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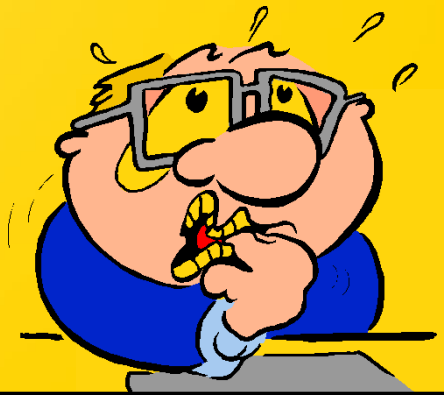
# Priors: When to worry?

Rens van de Schoot & Sarah Depaoli

www.rensvandeschoot.com



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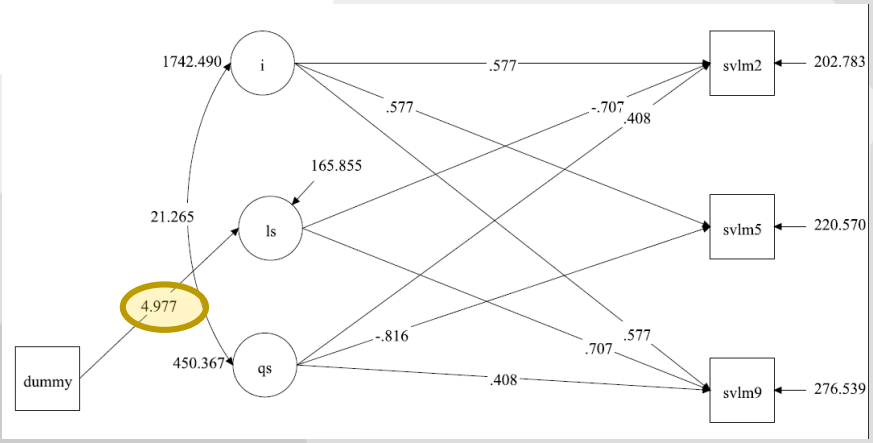
Dear dr. ,

We would kindly invite you to review this paper about …



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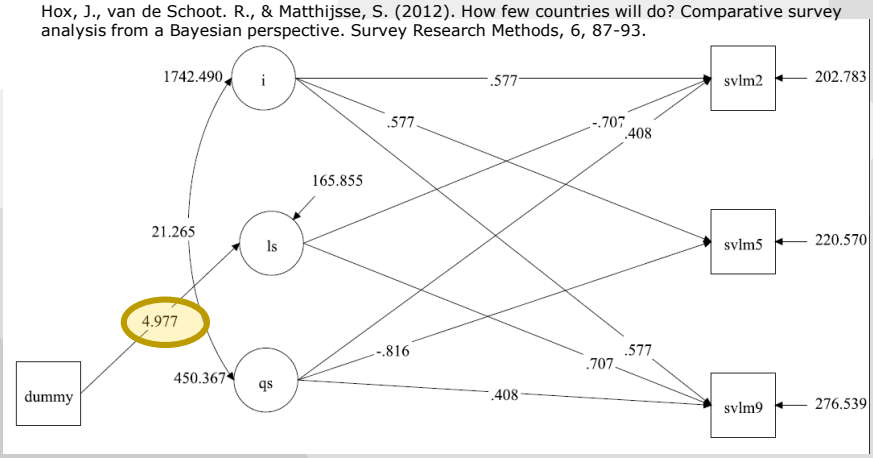
Because of the small sample size (n=20) we used Bayesian estimation. Hox et al. (2012) showed that a multilvel model with only 20 clusters could be estimated with Bayesian statistics whereas maximum likelihood estimation could not.

Hox, J., van de Schoot. R., & Matthijsse, S. (2012). How few countries will do? Comparative survey analysis from a Bayesian perspective. Survey Research Methods, 6, 87-93.

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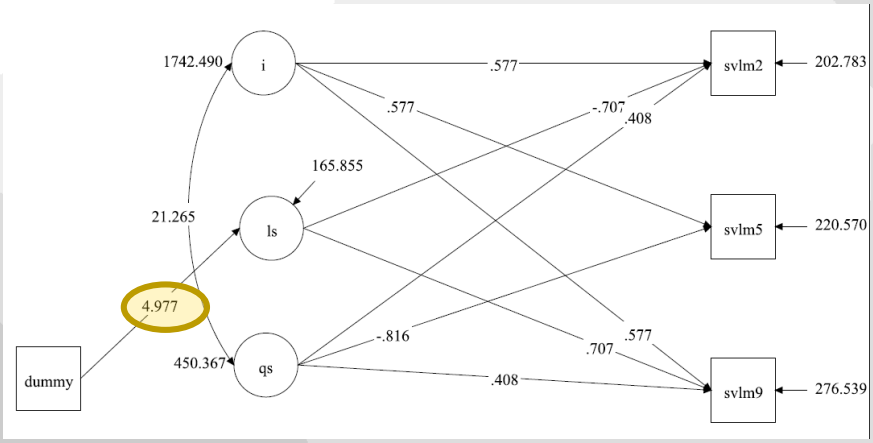
Since we are no experts in Bayesian estimation we relied on the default settings of Mplus and only specified:

ANALYSIS:ESTIMATOR is Bayes;



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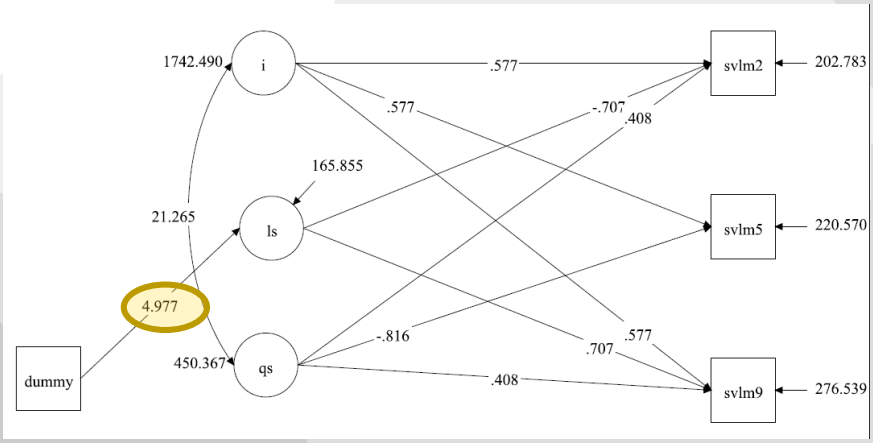
The results are completely in line with our hypothesis: there is a significant difference between the two groups on the slope parameter. All is fine, please accept our paper for publication.

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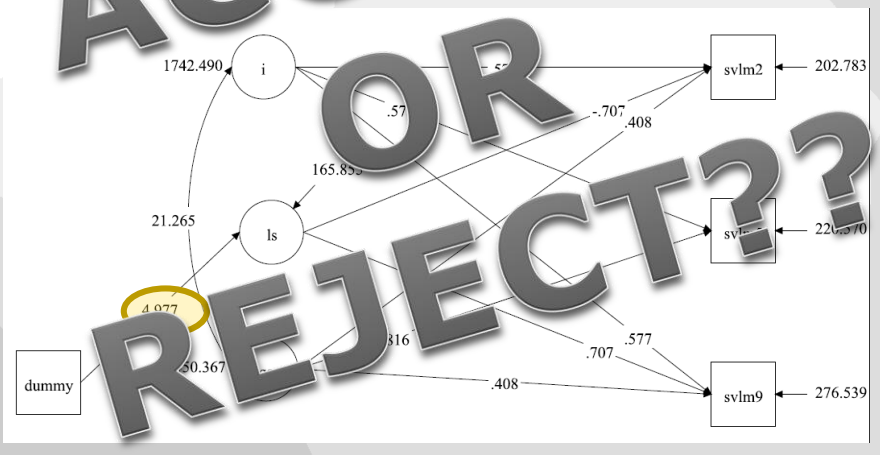
ACCEPT OR REJECT??



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# The WAMBS-Checklist

## When to worry, and how to Avoid the Misuse of Bayesian Statistics

*Depaoli & Van de Schoot (2014)*

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# The WAMBS-Checklist

Although it is very attractive to use Bayesian statistics, naively applying Bayesian methods can be dangerous:

1. the exact influence of the priors is often not well understood and priors might have a huge impact on the study results.

2. akin to many elements of frequentist statistics, some Bayesian features can be easily misinterpreted.

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**TO BE CHECKED AFTER ANALYSIS BUT BEFORE INSPECTING MODEL RESULTS**

**Step 2:** did the trace-plot reached the target distribution?

**Step 3:** does convergence remain after doubling the number of iterations?

**Step 4:** does the histogram have enough precision?

**Step 5:** does the posterior distribution make theoretical sense?

**Step 6:** do different specification of the multivariate variance priors influence the results?

**UNDERSTANDING THE EXACT INFLUENCE OF THE PRIORS**

**Step 7:** Is there bias when compared with non-informative priors?

**Step 8:** Are the results stable for a sensitivity analysis?

**AFTER INTERPRETATION OF MODEL RESULTS**

**Step 9:** Is the Bayesian way of interpreting model results used?

**Step 10**: Are the results reported according to the Bayesian approach?

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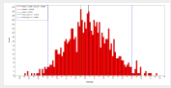
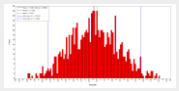
# Step 1

| Parameters[a] | Distributional form of the priors (e.g., normal, inverse gamma, etc) | Type of prior (non-, weakly, highly informative) | Source of background information | Graph of Plot[b] | Hyperparame |
|---|---|---|---|---|---|
| Y on $X_1$ | Normal | Highly inf. | Table x on page xx of the meta-analysis of Author et al. (2000) |  | N(.8,5); |
| Y on $X_2$ | Normal | Highly inf. | Obtained from expert knowledge, see for more information Appendix X. |  | N(.1,10); |
| Y: Mean | Normal | Non inf. (default of the software used) | n/a | n/a | N(0,100000000 |
| Y: residual variance | Inverse Gamma | Non inf. (default of the software used) | n/a | n/a | IG(-1,0); |

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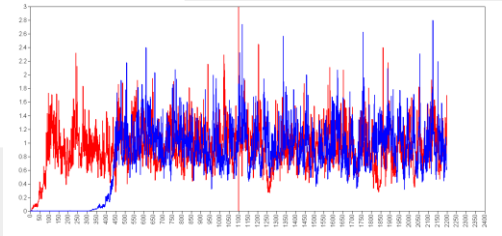
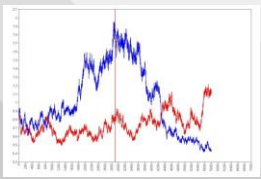
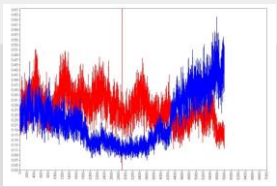
# Step 2







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# Step 3

```
ANALYSIS:
        ESTIMATOR IS BAYES;
        BSEED = 200;

OUTPUT: cinterval(hpd);

PLOT: type is plot2;
```

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# Step 3

```
ANALYSIS:
        ESTIMATOR IS BAYES;
        BSEED = 200;

        CHAINS = 4;
        BITERATIONS = 100000 (2000);
        BCONVERGENCE = .01;


OUTPUT: cinterval(hpd);

PLOT: type is plot2;
```

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# Step 3

```
ANALYSIS:
        ESTIMATOR IS BAYES;
        BSEED = 200;

        CHAINS = 4;

        FBITERATIONS = 4000;


OUTPUT: cinterval(hpd); TECH8;
PLOT: type is plot2;
```

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# Tech 8 - priors

TECHNICAL 8 OUTPUT FOR BAYES ESTIMATION

| CHAIN | BSEED |
|---|---|
| 1 | 0 |
| 2 | 285380 |

| ITERATION | POTENTIAL SCALE REDUCTION | PARAMETER WITH HIGHEST PSR |
|---|---|---|
| 100 | 1.010 | 1 |
| 200 | 1.000 | 2 |

Bconvergence = .01;

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# Tech 8 - priors

TECHNICAL 8 OUTPUT FOR BAYES ESTIMATION

| CHAIN | BSEED |
|---|---|
| 1 | 0 |
| 2 | 285380 |

| ITERATION | POTENTIAL SCALE REDUCTION | PARAMETER WITH HIGHEST PSR |
|---|---|---|
| 100 | 1.010 | 1 |
| 200 | 1.000 | 2 |

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# Tech 8 - priors

TECHNICAL 8 OUTPUT FOR BAYES ESTIMATION

| CHAIN | BSEED |
|---|---|
| 1 | 0 |
| 2 | 285380 |

| ITERATION | POTENTIAL SCALE REDUCTION | PARAMETER WITH HIGHEST PSR |
|---|---|---|
| 100 | 1.010 | 1 |
| 200 | 1.000 | 2 |
| 300 | 1.004 | 2 |
| 400 | 1.002 | 2 |
| 500 | 1.000 | 1 |
| 600 | 1.000 | 1 |
| 700 | 1.002 | 2 |
| 800 | 1.000 | 1 |
| 900 | 1.000 | 1 |
| 1000 | 1.000 | 1 |

Biterations = (1000);

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# Tech 8 - priors

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| CHAIN | BSEED |
|---|---|
| 1 | 0 |
| 2 | 285380 |

| ITERATION | POTENTIAL SCALE REDUCTION | PARAMETER WITH HIGHEST PSR |
|---|---|---|
| 100 | 1.010 | 1 |
| 200 | 1.000 | 2 |
| 300 | 1.004 | 2 |
| 400 | 1.002 | 2 |
| 500 | 1.000 | 1 |
| **600** | **1.000** | **1** |
| **700** | **1.002** | **2** |
| **800** | **1.000** | **1** |
| **900** | **1.000** | **1** |
| **1000** | **1.000** | **1** |

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# Tech 8 - priors

TECHNICAL 8 OUTPUT FOR BAYES ESTIMATION

| CHAIN | BSEED |
|---|---|
| 1 | 0 |
| 2 | 285380 |

| ITERATION | POTENTIAL SCALE REDUCTION | PARAMETER WITH HIGHEST PSR |
|---|---|---|
| 100 | 2.210 | 1 |
| 200 | 2.100 | 2 |
| 300 | 1.904 | 2 |
| 400 | 1.802 | 2 |
| 500 | 1.700 | 1 |
| 600 | 1.600 | 1 |
| 700 | 1.302 | 2 |
| 800 | 1.200 | 1 |
| 900 | 1.060 | 1 |
| **1000** | **1.040** | **1** |

Relied on defaults settings:
Bconvergence is .05;

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# Tech 8 - priors

TECHNICAL 8 OUTPUT FOR BAYES ESTIMATION

| CHAIN | BSEED |
|---|---|
| 1 | 0 |
| 2 | 285380 |

| ITERATION | POTENTIAL SCALE REDUCTION | PARAMETER WITH HIGHEST PSR |
|---|---|---|
| 100 | 2.210 | 1 |
| 200 | 2.100 | 2 |
| 300 | 1.904 | 2 |
| 400 | 1.802 | 2 |
| 500 | 1.700 | 1 |
| **600** | **1.600** | **1** |
| **700** | **1.302** | **2** |
| **800** | **1.200** | **1** |
| **900** | **1.060** | **1** |
| **1000** | **1.040** | **1** |

**!!!** The last 100 iterations are maybe oké, but not all iterations after burn-in **!!!**

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# Tech 8 - priors

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| CHAIN | BSEED |
|---|---|
| 1 | 0 |
| 2 | 285380 |

| ITERATION | POTENTIAL SCALE REDUCTION | PARAMETER WITH HIGHEST PSR |
|---|---|---|
| 100 | 2.210 | 1 |
| 200 | 2.100 | 2 |
| 300 | 1.904 | 2 |
| 400 | 1.802 | 2 |
| 500 | 1.700 | 1 |
| 600 | 1.600 | 1 |
| 700 | 1.302 | 2 |
| 800 | 1.200 | 1 |
| 900 | 1.060 | 1 |
| 1000 | 1.040 | 1 |
| **1100** | **1.010** | **1** |
| **1200** | **1.000** | **2** |
| **1300** | **1.004** | **2** |
| **1400** | **1.002** | **2** |
| **1500** | **1.000** | **1** |
| **1600** | **1.000** | **1** |
| **1700** | **1.002** | **2** |
| **1800** | **1.000** | **1** |
| **1900** | **1.000** | **1** |
| **2000** | **1.000** | **1** |

Solution: Increase number of iterations with

Fbiterations = 2000;

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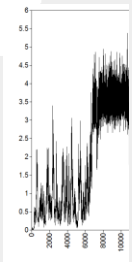
# Step 3



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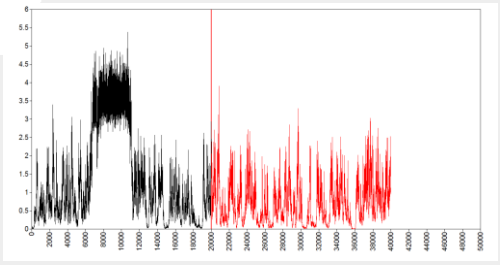
# Step 3



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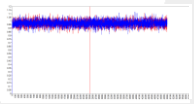
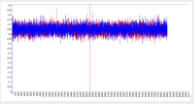
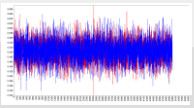
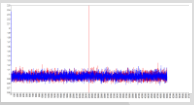
# Step 3

| Parameters | Trace plot |
|---|---|
| Y on $X_1$ |  |
| Y on $X_2$ |  |
| Y: Mean |  |
| Y: residual variance |  |

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# Step 3

| Parameters | Bias for Step 3[a]<br>[(initial converged model – model with double iterations)/model with double iterations]*100 |
|---|---|
| Y on $X_1$ | [(0.969-0.970)/ 0.970]*100= -0.10 |
| Y on $X_2$ | [(0.650-0.650)/ 0.650]*100= 0.00 |
| [Y] | [(0.510-0.511)/ 0.511]*100= -0.19 |
| Y | [(0.953-0.951)/ 0.951]*100= 0.21 |

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| |
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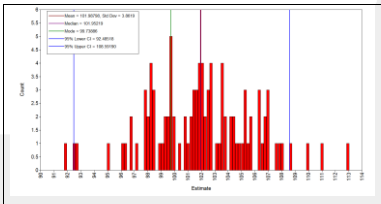
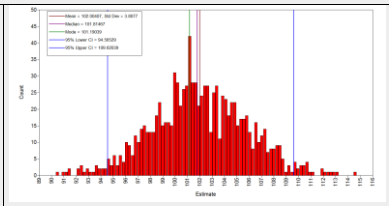
# Step 4

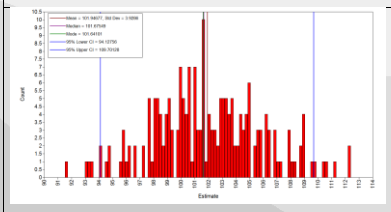
The more iterations, the more information in the histogram and the better the results approximate the posterior distribution



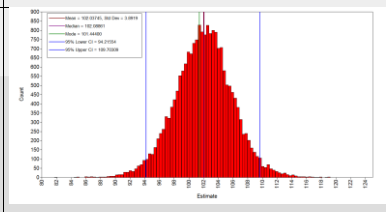
(A)



(C)



(B)



(D)

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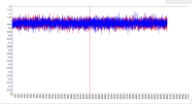
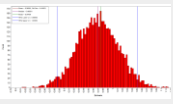
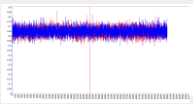
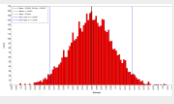
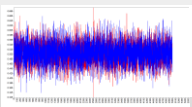
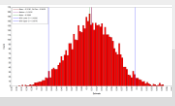
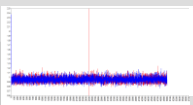
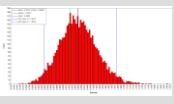
# Step 4

| Parameters | Trace plot | Histogram |
|---|---|---|
| Y on $X_1$ |  |  |
| Y on $X_2$ |  |  |
| Y: Mean |  |  |
| Y: residual variance |  |  |

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**AFTER INTERPRETATION OF MODEL RESULTS**

**Step 9:** Is the Bayesian way of interpreting model results used?

**Step 10**: Are the results reported according to the Bayesian approach?

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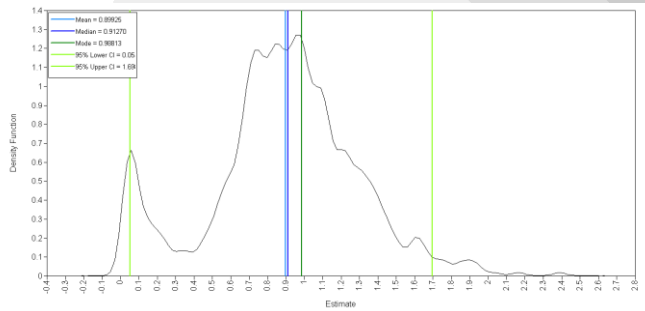
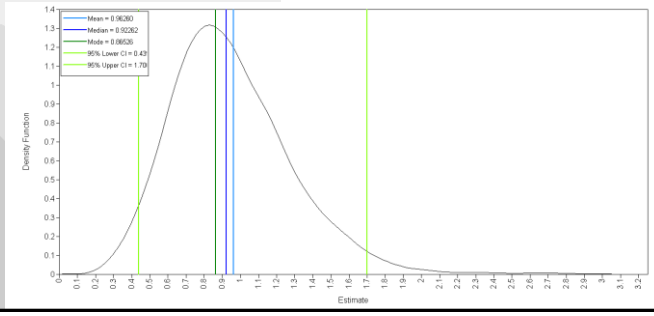
# Step 5

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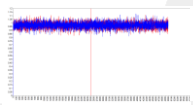
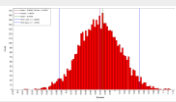
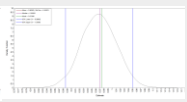
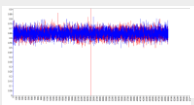
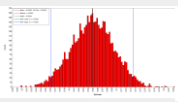
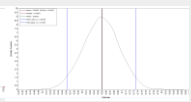
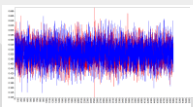
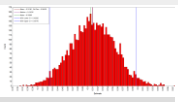
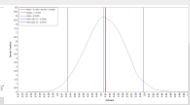
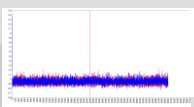
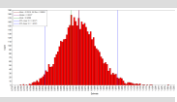
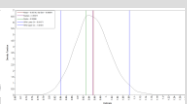
| Parameters | Trace plot | Histogram | Kernel density plot |
|---|---|---|---|
| Y on $X_1$ |  |  |  |
| Y on $X_2$ |  |  |  |
| Y: Mean |  |  |  |
| Y: residual variance |  |  |  |

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# The WAMBS-Checklist

**TO BE CHECKED BEFORE RUNNING THE ANALYSIS**

**Step 1:** do you understand the priors?

**TO BE CHECKED AFTER ANALYSIS BUT BEFORE INSPECTING MODEL RESULTS**

**Step 2:** did the trace-plot reached the target distribution?

**Step 3:** does convergence remain after doubling the number of iterations?

**Step 4:** does the histogram have enough precision?

**Step 5:** does the posterior distribution make theoretical sense?

**Step 6:** do different specification of the multivariate variance priors influence the results?

**UNDERSTANDING THE EXACT INFLUENCE OF THE PRIORS**

**Step 7:** Is there bias when compared with non-informative priors?

**Step 8:** Are the results stable for a sensitivity analysis?

**AFTER INTERPRETATION OF MODEL RESULTS**

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**Step 10**: Are the results reported according to the Bayesian approach?

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# The WAMBS-Checklist

| | **Bias for Step 3[a]** | **Bias for Step 6[b]** |
|---|---|---|
| | [(initial converged model – model with double iterations)/model with double iterations]*100 | [(initial variance priors – model with alternative priors)/model with alternative priors]*100 |
| **Parameters** | | |
| Y on $X_1$ | [(0.969-0.970)/ 0.970]*100= -0.10 | [(0.969-0.969)/ 0.969]*100= 0.00 |
| Y on $X_2$ | [(0.650-0.650)/ 0.650]*100= 0.00 | [(0.650-0.650)/ 0.650]*100= 0.00 |
| [Y] | [(0.510-0.511)/ 0.511]*100= -0.19 | [(0.510-0.510)/ 0.510]*100= 0.00 |
| Y | [(0.953-0.951)/ 0.951]*100= 0.21 | [(0.953-0.949)/ 0.949]*100= 0.42 |

[a] initially with 5,000 iterations, alternative model with 10,000 iterations

[b] initially with IG(-1,0), alternative model with IG(.1,.1)

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# The WAMBS-Checklist

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# The WAMBS-Checklist

| Parameters | **Bias for Step 3**[a]<br>[(initial converged model – model with double iterations)/model with double iterations]*100 | **Bias for Step 6**[b]<br>[(initial variance priors – model with alternative priors)/model with alternative priors]*100 | **Bias for Step 7**<br>[(initial priors – default/non-informative priors)/ default/non-informative priors]*100 |
|---|---|---|---|
| Y on $X_1$ | [(0.969-0.970)/ 0.970]*100= -0.10 | [(0.969-0.969)/ 0.969]*100= 0.00 | [(0.969-0.969)/ 0.969]*100= 0.00 |
| Y on $X_2$ | [(0.650-0.650)/ 0.650]*100= 0.00 | [(0.650-0.650)/ 0.650]*100= 0.00 | [(0.650-0.650)/ 0.650]*100= 0.00 |
| [Y] | [(0.510-0.511)/ 0.511]*100= -0.19 | [(0.510-0.510)/ 0.510]*100= 0.00 | [(0.510-0.510)/ 0.510]*100= 0.00 |
| Y | [(0.953-0.951)/ 0.951]*100= 0.21 | [(0.953-0.949)/ 0.949]*100= 0.42 | [(0.953-0.953)/ 0.953]*100= 0.00 |

[a] initially with 5,000 iterations, alternative model with 10,000 iterations

[b] initially with IG(-1,0), alternative model with IG(.1,.1)

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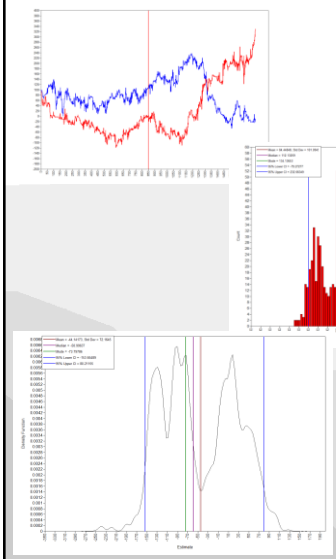
## Back to the example:



| POTENTIAL ITERATION HIGHEST PSR | PARAMETER WITH SCALE REDUCTION | |
|---|---|---|
| 100 | 3.870 | 7 |
| 200 | 2.679 | 7 |
| 300 | 3.405 | 7 |
| 400 | 4.204 | 7 |
| 500 | 3.642 | 1 |
| 600 | 3.536 | 7 |
| 700 | 3.995 | 7 |
| 800 | 4.025 | 7 |
| 900 | 3.176 | 7 |
| 1000 | 3.203 | 7 |
| 1100 | 3.588 | 7 |
| 1200 | 3.120 | 7 |
| 1300 | 2.656 | 7 |
| 1400 | 1.862 | 3 |
| 1500 | 1.338 | 3 |
| 1600 | 1.113 | 3 |
| 1700 | 1.021 | 3 |

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## Back to the example:

| POTENTIAL ITERATION HIGHEST PSR | PARAMETER WITH SCALE REDUCTION | |
|---|---|---|
| 100 | 3.870 | |
| 200 | 2.679 | 7 |
| 300 | | 7 |
| 400 | 4.204 | 7 |
| | 3.642 | 1 |
| 00 | 3.536 | 7 |
| | | 7 |
| 0 | | 7 |
| | 3.176 | 7 |
| 000 | 3.203 | 7 |
| 1100 | 3.588 | 7 |
| 1200 | 3.120 | 7 |
| 1300 | 2.656 | 7 |
| 1400 | 1.862 | 3 |
| 1500 | 1.338 | 3 |
| 1600 | 1.113 | 3 |
| 1700 | 1.021 | 3 |

REJECT