OSMASEM and TSSEM

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```
# Data preparation
library(metaSEM)
```

```
## Loading required package: OpenMx
```

```
## To take full advantage of multiple cores, use:
##   mxOption(NULL, 'Number of Threads', parallel::detectCores()) #now
##   Sys.setenv(OMP_NUM_THREADS=parallel::detectCores()) #before library(OpenMx)
```

```
## "SLSQP" is set as the default optimizer in OpenMx.
```

```
## mxOption(NULL, "Gradient algorithm") is set at "central".
```

```
## mxOption(NULL, "Optimality tolerance") is set at "6.3e-14".
```

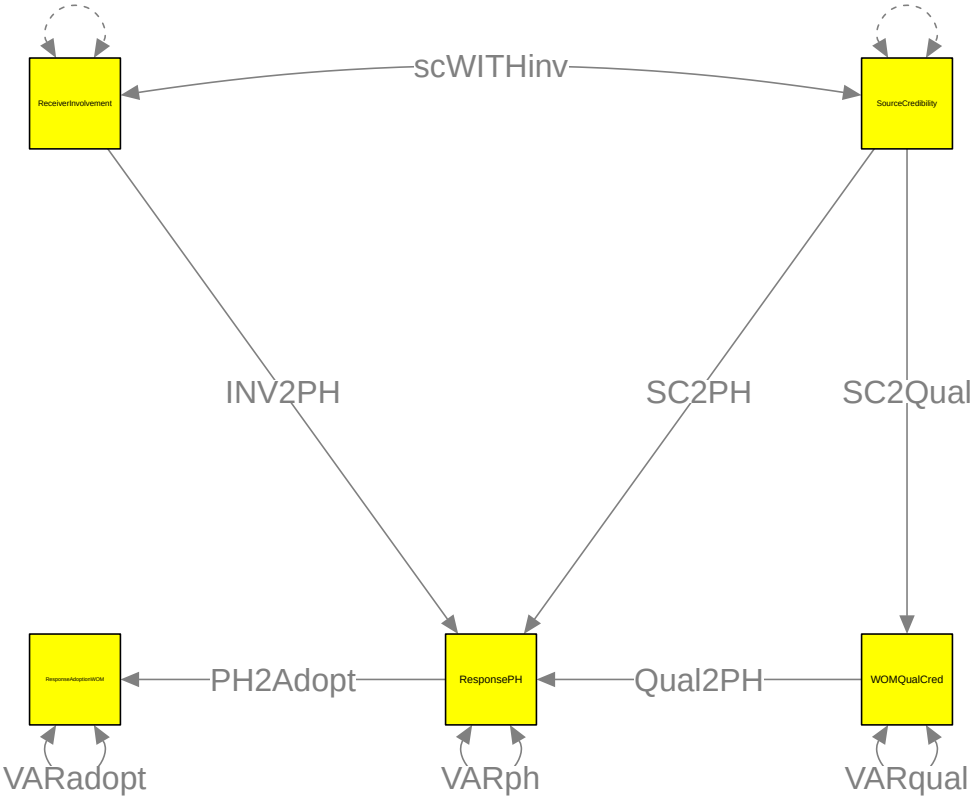
```
## mxOption(NULL, "Gradient iterations") is set at "2".
```

```
## Read List
ewomDataNew2.culture <- readRDS("ewomDataNew2.culture.RData")

## Check the number of studies per correlation coefficient
pattern.na(ewomDataNew2.culture$Data, show.na = FALSE)
```

```
##                     ReceiverInvolvement ResponseAdoptionWOM ResponsePH
## ReceiverInvolvement                  62                   6          5
## ResponseAdoptionWOM                   6                  62         23
## ResponsePH                            5                  23         62
## SourceCredibility                     8                  22         26
## WOMQualCred                           9                  27         32
##                     SourceCredibility WOMQualCred
## ReceiverInvolvement                 8           9
## ResponseAdoptionWOM                22          27
## ResponsePH                         26          32
## SourceCredibility                  62          41
## WOMQualCred                        41          62
```

```
## Calculate the sampling covariance matrix of the correlations
my.df_ewom <- Cor2DataFrame(ewomDataNew2.culture$Data, ewomDataNew2.culture$n, acov = "weighted")

# One-Stage MASEM
## Model without moderation
ewom_model1 <- 'ResponseAdoptionWOM ~ PH2Adopt*ResponsePH
                ResponsePH ~ INV2PH*ReceiverInvolvement + Qual2PH*WOMQualCred + SC2PH*SourceCredibility
                WOMQualCred ~ SC2Qual*SourceCredibility
                SourceCredibility ~~ scWITHinv*ReceiverInvolvement
                SourceCredibility ~~ 1*SourceCredibility
                ReceiverInvolvement ~~ 1*ReceiverInvolvement
                WOMQualCred ~~ VARqual*WOMQualCred
                ResponsePH ~~ VARph*ResponsePH
                ResponseAdoptionWOM ~~ VARadopt*ResponseAdoptionWOM'
```

```
plot(ewom_model1, col="yellow")
```




```
## Convert the lavaan syntax into the RAM specification
ewom_RAM1 <- lavaan2RAM(ewom_model1, obs.variables=c("ReceiverInvolvement", "ResponseAdoptionWOM",
                                                     "ResponsePH", "SourceCredibility", "WOMQualCred"))
ewom_RAM1
```

```
## $A
##                       ReceiverInvolvement ResponseAdoptionWOM ResponsePH
## ReceiverInvolvement   "0"                 "0"                 "0"
## ResponseAdoptionWOM   "0"                 "0"                 "0*PH2Adopt"
## ResponsePH            "0*INV2PH"          "0"                 "0"
## SourceCredibility     "0"                 "0"                 "0"
## WOMQualCred           "0"                 "0"                 "0"
##                       SourceCredibility WOMQualCred
## ReceiverInvolvement   "0"               "0"
## ResponseAdoptionWOM   "0"               "0"
## ResponsePH            "0*SC2PH"         "0*Qual2PH"
## SourceCredibility     "0"               "0"
## WOMQualCred           "0*SC2Qual"       "0"
##
## $S
##                       ReceiverInvolvement ResponseAdoptionWOM ResponsePH
## ReceiverInvolvement   "1"                 "0"                 "0"
## ResponseAdoptionWOM   "0"                 "0*VARadopt"        "0"
## ResponsePH            "0"                 "0"                 "0*VARph"
## SourceCredibility     "0*scWITHinv"       "0"                 "0"
## WOMQualCred           "0"                 "0"                 "0"
```

```
##                      SourceCredibility WOMQualCred
## ReceiverInvolvement "0*scWITHinv"     "0"
## ResponseAdoptionWOM "0"               "0"
## ResponsePH          "0"               "0"
## SourceCredibility   "1"               "0"
## WOMQualCred         "0"               "0*VARqual"
##
## $F
##                      ReceiverInvolvement ResponseAdoptionWOM ResponsePH
## ReceiverInvolvement                    1                   0          0
## ResponseAdoptionWOM                    0                   1          0
## ResponsePH                             0                   0          1
## SourceCredibility                      0                   0          0
## WOMQualCred                            0                   0          0
##                      SourceCredibility WOMQualCred
## ReceiverInvolvement                  0           0
## ResponseAdoptionWOM                  0           0
## ResponsePH                           0           0
## SourceCredibility                    1           0
## WOMQualCred                          0           1
##
## $M
##   ReceiverInvolvement ResponseAdoptionWOM ResponsePH SourceCredibility
## 1                   0                   0          0                 0
##   WOMQualCred
## 1           0
```

```
## Model without moderator
## Create the model implied correlation structure with implicit diagonal constraints
M0 <- create.vechsR(A0=ewom_RAM1$A, S0=ewom_RAM1$S)

## Create the heterogeneity variance-covariance matrix
## RE.type= either "Diag" or "Symm"
## Transform= either "expLog" or "sqSD" for better estimation of variances
T0 <- create.Tau2(RAM=ewom_RAM1, RE.type="Diag", Transform="expLog", RE.startvalues=0.05)

## Fit the model using One-Stage MASEM
mx.fit0_ewom <- osmasem(model.name="eWoM No moderator", Mmatrix=M0, Tmatrix=T0, data=my.df_ewom)
summary(mx.fit0_ewom, Saturated = TRUE)
```

```
## Summary of eWoM No moderator
##
## free parameters:
##         name  matrix                row                 col   Estimate
## 1     INV2PH      A0          ResponsePH ReceiverInvolvement  0.3918654
## 2   PH2Adopt      A0 ResponseAdoptionWOM          ResponsePH  0.8123080
## 3      SC2PH      A0          ResponsePH   SourceCredibility  0.2180440
## 4    SC2Qual      A0         WOMQualCred   SourceCredibility  0.5354310
## 5    Qual2PH      A0          ResponsePH         WOMQualCred  0.4461319
## 6  scWITHinv      S0   SourceCredibility ReceiverInvolvement  0.2687476
## 7     Tau1_1 vecTau1                   1                   1 -1.8847894
## 8     Tau1_2 vecTau1                   2                   1 -1.8572631
## 9     Tau1_3 vecTau1                   3                   1 -2.3683576
## 10    Tau1_4 vecTau1                   4                   1 -1.2437278
## 11    Tau1_5 vecTau1                   5                   1 -1.2300574
```

```
## 12    Tau1_6 vecTau1                  6                   1 -1.9897811
## 13    Tau1_7 vecTau1                  7                   1 -2.0306503
## 14    Tau1_8 vecTau1                  8                   1 -2.0766360
## 15    Tau1_9 vecTau1                  9                   1 -1.7814900
## 16   Tau1_10 vecTau1                 10                   1 -1.7717364
##     Std.Error A    z value     Pr(>|z|)
## 1  0.06270486     6.249362 4.121328e-10
## 2  0.04827675    16.826071 0.000000e+00
## 3  0.04468874     4.879171 1.065329e-06
## 4  0.02804820    19.089672 0.000000e+00
## 5  0.04181465    10.669272 0.000000e+00
## 6  0.04017397     6.689595 2.237899e-11
## 7  0.32661353    -5.770702 7.894182e-09
## 8  0.34115406    -5.444060 5.207975e-08
## 9  0.36234408    -6.536212 6.309664e-11
## 10 0.25250535    -4.925550 8.412332e-07
## 11 0.20375813    -6.036850 1.571513e-09
## 12 0.16812472   -11.835149 0.000000e+00
## 13 0.16214650   -12.523553 0.000000e+00
## 14 0.15870144   -13.085174 0.000000e+00
## 15 0.14250529   -12.501220 0.000000e+00
## 16 0.11616287   -15.252175 0.000000e+00
##
## Model Statistics:
##                |  Parameters  |  Degrees of Freedom  |  Fit (-2lnL units)
##        Model:             16                   183             -137.1828
##    Saturated:             20                   179             -185.5389
## Independence:             20                   179                    NA
## Number of observations/statistics: 28516/199
##
## chi-square:  ²( df=4 ) = 48.35611,  p = 7.954756e-10
## Information Criteria:
##       |  df Penalty  |  Parameters Penalty  |  Sample-Size Adjusted
## AIC:      -503.1828             -105.18281               -105.16373
## BIC:     -2014.4372               26.94872                -23.89902
## CFI: NA
## TLI: NA   (also known as NNFI)
## RMSEA:  0.0197198  [95% CI (0.01401375, 0.02582225)]
## Prob(RMSEA <= 0.05): 1
## To get additional fit indices, see help(mxRefModels)
## timestamp: 2019-04-24 12:53:32
## Wall clock time: 1.460166 secs
## optimizer:  SLSQP
## OpenMx version number: 2.12.2
## Need help?  See help(mxSummary)
```

```
osmasemSRMR(mx.fit0_ewom)
```

```
## [1] 0.1150122
```

```
## The variance-covariance matrix in mx.fit0 is based on the untransformed matrix
## Extract the heterogeneity variance-covariance matrix using VarCorr()
VarCorr(mx.fit0_ewom)
```

```
##             Tau2_1     Tau2_2      Tau2_3     Tau2_4     Tau2_5     Tau2_6
```

```
## Tau2_1  0.02306177 0.00000000 0.000000000 0.00000000 0.00000000 0.00000000
## Tau2_2  0.00000000 0.02436699 0.000000000 0.00000000 0.00000000 0.00000000
## Tau2_3  0.00000000 0.00000000 0.008767399 0.00000000 0.00000000 0.00000000
## Tau2_4  0.00000000 0.00000000 0.000000000 0.08312119 0.00000000 0.00000000
## Tau2_5  0.00000000 0.00000000 0.000000000 0.00000000 0.08542515 0.00000000
## Tau2_6  0.00000000 0.00000000 0.000000000 0.00000000 0.00000000 0.01869382
## Tau2_7  0.00000000 0.00000000 0.000000000 0.00000000 0.00000000 0.00000000
## Tau2_8  0.00000000 0.00000000 0.000000000 0.00000000 0.00000000 0.00000000
## Tau2_9  0.00000000 0.00000000 0.000000000 0.00000000 0.00000000 0.00000000
## Tau2_10 0.00000000 0.00000000 0.000000000 0.00000000 0.00000000 0.00000000
##            Tau2_7     Tau2_8     Tau2_9    Tau2_10
## Tau2_1  0.0000000 0.00000000 0.00000000 0.00000000
## Tau2_2  0.0000000 0.00000000 0.00000000 0.00000000
## Tau2_3  0.0000000 0.00000000 0.00000000 0.00000000
## Tau2_4  0.0000000 0.00000000 0.00000000 0.00000000
## Tau2_5  0.0000000 0.00000000 0.00000000 0.00000000
## Tau2_6  0.0000000 0.00000000 0.00000000 0.00000000
## Tau2_7  0.0172266 0.00000000 0.00000000 0.00000000
## Tau2_8  0.0000000 0.01571292 0.00000000 0.00000000
## Tau2_9  0.0000000 0.00000000 0.02835421 0.00000000
## Tau2_10 0.0000000 0.00000000 0.00000000 0.02891274
```

```
# TSSEM
## Model without moderator

## Stage 1 analysis
ewom_random1 <- tssem1(ewomDataNew2.culture$Data, ewomDataNew2.culture$n, method="REM", RE.type="Diag")
summary(ewom_random1)
```

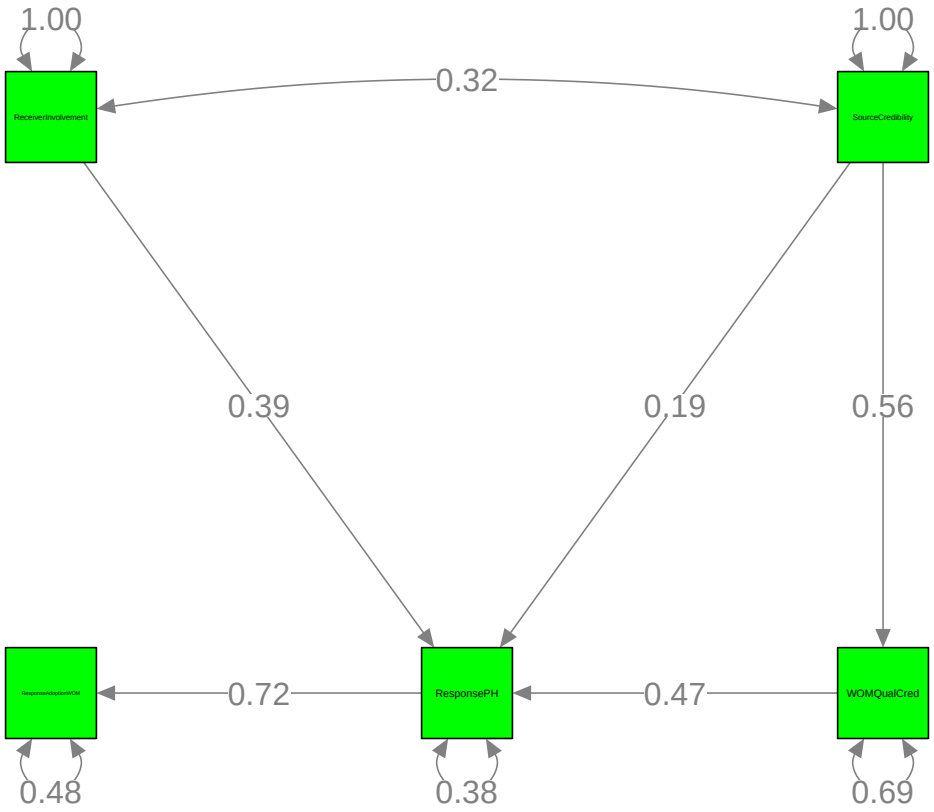
```
##
## Call:
## meta(y = ES, v = acovR, RE.constraints = Diag(paste0(RE.startvalues,
##     "*Tau2_", 1:no.es, "_", 1:no.es)), RE.lbound = RE.lbound,
##     I2 = I2, model.name = model.name, suppressWarnings = TRUE,
##     silent = silent, run = run)
##
## 95% confidence intervals: z statistic approximation
## Coefficients:
##               Estimate  Std.Error     lbound     ubound z value  Pr(>|z|)
## Intercept1   0.4468965  0.0656584  0.3182083  0.5755847  6.8064 1.001e-11
## Intercept2   0.4936833  0.0734816  0.3496619  0.6377046  6.7185 1.837e-11
## Intercept3   0.2505928  0.0392090  0.1737446  0.3274411  6.3912 1.646e-10
## Intercept4   0.3988718  0.0480125  0.3047690  0.4929746  8.3077 < 2.2e-16
## Intercept5   0.5667571  0.0355506  0.4970792  0.6364350 15.9423 < 2.2e-16
## Intercept6   0.4886148  0.0312245  0.4274160  0.5498137 15.6485 < 2.2e-16
## Intercept7   0.5497398  0.0265882  0.4976279  0.6018518 20.6761 < 2.2e-16
## Intercept8   0.5405100  0.0270608  0.4874718  0.5935482 19.9739 < 2.2e-16
## Intercept9   0.5648842  0.0303301  0.5054383  0.6243302 18.6245 < 2.2e-16
## Intercept10  0.5306669  0.0284074  0.4749895  0.5863443 18.6806 < 2.2e-16
## Tau2_1_1     0.0212558  0.0149490 -0.0080437  0.0505554  1.4219 0.1550590
## Tau2_2_2     0.0235264  0.0167537 -0.0093102  0.0563631  1.4043 0.1602436
## Tau2_3_3     0.0085736  0.0062289 -0.0036348  0.0207821  1.3764 0.1686912
## Tau2_4_4     0.0168496  0.0102027 -0.0031474  0.0368466  1.6515 0.0986401
## Tau2_5_5     0.0252136  0.0082472  0.0090495  0.0413777  3.0572 0.0022338
## Tau2_6_6     0.0176311  0.0059478  0.0059737  0.0292886  2.9643 0.0030336
```

```
## Tau2_7_7     0.0152332  0.0046654  0.0060891  0.0243772  3.2651 0.0010941
## Tau2_8_8     0.0151144  0.0048948  0.0055208  0.0247079  3.0879 0.0020160
## Tau2_9_9     0.0255151  0.0069029  0.0119858  0.0390445  3.6963 0.0002188
## Tau2_10_10   0.0295540  0.0069100  0.0160106  0.0430975  4.2770 1.895e-05
##
## Intercept1  ***
## Intercept2  ***
## Intercept3  ***
## Intercept4  ***
## Intercept5  ***
## Intercept6  ***
## Intercept7  ***
## Intercept8  ***
## Intercept9  ***
## Intercept10 ***
## Tau2_1_1
## Tau2_2_2
## Tau2_3_3
## Tau2_4_4    .
## Tau2_5_5    **
## Tau2_6_6    **
## Tau2_7_7    **
## Tau2_8_8    **
## Tau2_9_9    ***
## Tau2_10_10  ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Q statistic on the homogeneity of effect sizes: 3761.543
## Degrees of freedom of the Q statistic: 189
## P value of the Q statistic: 0
##
## Heterogeneity indices (based on the estimated Tau2):
##                               Estimate
## Intercept1: I2 (Q statistic)    0.9038
## Intercept2: I2 (Q statistic)    0.9123
## Intercept3: I2 (Q statistic)    0.7912
## Intercept4: I2 (Q statistic)    0.8818
## Intercept5: I2 (Q statistic)    0.9217
## Intercept6: I2 (Q statistic)    0.8890
## Intercept7: I2 (Q statistic)    0.8761
## Intercept8: I2 (Q statistic)    0.8766
## Intercept9: I2 (Q statistic)    0.9236
## Intercept10: I2 (Q statistic)   0.9372
##
## Number of studies (or clusters): 62
## Number of observed statistics: 199
## Number of estimated parameters: 20
## Degrees of freedom: 179
## -2 log likelihood: -179.5602
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values may indicate problems.)
```

```r
## Stage 2 analysis
ewom_random2 <- tssem2(ewom_random1, Amatrix=ewom_RAM1$A, Smatrix=ewom_RAM1$S,
                       Fmatrix = ewom_RAM1$F, diag.constraints = FALSE,
                       intervals.type = "z")
summary(ewom_random2)
```

```
##
## Call:
## wls(Cov = pooledS, aCov = aCov, n = tssem1.obj$total.n, Amatrix = Amatrix,
##     Smatrix = Smatrix, Fmatrix = Fmatrix, diag.constraints = diag.constraints,
##     cor.analysis = cor.analysis, intervals.type = intervals.type,
##     mx.algebras = mx.algebras, model.name = model.name, suppressWarnings = suppressWarnings,
##     silent = silent, run = run)
##
## 95% confidence intervals: z statistic approximation
## Coefficients:
##           Estimate Std.Error   lbound   ubound z value  Pr(>|z|)
## PH2Adopt  0.722524  0.025698 0.672157 0.772892 28.1159 < 2.2e-16 ***
## INV2PH    0.390104  0.065992 0.260761 0.519446  5.9114 3.393e-09 ***
## SC2PH     0.193565  0.047918 0.099647 0.287484  4.0395 5.357e-05 ***
## Qual2PH   0.467647  0.038891 0.391421 0.543872 12.0245 < 2.2e-16 ***
## SC2Qual   0.556167  0.027911 0.501462 0.610872 19.9262 < 2.2e-16 ***
## scWITHinv 0.324695  0.036306 0.253536 0.395853  8.9432 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Goodness-of-fit indices:
##                                                Value
## Sample size                                28516.0000
## Chi-square of target model                    70.2071
## DF of target model                             4.0000
## p value of target model                        0.0000
## Number of constraints imposed on "Smatrix"     0.0000
## DF manually adjusted                           0.0000
## Chi-square of independence model            2073.9395
## DF of independence model                      10.0000
## RMSEA                                          0.0241
## RMSEA lower 95% CI                             0.0193
## RMSEA upper 95% CI                             0.0292
## SRMR                                           0.1016
## TLI                                            0.9198
## CFI                                            0.9679
## AIC                                           62.2071
## BIC                                           29.1742
## OpenMx status1: 0 ("0" or "1": The optimization is considered fine.
## Other values indicate problems.)
```

```r
## Plot the model
plot(ewom_random2, col="green")
```




```
osmasem_coef <- coef(mx.fit0_ewom)
tssem_coef <- coef(ewom_random2)

## OSMASEM coefficients
osmasem_coef[sort(names(osmasem_coef))]
```

```
##    INV2PH  PH2Adopt   Qual2PH     SC2PH   SC2Qual scWITHinv
## 0.3918654 0.8123080 0.4461319 0.2180440 0.5354310 0.2687476
```

```
## TSSEM coefficients
tssem_coef[sort(names(tssem_coef))]
```

```
##    INV2PH  PH2Adopt   Qual2PH     SC2PH   SC2Qual scWITHinv
## 0.3901037 0.7225243 0.4676467 0.1935655 0.5561668 0.3246947
```

```
## OSMASEM variance components
diag(VarCorr(mx.fit0_ewom))
```

```
##      Tau2_1      Tau2_2      Tau2_3      Tau2_4      Tau2_5      Tau2_6
## 0.023061773 0.024366986 0.008767399 0.083121192 0.085425149 0.018693820
##      Tau2_7      Tau2_8      Tau2_9     Tau2_10
## 0.017226600 0.015712919 0.028354206 0.028912744
```

```
## TSSEM variance components
coef(ewom_random1, select="random")
```

```
##    Tau2_1_1    Tau2_2_2    Tau2_3_3    Tau2_4_4    Tau2_5_5    Tau2_6_6
## 0.021255837 0.023526429 0.008573639 0.016849620 0.025213596 0.017631114
##    Tau2_7_7    Tau2_8_8    Tau2_9_9  Tau2_10_10
## 0.015233156 0.015114385 0.025515120 0.029554033
```

```
## Fit indices for OSMASEM
# chi-square:  chisq ( df=4 ) = 48.3561,  p = 7.954771e-10
# RMSEA:  0.01971979  [95% CI (0.01401375, 0.02582224)]
# SRMR: 0.1150122

## Fit indices for TSSEM
# chi-square:  chisq ( df=4 ) = 70.2071,  p = .0000
# RMSEA:  0.0241  [95% CI (0.0193, 0.0292)]
# SRMR: 0.1016

sessionInfo()
```

```
## R version 3.5.1 (2018-07-02)
## Platform: x86_64-pc-linux-gnu (64-bit)
## Running under: Ubuntu 18.04.2 LTS
##
## Matrix products: default
## BLAS: /opt/microsoft/ropen/3.5.1/lib64/R/lib/libRblas.so
## LAPACK: /opt/microsoft/ropen/3.5.1/lib64/R/lib/libRlapack.so
##
## locale:
##  [1] LC_CTYPE=en_US.UTF-8       LC_NUMERIC=C
##  [3] LC_TIME=en_US.UTF-8        LC_COLLATE=en_US.UTF-8
##  [5] LC_MONETARY=en_US.UTF-8    LC_MESSAGES=en_US.UTF-8
##  [7] LC_PAPER=en_US.UTF-8       LC_NAME=C
##  [9] LC_ADDRESS=C               LC_TELEPHONE=C
## [11] LC_MEASUREMENT=en_US.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
## [1] metaSEM_1.2.1.1      OpenMx_2.12.2        RevoUtils_11.0.1
## [4] RevoUtilsMath_11.0.0
##
## loaded via a namespace (and not attached):
##  [1] nlme_3.1-137        RColorBrewer_1.1-2  mi_1.0
##  [4] tools_3.5.1         backports_1.1.3     R6_2.4.0
##  [7] d3Network_0.5.2.1   rpart_4.1-13        Hmisc_4.2-0
## [10] lazyeval_0.2.1      colorspace_1.4-0    nnet_7.3-12
## [13] tidyselect_0.2.5    gridExtra_2.3       mnormt_1.5-5
## [16] compiler_3.5.1      qgraph_1.6.1        fdrtool_1.2.15
## [19] htmlTable_1.13.1    scales_1.0.0        checkmate_1.9.1
## [22] mvtnorm_1.0-9       psych_1.8.12        pbapply_1.4-0
## [25] sem_3.1-9           stringr_1.4.0       digest_0.6.18
## [28] pbivnorm_0.6.0      foreign_0.8-71      minqa_1.2.4
## [31] rmarkdown_1.11      base64enc_0.1-3     jpeg_0.1-8
## [34] pkgconfig_2.0.2     htmltools_0.3.6     lme4_1.1-20
## [37] lisrelToR_0.1.4     htmlwidgets_1.3     rlang_0.3.1
## [40] rstudioapi_0.9.0    huge_1.3.0          gtools_3.8.1
## [43] acepack_1.4.1       dplyr_0.8.0.1       zip_2.0.0
## [46] magrittr_1.5        Formula_1.2-3       Matrix_1.2-15
## [49] Rcpp_1.0.0          munsell_0.5.0       abind_1.4-5
## [52] rockchalk_1.8.140   whisker_0.3-2       stringi_1.3.1
```

```
## [55] yaml_2.2.0          carData_3.0-2       MASS_7.3-51.1
## [58] plyr_1.8.4          matrixcalc_1.0-3    lavaan_0.6-3
## [61] grid_3.5.1          parallel_3.5.1      crayon_1.3.4
## [64] lattice_0.20-38     semPlot_1.1         kutils_1.64
## [67] splines_3.5.1       knitr_1.21          pillar_1.3.1
## [70] igraph_1.2.4        rjson_0.2.20        boot_1.3-20
## [73] corpcor_1.6.9       BDgraph_2.55        reshape2_1.4.3
## [76] stats4_3.5.1        XML_3.98-1.17       glue_1.3.0
## [79] evaluate_0.13       latticeExtra_0.6-28 data.table_1.12.0
## [82] png_0.1-7           nloptr_1.2.1        gtable_0.2.0
## [85] purrr_0.3.0         assertthat_0.2.0    ggplot2_3.1.0
## [88] xfun_0.5            openxlsx_4.1.0      xtable_1.8-3
## [91] semTools_0.5-1      coda_0.19-2         survival_2.43-3
## [94] glasso_1.10         tibble_2.0.1        arm_1.10-1
## [97] ggm_2.3             ellipse_0.4.1       cluster_2.0.7-1
```