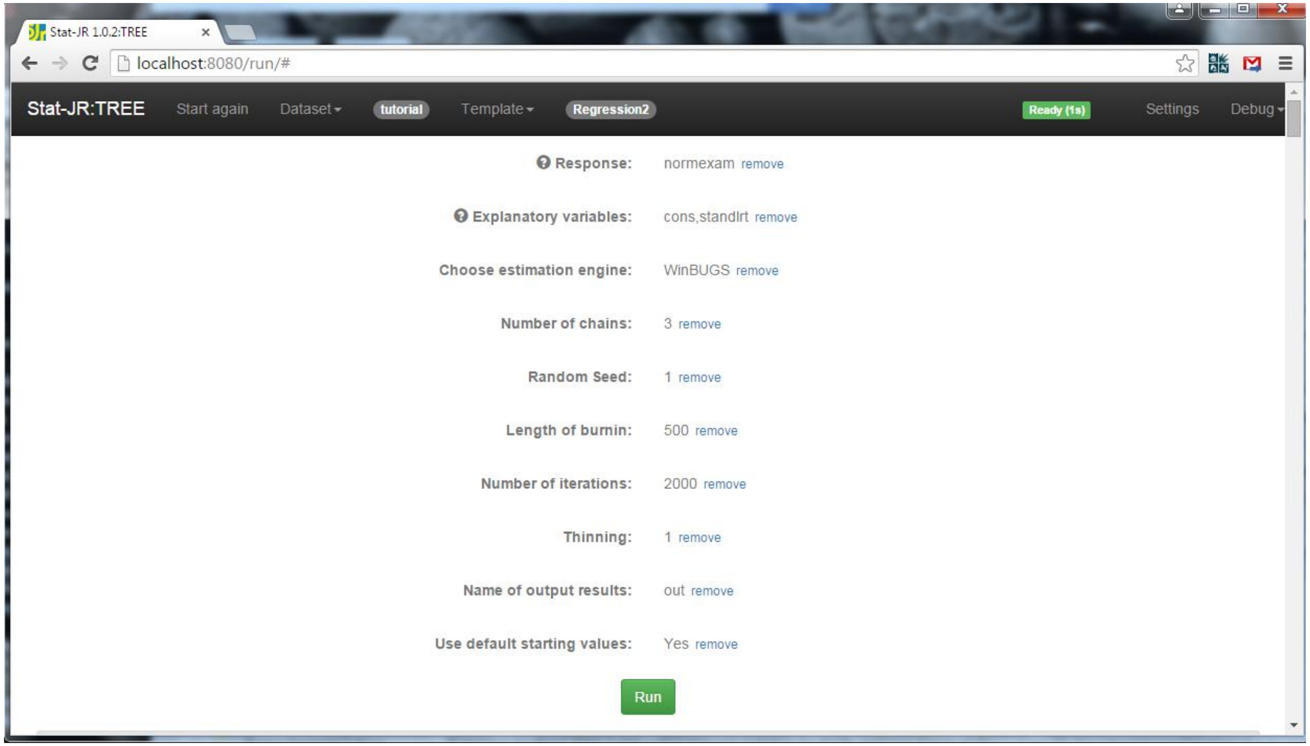
– Estimates and the DIC diagnostic can be viewed for the model fitted.

Output from the E-STAT engine



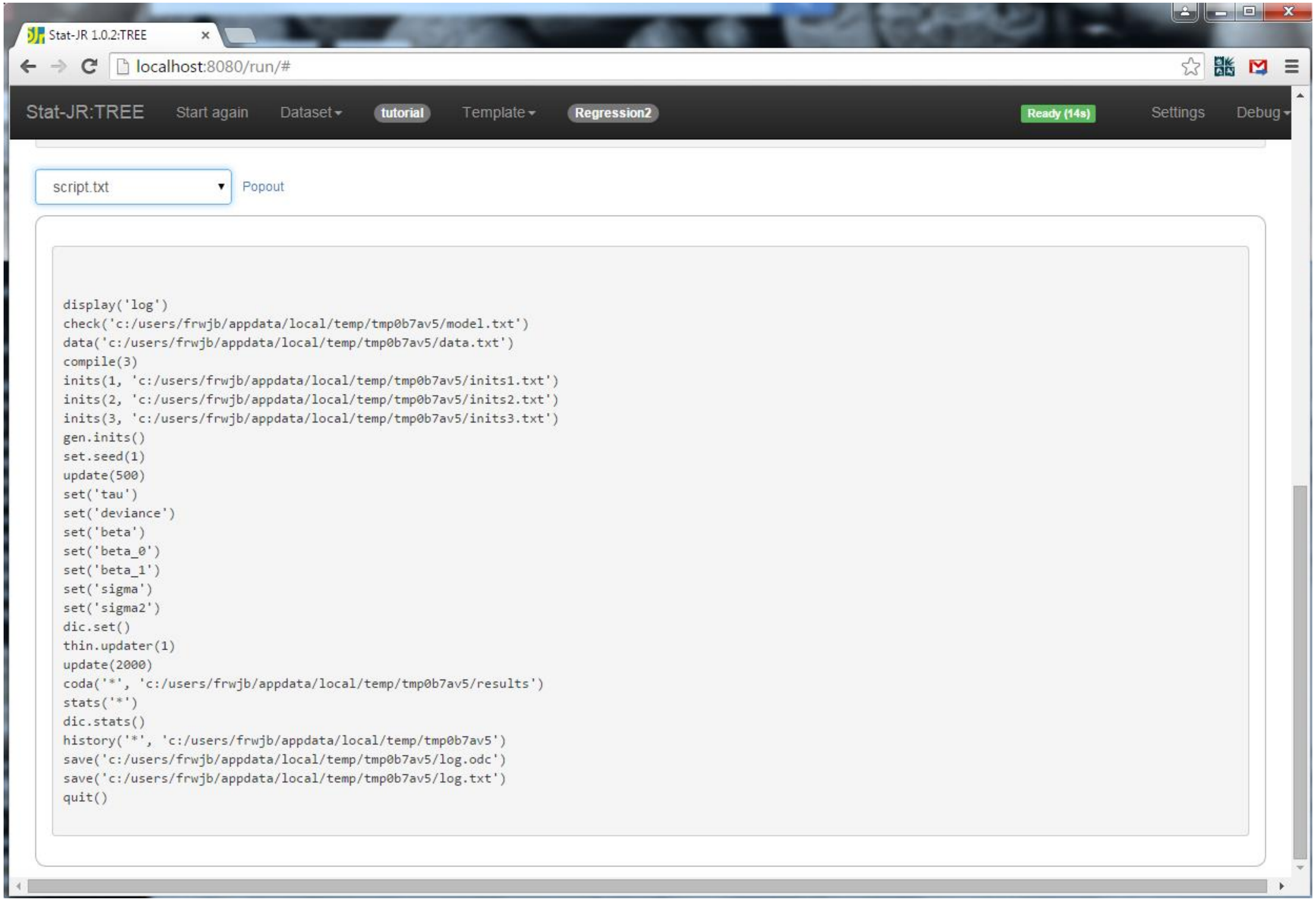
- E-STAT offers multiple chains so that we can use multiple chain diagnostics to aid convergence checking.
- Graphics are in svg format so scale nicely.

Interoperability with WinBUGS (Regression 2)



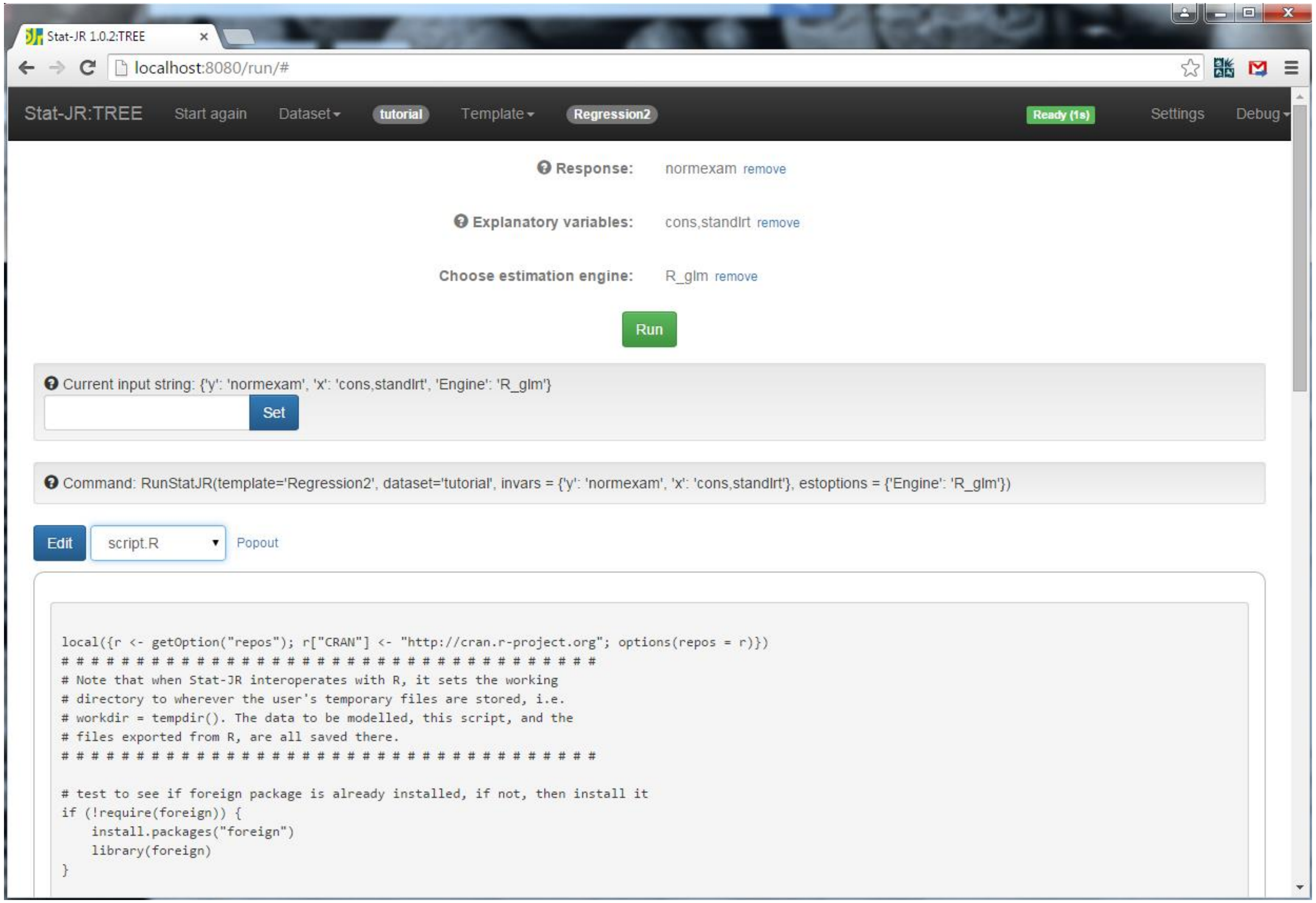
- This template offers the choice of many software packages for fitting a regression model.
- STAT-JR checks what is installed on the machine and only offers packages that are installed. Here we choose WinBUGS.
- Interoperability in the user interface is obtained via a few extra inputs. In fact in the template code user written functions are required for all packages apart from WinBUGS, OpenBUGS and JAGS. The transfer of data between packages is however generic.

Interoperability with WinBUGS (Regression 2)



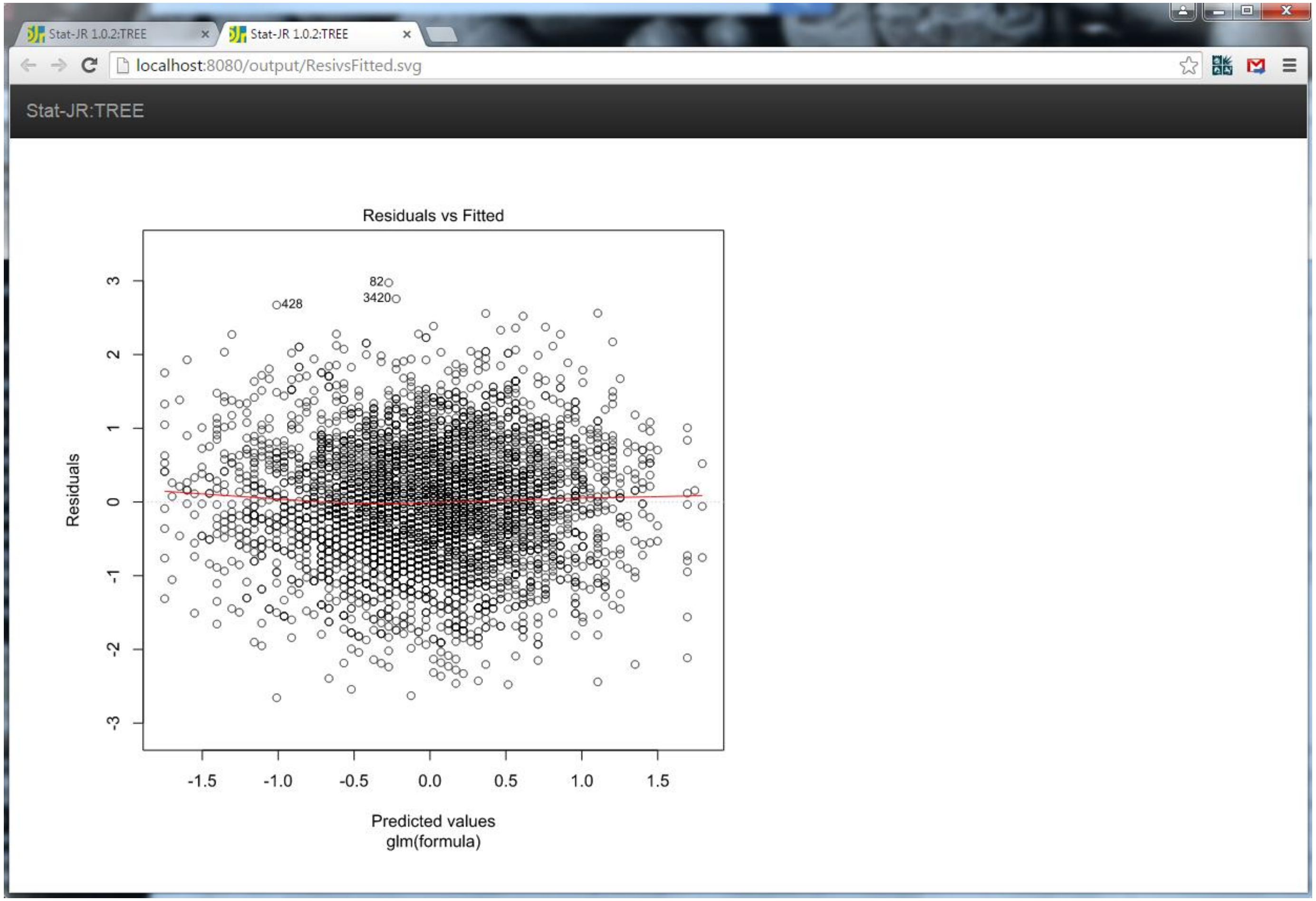
- Here we can view the files required to run WinBUGS in the pane (script file shown but model, inits and data also available)
- The model can be run by press of a button.

Interoperability with R



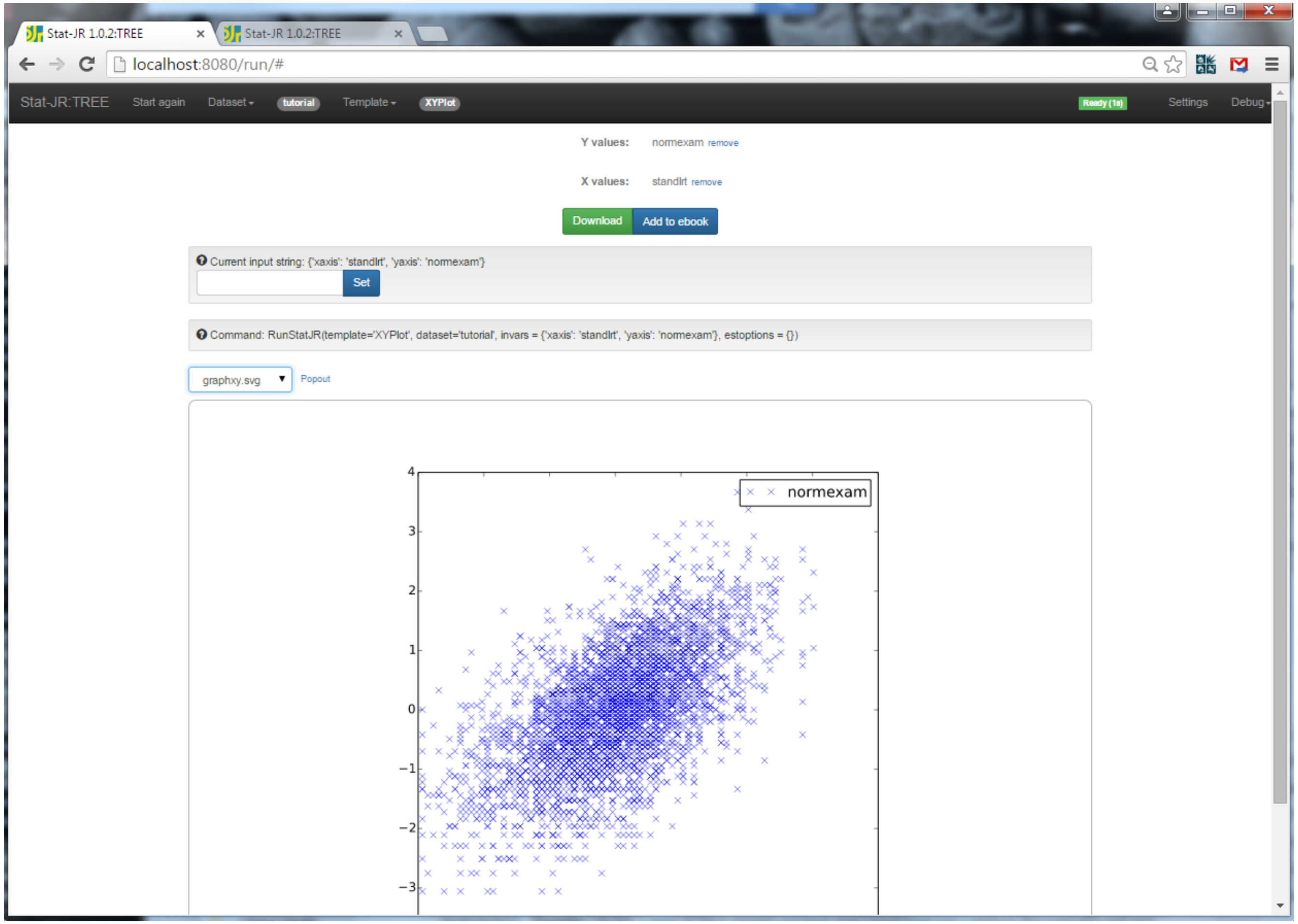
- R can be chosen as another alternative. In fact here we have 2 choices – glm or MCMCglmm.
- You will see in the pane the script file ready for input to R. There will also be the data file that R requires.

Interoperability with R



- If written in to the code in the template – graphics from other software can be extracted.
- Here for example is a residual plot associated with the R fit of the model.

Other templates - XYplot



- There are also templates for plotting. For example here is a plot using the XYplot template.
- Shown is the plot whilst the Python command script is also available.
- For more details on StatJR go to http://www.bristol.ac.uk/cmm/software/statjr/

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