パス解析 — semパッケージを使う方法

パッケージの読み込み

```
library(sem)
```

適合度指標の設定

```
opt <- options(fit.indices = c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI", "IFI",
                              "SRMR", "AIC", "AICc", "BIC", "CAIC"))
```

モデルの設定

specifyEquations を使う方法

```
 モデル名 <- specifyEquations()
   予測式
   V(変数名.)= 分散，誤差分散を表すパラメタ（または設定値）
   C(変数名1, 変数名2)= 共分散表すパラメタ（または設定値）
```

specifyModel を使う方法

```
 モデル名 <- specifyModel()
   各パラメタ（または設定値）を設定する式
```

パラメタ値の推定

```
semオブジェクト名 <- sem(モデル名, 共分散行列（またはデータ行列）, N=標本サイズ)
summary(semオブジェクト名)
```

標準化解の推定

```
stdCoef(semオブジェクト名)
```

あらかじめsemパッケージをインストールしておく必要がある．
適合度指標は，デフォルトではAICくらいしか出力されない．必要なものを出力するように指定する．
パス係数の頭文字は b にしておくのが無難．他の文字を用いると，それだけで不具合になる場合がある．
空白行があるところで，モデルの設定が修了したとみなされる．
（逆に，行をあけないと，モデル設定が終了したことにならない）

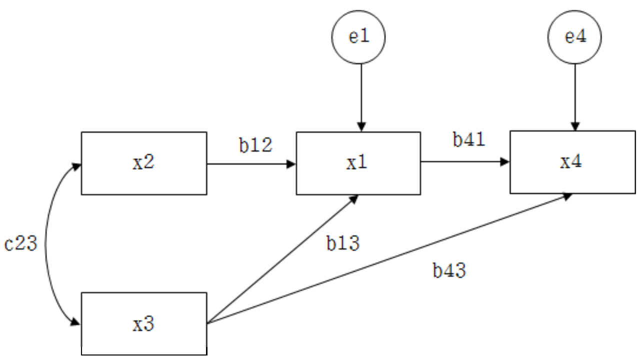
モデル部分のスクリプトの例

パスモデル１

```
x1 = b12 * x2 + b13 * x3 + e1        # x1についての回帰式
x4 = b41 * x1 + b43 * x3 + e4        # x4についての回帰式
```

```
# specifyEquations を使う方法

seq.1 <- specifyEquations()
 x1 = b12*x2 + b13*x3            # 予測式
 x4 = b41*x1 + b43*x3
 V(x1) = ev1                     # 内生変数の誤差分散
 V(x4) = ev4
 V(x2) = v2                      # 外生変数の分散
 V(x3) = v3
 C(x2,x3) = c23                  # 外生変数の共分散
```

```
# specifyModel を使う方法

model.1 <- specifyModel()
 x1 <- x2, b12, NA
 x1 <- x3, b13, NA
 x4 <- x1, b41, NA
 x4 <- x3, b43, NA
 x1 <-> x1, ev1, NA
 x4 <-> x4, ev4, NA
 x2 <-> x2, v2, NA
 x3 <-> x3, v3, NA
 x2 <-> x3, c23, NA
```




```
# 1行目：x1に対するx2の偏回帰係数をb12とする（NAは，初期値を特に指定しないの意．以下同様）
# 2行目：x1に対するx3の偏回帰係数をb13とする
# 3行目：x4に対するx1の偏回帰係数をb41とする
```

```
# 4行目：x4に対するx3の偏回帰係数をb43とする
# 5行目：x1の誤差分散をev1とする
# 6行目：x4の誤差分散をev4とする
# 7行目：x2の分散をv2とする
# 8行目：x3の分散をv3とする
# 9行目：x2とx3の共分散をc12とする
```

パスモデル２　　パスモデル１において，x2 と x3 の共分散を0と固定するモデル.

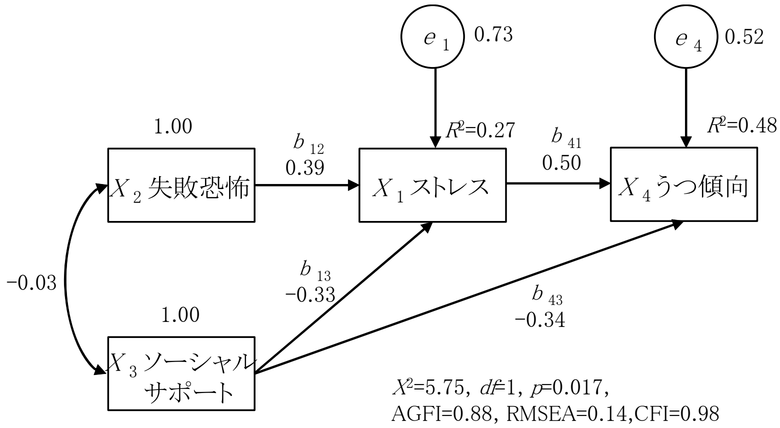
```
# specifyEquations を使う方法

seq.1 <- specifyEquations()
 x1 = b12*x2 + b13*x3          # 予測式
 x4 = b41*x1 + b43*x3
 V(x1) = ev1                   # 内生変数の誤差分散
 V(x4) = ev4
 V(x2) = v2                    # 外生変数の分散
 V(x3) = v3
 C(x2,x3) = 0                  # 外生変数の共分散


# specifyModel を使う方法

model.1 <- specifyModel()
 x1 <- x2, b12, NA
 x1 <- x3, b13, NA
 x4 <- x1, b41, NA
 x4 <- x3, b43, NA
 x1 <-> x1, ev1, NA
 x4 <-> x4, ev4, NA
 x2 <-> x2, v2, NA
 x3 <-> x3, v3, NA

 # x2 <-> x3, c23, NA を削除
 # x2 <-> x3, NA, 0 と指定しても同じ
```

```
> setwd("i:¥¥Rdocuments¥¥scripts¥¥")
> d1 <- read.table("回帰分析データ.csv", header=TRUE, sep=",")
> head(d1)
  id stress kyoufu support utsu work result
1  1     20    2.2      17   18    0      0
2  2     23    4.8      18   21    1      0
3  3     30    5.8      12   29    1      1
4  4     25    5.2      18   29    0      1
5  5     26    2.0       8   22    1      0
6  6     21    5.0      26   19    1      0
>
>
> # 記述統計量
> dtmp <- d1[,c(-1)]
> ntmp <- nrow(dtmp)
> mtmp <- colMeans(dtmp)
> stmp <- apply(dtmp, 2, sd)
> ctmp <- cor(dtmp)
> ktmp <- round(data.frame(ntmp, mtmp, stmp, ctmp),2)
> colnames(ktmp) <- c("N","Mean","SD",colnames(ctmp))
> ktmp
          N  Mean   SD stress kyoufu support  utsu  work result
stress  245 22.94 5.25   1.00   0.40   -0.34  0.62  0.03   0.44
kyoufu  245  4.05 1.17   0.40   1.00   -0.03  0.31  0.10   0.20
support 245 18.42 4.96  -0.34  -0.03    1.00 -0.51 -0.03  -0.39
utsu    245 20.29 6.49   0.62   0.31   -0.51  1.00  0.02   0.76
work    245  0.50 0.50   0.03   0.10   -0.03  0.02  1.00  -0.08
result  245  0.26 0.44   0.44   0.20   -0.39  0.76 -0.08   1.00
```

1	id	stress	kyoufu	support	utsu	work	result
2	1	20	2.2	17	18	0	0
3	2	23	4.8	18	21	1	0
4	3	30	5.8	12	29	1	1
5	4	25	5.2	18	29	0	1
6	5	26	2	8	22	1	0
7	6	21	5	26	19	1	0
8	7	14	2.2	24	12	0	0
9	8	22	4.4	17	19	1	0
10	9	26	4.2	11	27	0	1
11	10	26	4.2	18	18	1	0
12	11	21	2	27	18	0	0
13	12	24	4.8	19	29	1	1
14	13	24	3.4	23	19	1	0
15	14	23	2.2	10	24	1	0
16	15	23	4.4	24	20	0	0
17	16	35	7.2	12	31	0	1
18	17	25	3.2	17	19	1	0
19	18	33	3.4	14	26	0	1
20	19	30	4.4	20	30	1	1
21	20	19	5.6	18	12	1	0

```
>


> #変数名の変更（式を書くのにはこのほうが簡単）
> # x1:ストレス　x2:失敗恐怖　x3:ソーシャルサポート　x4:うつ傾向
> colnames(d1) <- c("id", "x1", "x2", "x3", "x4","work","result")
> head(d1)
  id x1  x2 x3 x4 work result
1  1 20 2.2 17 18    0      0
2  2 23 4.8 18 21    1      0
3  3 30 5.8 12 29    1      1
4  4 25 5.2 18 29    0      1
5  5 26 2.0  8 22    1      0
6  6 21 5.0 26 19    1      0
>

> # 共分散行列・相関係数行列
> cov.d1 <- cov(d1[,c("x1", "x2", "x3", "x4")])
> cor.d1 <- cor(d1[,c("x1", "x2", "x3", "x4")])
>
>

> #sem パッケージの読み込み
> library(sem)
>
> # 適合度指標出力の指定
> opt <- options(fit.indices = c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI", "IFI", "SRM
R", "AIC", "AICc", "BIC", "CAIC"))
>
>


> # パスモデル
> # specifyEquations を使う方法
> seq.1 <- specifyEquations()
1:  x1 = b12*x2 + b13*x3
2:  x4 = b41*x1 + b43*x3
3:  V(x1) = ev1
4:  V(x4) = ev4
5:  V(x2) = v2
6:  V(x3) = v3
7:  C(x2,x3) = c23
8:
Read 7 items


> # 標準化解の推定
> sem.seq.1s <- sem(seq.1, cor.d1, N=nrow(d1))
> summary(sem.seq.1s)

 Model Chisquare =  5.748331   Df =  1 Pr(>Chisq) = 0.01650433
 Goodness-of-fit index =  0.9884923
 Adjusted goodness-of-fit index =  0.8849227
 RMSEA index =  0.1395004   90% CI: (0.0476635, 0.2587895)
 Bentler-Bonett NFI =  0.9763773
 Tucker-Lewis NNFI =  0.8799611
 Bentler CFI =  0.9799935
 Bentler RNI =  0.9799935
 Bollen IFI =  0.9804063
 SRMR =  0.03150648
 AIC =  23.74833
 AICc =  6.514288
 BIC =  0.2470727
 CAIC =  -0.7529273

 Normalized Residuals
   Min.  1st Qu.  Median    Mean 3rd Qu.    Max.
 0.0000  0.0000  0.0000  0.1903  0.0000  1.5220

 R-square for Endogenous Variables
    x1     x4
0.2700 0.4823
```

```
 Parameter Estimates
    Estimate    Std Error  z value    Pr(>|z|)
b12  0.39495553 0.05471571  7.2183210 5.263335e-13 x1 <--- x2
b13 -0.32731966 0.05471571 -5.9821884 2.201594e-09 x1 <--- x3
b41  0.50485409 0.04894234 10.3152836 6.010359e-25 x4 <--- x1
b43 -0.33585592 0.04894234 -6.8622780 6.777099e-12 x4 <--- x3
ev1  0.72996847 0.06608824 11.0453610 2.308379e-28 x1 <--> x1
ev4  0.51774751 0.04687466 11.0453610 2.308379e-28 x4 <--> x4
v2   1.00000000 0.09053575 11.0453610 2.308379e-28 x2 <--> x2
v3   1.00000000 0.09053575 11.0453610 2.308379e-28 x3 <--> x3
c23 -0.02670051 0.06404126 -0.4169266 6.767321e-01 x3 <--> x2

 Iterations =  0
>
>
> stdCoef(sem.seq.1s)
        Std. Estimate
b12 b12     0.39495553 x1 <--- x2
b13 b13    -0.32731966 x1 <--- x3
b41 b41     0.50485409 x4 <--- x1
b43 b43    -0.33585592 x4 <--- x3
ev1 ev1     0.72996847 x1 <--> x1
ev4 ev4     0.51774751 x4 <--> x4
v2   v2     1.00000000 x2 <--> x2
v3   v3     1.00000000 x3 <--> x3
c23 c23    -0.02670051 x3 <--> x2
```




```
>
>
> # x1とx2の共分散を0に固定するモデル
> seq.2 <- specifyEquations()
1:  x1 = b12*x2 + b13*x3
2:  x4 = b41*x1 + b43*x3
3:  V(x1) = ev1
4:  V(x4) = ev4
5:  V(x2) = v2
6:  V(x3) = v3
7:  C(x2,x3) = 0
8:
Read 7 items


> # 標準化解の推定
> sem.seq.2 <- sem(seq.2, cor.d1, N=nrow(d1))
> summary(sem.seq.2)

 Model Chisquare =  5.922345   Df =  2 Pr(>Chisq) = 0.0517582
 Goodness-of-fit index =  0.9881508
 Adjusted goodness-of-fit index =  0.9407539
 RMSEA index =  0.08965262   90% CI: (NA, 0.1772158)
 Bentler-Bonett NFI =  0.9756622
 Tucker-Lewis NNFI =  0.9504211
 Bentler CFI =  0.9834737
 Bentler RNI =  0.9834737
 Bollen IFI =  0.9837476
 SRMR =  0.03718342
 AIC =  21.92234
 AICc =  6.532514
 BIC =  -5.080172
 CAIC =  -7.080172

 Normalized Residuals
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-0.41710 -0.09514  0.02963  0.17210  0.10240  1.73600

 R-square for Endogenous Variables
    x1     x4
0.2650 0.4795

 Parameter Estimates
```

```
    Estimate   Std Error  z value   Pr(>|z|)
b12  0.3949555 0.05469620  7.220895 5.164635e-13 x1 <--- x2
b13 -0.3273197 0.05469620 -5.984322 2.172932e-09 x1 <--- x3
b41  0.5048541 0.04893927 10.315931 5.969982e-25 x4 <--- x1
b43 -0.3358559 0.04877005 -6.886520 5.717353e-12 x4 <--- x3
ev1  0.7299685 0.06608824 11.045361 2.308379e-28 x1 <--> x1
ev4  0.5177475 0.04687466 11.045361 2.308379e-28 x4 <--> x4
v2   1.0000000 0.09053575 11.045361 2.308379e-28 x2 <--> x2
v3   1.0000000 0.09053575 11.045361 2.308379e-28 x3 <--> x3

 Iterations =  0
>
>
> stdCoef(sem.seq.2)
        Std. Estimate
b12 b12     0.3963259 x1 <--- x2
b13 b13    -0.3284554 x1 <--- x3
b41 b41     0.5044561 x4 <--- x1
b43 b43    -0.3367555 x4 <--- x3
ev1 ev1     0.7350428 x1 <--> x1
ev4 ev4     0.5205249 x4 <--> x4
v2   v2     1.0000000 x2 <--> x2
v3   v3     1.0000000 x3 <--> x3
            0.0000000 x3 <--> x2
>
>
>
> # specifyModel を使う方法
> smd.1 <- specifyModel()
1:  x1 <- x2, b12, NA
2:  x1 <- x3, b13, NA
3:  x4 <- x1, b41, NA
4:  x4 <- x3, b43, NA
5:  x1 <-> x1, ev1, NA
6:  x4 <-> x4, ev4, NA
7:  x2 <-> x2, v2, NA
8:  x3 <-> x3, v3, NA
9:  x2 <-> x3, c23, NA
10:
Read 9 records
NOTE: it is generally simpler to use specifyEquations() or cfa()
      see ?specifyEquations


> # 標準化解の推定
> sem.smd.1 <- sem(smd.1, cor.d1, N=nrow(d1))
> summary(sem.smd.1)

 Model Chisquare =  5.748331   Df =  1 Pr(>Chisq) = 0.01650433
 Goodness-of-fit index =  0.9884923
 Adjusted goodness-of-fit index =  0.8849227
 RMSEA index =  0.1395004   90% CI: (0.0476635, 0.2587895)
 Bentler-Bonett NFI =  0.9763773
 Tucker-Lewis NNFI =  0.8799611
 Bentler CFI =  0.9799935
 Bentler RNI =  0.9799935
 Bollen IFI =  0.9804063
 SRMR =  0.03150648
 AIC =  23.74833
 AICc =  6.514288
 BIC =  0.2470727
 CAIC =  -0.7529273

 Normalized Residuals
   Min.  1st Qu.  Median    Mean  3rd Qu.    Max.
 0.0000  0.0000  0.0000  0.1903  0.0000  1.5220

 R-square for Endogenous Variables
    x1     x4
0.2700 0.4823

 Parameter Estimates
```

```
    Estimate    Std Error  z value    Pr(>|z|)
b12  0.39495553 0.05471571  7.2183210 5.263335e-13 x1 <--- x2
b13 -0.32731966 0.05471571 -5.9821884 2.201594e-09 x1 <--- x3
b41  0.50485409 0.04894234 10.3152836 6.010359e-25 x4 <--- x1
b43 -0.33585592 0.04894234 -6.8622780 6.777099e-12 x4 <--- x3
ev1  0.72996847 0.06608824 11.0453610 2.308379e-28 x1 <--> x1
ev4  0.51774751 0.04687466 11.0453610 2.308379e-28 x4 <--> x4
v2   1.00000000 0.09053575 11.0453610 2.308379e-28 x2 <--> x2
v3   1.00000000 0.09053575 11.0453610 2.308379e-28 x3 <--> x3
c23 -0.02670051 0.06404126 -0.4169266 6.767321e-01 x3 <--> x2

 Iterations =  0
>
> stdCoef(sem.seq.1)
        Std. Estimate
1            0.4373010 x1 <--- f1
2     b2     0.6293252 x2 <--- f1
3     b3     0.3688269 x3 <--- f1
4            0.6154132 x7 <--- f3
5     b8     0.3753166 x8 <--- f3
6     b9     0.4116027 x9 <--- f3
7    a31     0.5232285 f3 <--- f1
8    ev1     0.8087679 x1 <--> x1
9    ev2     0.6039498 x2 <--> x2
10   ev3     0.8639667 x3 <--> x3
11   ev7     0.6212666 x7 <--> x7
12   ev8     0.8591374 x8 <--> x8
13   ev9     0.8305832 x9 <--> x9
14 evf3      0.7262319 f3 <--> f3
15  vf1      1.0000000 f1 <--> f1
>
>
```

多母集団のパス解析 ― semパッケージを使う方法

```
library(sem)
opt <- options(fit.indices = c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI", "IFI",
                               "SRMR", "AIC", "AICc", "BIC", "CAIC"))

モデル名1 <- specifyEquations()
  構造方程式

モデル名2 <- specifyEquations()
  構造方程式

…

mgオブジェクト名 <- multigroupModel(モデル名1, モデル名2, …, groups=c("群名1","群名2"…))
群分け変数名 <- factor(群分け変数名)

semオブジェクト名 <- sem(mgオブジェクト名, データ行列, N=標本サイズ)
summary(semオブジェクト名)

stdCoef(semオブジェクト名)
```

各群のモデルで，同じパラメタ名にすると等値制約になる
群分け変数名はfactor関数を使ってfactor化しておかなければならない
群分け変数名に「group」を用いると不具合が生じることがあるので他の名前を使う
　等値制約を加える場合は，例えば，b12.1 と b12.2 をともに b12というパラメタ名にすると，両群に共通な b12 というパラメタ値を推定する

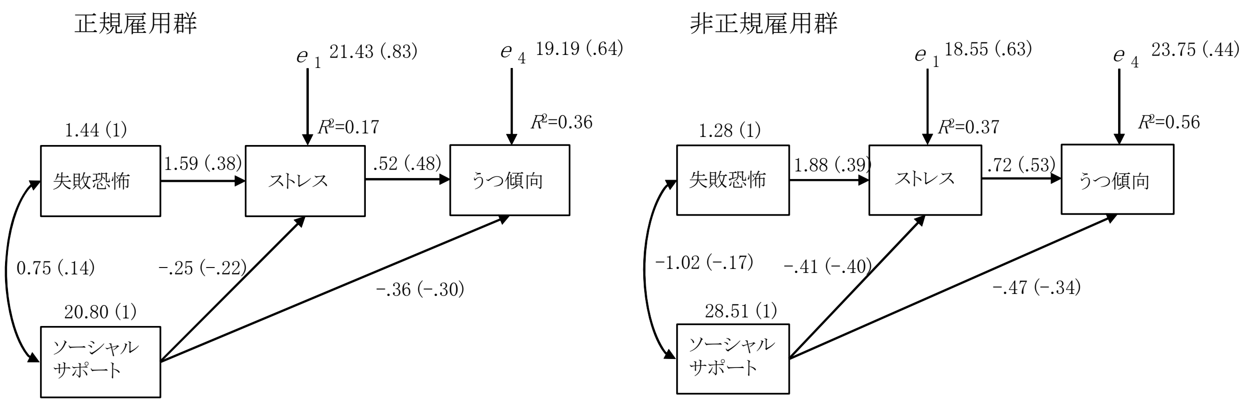
　あらかじめsemパッケージをインストールしておく必要がある．
　適合度指標は，デフォルトではAICくらいしか出力されない．必要なものを出力するように指定する．
　パス係数の頭文字は b にしておくのが無難．他の文字を用いると，それだけで不具合になる場合がある．
　空白行があるところで，モデルの設定が修了したとみなされる．
　（逆に，行をあけないと，モデル設定が終了したことにならない）

```
> setwd("i:¥¥Rdocuments¥¥scripts¥¥")
> d1 <- read.table("回帰分析データ.csv", header=TRUE, sep=",")
> head(d1)
  id stress kyoufu support utsu work result
1  1     20    2.2      17   18    0      0
2  2     23    4.8      18   21    1      0
3  3     30    5.8      12   29    1      1
4  4     25    5.2      18   29    0      1
5  5     26    2.0       8   22    1      0
6  6     21    5.0      26   19    1      0
>
>
> # 群別データ
> d11 <- d1[d1$work==1, colnames(d1) %in% c("work")==F]
> d10 <- d1[d1$work==0, colnames(d1) %in% c("work")==F]
>
>
> # 記述統計量
> dtmp <- d11[,c(-1)]
> ntmp <- nrow(dtmp)
> mtmp <- colMeans(dtmp)
> stmp <- apply(dtmp, 2, sd)
> ctmp <- cor(dtmp)
> ktmp <- round(data.frame(ntmp, mtmp, stmp, ctmp),2)
> colnames(ktmp) <- c("N","Mean","SD",colnames(ctmp))
> ktmp
          N  Mean   SD stress kyoufu support  utsu result
stress  122 23.10 5.08   1.00   0.35   -0.17  0.53   0.33
kyoufu  122  4.17 1.20   0.35   1.00    0.14  0.27   0.17
support 122 18.25 4.56  -0.17   0.14    1.00 -0.38  -0.31
utsu    122 20.44 5.49   0.53   0.27   -0.38  1.00   0.75
result  122  0.22 0.42   0.33   0.17   -0.31  0.75   1.00
>
```

```
> dtmp <- d10[,c(-1)]
> ntmp <- nrow(dtmp)
> mtmp <- colMeans(dtmp)
> stmp <- apply(dtmp, 2, sd)
> ctmp <- cor(dtmp)
> ktmp <- round(data.frame(ntmp, mtmp, stmp, ctmp),2)
> colnames(ktmp) <- c("N","Mean","SD",colnames(ctmp))
> ktmp
          N  Mean   SD stress kyoufu support  utsu result
stress  123 22.78 5.43   1.00   0.46   -0.47  0.69   0.54
kyoufu  123  3.93 1.13   0.46   1.00   -0.17  0.35   0.25
support 123 18.59 5.34  -0.47  -0.17    1.00 -0.59  -0.45
utsu    123 20.13 7.38   0.69   0.35   -0.59  1.00   0.79
result  123  0.29 0.46   0.54   0.25   -0.45  0.79   1.00
>
>
> #変数名の変更（式を書くのにはこのほうが簡単）
> # x1:ストレス  x2:失敗恐怖  x3:ソーシャルサポート  x4:うつ傾向
> colnames(d1) <- c("id", "x1", "x2", "x3", "x4","work","result")
> head(d1)
  id x1  x2 x3 x4 work result
1  1 20 2.2 17 18    0      0
2  2 23 4.8 18 21    1      0
3  3 30 5.8 12 29    1      1
4  4 25 5.2 18 29    0      1
5  5 26 2.0  8 22    1      0
6  6 21 5.0 26 19    1      0
>
>
>
> #sem パッケージの読み込み
> library(sem)
>
> # 適合度指標出力の指定
> opt <- options(fit.indices = c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI", "IFI", "SRM
R", "AIC", "AICc", "BIC", "CAIC"))
>
>
> # 多母集団分析
> # モデルの設定
> seq.1 <- specifyEquations()
1:  x1 = b12.1*x2 + b13.1*x3
2:  x4 = b41.1*x1 + b43.1*x3
3:  V(x1) = ev1.1
4:  V(x4) = ev4.1
5:  V(x2) = v2.1
6:  V(x3) = v3.1
7:  C(x2,x3) = c23.1
8:
Read 7 items

> seq.2 <- specifyEquations()
1:  x1 = b12.2*x2 + b13.2*x3
2:  x4 = b41.2*x1 + b43.2*x3
3:  V(x1) = ev1.2
4:  V(x4) = ev4.2
5:  V(x2) = v2.2
6:  V(x3) = v3.2
7:  C(x2,x3) = c23.2
8:
Read 7 items

> mg.seq <- multigroupModel(seq.1, seq.2, groups=c("1","0"))
> d1$work <- factor(d1$work, levels=c(1,0))
> sem.mg.seq <- sem(mg.seq, data=d1, group="work")
> summary(sem.mg.seq)

 Model Chisquare = 6.042957  Df = 2  Pr(>Chisq) = 0.04872913
 Chisquare (null model) = 246.2831  Df = 12
 Goodness-of-fit index = 0.9880118
 Adjusted goodness-of-fit index = 0.9040942
 RMSEA index = 0.1289871 90% CI: (0.008417286, 0.2528073)
```

```
 Bentler-Bonett NFI = 0.9754634
 Tucker-Lewis NNFI = 0.8964597
 Bentler CFI = 0.9827433
 Bentler RNI =  0.9827433
 Bollen IFI =  0.9834497
 SRMR = 0.0314776
 AIC = 42.04296
 AICc = 9.069505
 BIC = -4.95956

Iterations: initial fits, 0 0   final fit, 0


  work: 1

 Model Chisquare =  5.140324   Df =  1 Pr(>Chisq) = 0.02337628
 Goodness-of-fit index =  0.9796275
 Adjusted goodness-of-fit index =  0.7962752
 RMSEA index =  0.1849799   90% CI: (0.05473528, 0.3556438)
 Bentler-Bonett NFI =  0.9390293
 Tucker-Lewis NNFI =  0.6827666
 Bentler CFI =  0.9471278
 Bentler RNI =  0.9471278
 Bollen IFI =  0.9503011
 SRMR =  0.04718079
 AIC =  23.14032
 AICc =  6.747467
 BIC =  0.3363034
 CAIC =  -0.6636966

 Normalized Residuals
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.0000  0.0000  0.0000  0.2036  0.0000  1.6290

 R-square for Endogenous Variables
    x1     x4
0.1685 0.3628

 Parameter Estimates
      Estimate   Std Error  z value   Pr(>|z|)
b12.1  1.5940497 0.35351596  4.509131 6.509380e-06 x1 <--- x2
b13.1 -0.2464606 0.09316002 -2.645562 8.155534e-03 x1 <--- x3
b41.1  0.5150020 0.07959184  6.470538 9.765471e-11 x4 <--- x1
b43.1 -0.3567843 0.08859546 -4.027118 5.646481e-05 x4 <--- x3
ev1.1 21.4329344 2.75552240  7.778175 7.357848e-15 x1 <--> x1
ev4.1 19.1893399 2.46707498  7.778175 7.357848e-15 x4 <--> x4
v2.1   1.4446416 0.18573016  7.778175 7.357848e-15 x2 <--> x2
v3.1  20.8026690 2.67449242  7.778175 7.357848e-15 x3 <--> x3
c23.1  0.7534345 0.50304910  1.497736 1.342020e-01 x3 <--> x2

  work: 0

 Model Chisquare =  0.9026323   Df =  1 Pr(>Chisq) = 0.3420769
 Goodness-of-fit index =  0.9963279
 Adjusted goodness-of-fit index =  0.9632787
 RMSEA index =  0   90% CI: (NA, 0.23476)
 Bentler-Bonett NFI =  0.9944273
 Tucker-Lewis NNFI =  1.003746
 Bentler CFI =  1
 Bentler RNI =  1.000624
 Bollen IFI =  1.000605
 SRMR =  0.01590207
 AIC =  18.90263
 AICc =  2.495553
 BIC =  -3.909552
 CAIC =  -4.909552

 Normalized Residuals
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.0000  0.0000  0.0000  0.0665  0.0000  0.5320
```

```
 R-square for Endogenous Variables
    x1     x4
0.3704 0.5634

 Parameter Estimates
      Estimate   Std Error  z value   Pr(>|z|)
b12.2  1.8791914 0.34991236  5.370463 7.853478e-08 x1 <--- x2
b13.2 -0.4114030 0.07410181 -5.551862 2.826424e-08 x1 <--- x3
b41.2  0.7164477 0.09212589  7.776834 7.436204e-15 x4 <--- x1
b43.2 -0.4709965 0.09366555 -5.028493 4.943508e-07 x4 <--- x3
ev1.2 18.5541031 2.37560947  7.810250 5.707481e-15 x1 <--> x1
ev4.2 23.7533710 3.04130751  7.810250 5.707481e-15 x4 <--> x4
v2.2   1.2784699 0.16369130  7.810250 5.707481e-15 x2 <--> x2
v3.2  28.5069972 3.64994698  7.810250 5.707481e-15 x3 <--> x3
c23.2 -1.0180328 0.55428088 -1.836673 6.625817e-02 x3 <--> x2

> stdCoef(sem.mg.seq)


 Group:  1
       Std. Estimate
1 b12.1      0.3773805 x1 <--- x2
2 b13.1     -0.2214137 x1 <--- x3
3 b41.1      0.4764409 x4 <--- x1
4 b43.1     -0.2965261 x4 <--- x3
5 ev1.1      0.8315277 x1 <--> x1
6 ev4.1      0.6371700 x4 <--> x4
7  v2.1      1.0000000 x2 <--> x2
8  v3.1      1.0000000 x3 <--> x3
9 c23.1      0.1374377 x3 <--> x2


 Group:  0
       Std. Estimate
1 b12.2      0.3914194 x1 <--- x2
2 b13.2     -0.4046404 x1 <--- x3
3 b41.2      0.5272571 x4 <--- x1
4 b43.2     -0.3409239 x4 <--- x3
5 ev1.2      0.6296396 x1 <--> x1
6 ev4.2      0.4365693 x4 <--> x4
7  v2.2      1.0000000 x2 <--> x2
8  v3.2      1.0000000 x3 <--> x3
9 c23.2     -0.1686323 x3 <--> x2
>
>
```



非標準化解 (標準化解)

X^2=6.04, df=2, p=0.049,
AGFI=0.90, RMSEA=0.13, CFI=0.98 , AIC=42.04

```
> # specifyModel を使う方法
> smd.1 <- specifyModel()
1:  x1 <- x2, b12.1, NA
2:  x1 <- x3, b13.1, NA
3:  x4 <- x1, b41.1, NA
4:  x4 <- x3, b43.1, NA
5:  x1 <-> x1, ev1.1, NA
6:  x4 <-> x4, ev4.1, NA
7:  x2 <-> x2, v2.1, NA
8:  x3 <-> x3, v3.1, NA
9:  x2 <-> x3, c23.1, NA
10:
Read 9 records
NOTE: it is generally simpler to use specifyEquations() or cfa()
      see ?specifyEquations

> smd.2 <- specifyModel()
1:  x1 <- x2, b12.2, NA
2:  x1 <- x3, b13.2, NA
3:  x4 <- x1, b41.2, NA
4:  x4 <- x3, b43.2, NA
5:  x1 <-> x1, ev1.2, NA
6:  x4 <-> x4, ev4.2, NA
7:  x2 <-> x2, v2.2, NA
8:  x3 <-> x3, v3.2, NA
9:  x2 <-> x3, c23.2, NA
10:
Read 9 records
NOTE: it is generally simpler to use specifyEquations() or cfa()
      see ?specifyEquations

> mg.smd <- multigroupModel(smd.1, smd.2, groups=c("1","0"))
> d1$work <- factor(d1$work)
> sem.mg.smd <- sem(mg.smd, data=d1, group="work")
> summary(sem.mg.smd)

 Model Chisquare = 6.042957  Df = 2  Pr(>Chisq) = 0.04872913
 Chisquare (null model) = 246.2831  Df = 12
 Goodness-of-fit index = 0.9880118
 Adjusted goodness-of-fit index = 0.9040942
 RMSEA index = 0.1289871 90% CI: (0.008417286, 0.2528073)
 Bentler-Bonett NFI = 0.9754634
 Tucker-Lewis NNFI = 0.8964597
 Bentler CFI = 0.9827433
 Bentler RNI =  0.9827433
 Bollen IFI =  0.9834497
 SRMR = 0.0314776
 AIC = 42.04296
 AICc = 9.069505
 BIC = -4.95956

Iterations: initial fits, 0 0   final fit, 0


  work: 1

 Model Chisquare =  5.140324   Df =  1 Pr(>Chisq) = 0.02337628
 Goodness-of-fit index =  0.9796275
 Adjusted goodness-of-fit index =  0.7962752
 RMSEA index =  0.1849799   90% CI: (0.05473528, 0.3556438)
 Bentler-Bonett NFI =  0.9390293
 Tucker-Lewis NNFI =  0.6827666
 Bentler CFI =  0.9471278
 Bentler RNI =  0.9471278
 Bollen IFI =  0.9503011
 SRMR =  0.04718079
 AIC =  23.14032
 AICc =  6.747467
 BIC =  0.3363034
 CAIC =  -0.6636966

 Normalized Residuals
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
 0.0000  0.0000  0.0000  0.2036  0.0000  1.6290 

 R-square for Endogenous Variables
    x1     x4 
0.1685 0.3628 

 Parameter Estimates
      Estimate   Std Error  z value   Pr(>|z|)                
b12.1  1.5940497 0.35351596  4.509131 6.509380e-06 x1 <--- x2
b13.1 -0.2464606 0.09316002 -2.645562 8.155534e-03 x1 <--- x3
b41.1  0.5150020 0.07959184  6.470538 9.765471e-11 x4 <--- x1
b43.1 -0.3567843 0.08859546 -4.027118 5.646481e-05 x4 <--- x3
ev1.1 21.4329344 2.75552240  7.778175 7.357848e-15 x1 <--> x1
ev4.1 19.1893399 2.46707498  7.778175 7.357848e-15 x4 <--> x4
v2.1   1.4446416 0.18573016  7.778175 7.357848e-15 x2 <--> x2
v3.1  20.8026690 2.67449242  7.778175 7.357848e-15 x3 <--> x3
c23.1  0.7534345 0.50304910  1.497736 1.342020e-01 x3 <--> x2

  work: 0 

 Model Chisquare =  0.9026323   Df =  1 Pr(>Chisq) = 0.3420769
 Goodness-of-fit index =  0.9963279
 Adjusted goodness-of-fit index =  0.9632787
 RMSEA index =  0   90% CI: (NA, 0.23476)
 Bentler-Bonett NFI =  0.9944273
 Tucker-Lewis NNFI =  1.003746
 Bentler CFI =  1
 Bentler RNI =  1.000624
 Bollen IFI =  1.000605
 SRMR =  0.01590207
 AIC =  18.90263
 AICc =  2.495553
 BIC =  -3.909552
 CAIC =  -4.909552

 Normalized Residuals
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
 0.0000  0.0000  0.0000  0.0665  0.0000  0.5320 

 R-square for Endogenous Variables
    x1     x4 
0.3704 0.5634 

 Parameter Estimates
      Estimate   Std Error  z value   Pr(>|z|)                
b12.2  1.8791914 0.34991236  5.370463 7.853478e-08 x1 <--- x2
b13.2 -0.4114030 0.07410181 -5.551862 2.826424e-08 x1 <--- x3
b41.2  0.7164477 0.09212589  7.776834 7.436204e-15 x4 <--- x1
b43.2 -0.4709965 0.09366555 -5.028493 4.943508e-07 x4 <--- x3
ev1.2 18.5541031 2.37560947  7.810250 5.707481e-15 x1 <--> x1
ev4.2 23.7533710 3.04130751  7.810250 5.707481e-15 x4 <--> x4
v2.2   1.2784699 0.16369130  7.810250 5.707481e-15 x2 <--> x2
v3.2  28.5069972 3.64994698  7.810250 5.707481e-15 x3 <--> x3
c23.2 -1.0180328 0.55428088 -1.836673 6.625817e-02 x3 <--> x2

> stdCoef(sem.mg.smd)


 Group:  1 
        Std. Estimate            
1 b12.1     0.3773805 x1 <--- x2
2 b13.1    -0.2214137 x1 <--- x3
3 b41.1     0.4764409 x4 <--- x1
4 b43.1    -0.2965261 x4 <--- x3
5 ev1.1     0.8315277 x1 <--> x1
6 ev4.1     0.6371700 x4 <--> x4
7  v2.1     1.0000000 x2 <--> x2
8  v3.1     1.0000000 x3 <--> x3
9 c23.1     0.1374377 x3 <--> x2
```

```
 Group:  0
        Std. Estimate
1 b12.2     0.3914194 x1 <--- x2
2 b13.2    -0.4046404 x1 <--- x3
3 b41.2     0.5272571 x4 <--- x1
4 b43.2    -0.3409239 x4 <--- x3
5 ev1.2     0.6296396 x1 <--> x1
6 ev4.2     0.4365693 x4 <--> x4
7  v2.2     1.0000000 x2 <--> x2
8  v3.2     1.0000000 x3 <--> x3
9 c23.2    -0.1686323 x3 <--> x2
>
>
```

多母集団パス解析におけるパス係数の検定

制約モデル

```
seq.1 <- specifyEquations()
 x1 = b12*x2 + b13.1*x3
 x4 = b41.1*x1 + b43*x3
 V(x1) = ev1.1
 V(x4) = ev4.1
 V(x2) = v2.1
 V(x3) = v3.1
 C(x2,x3) = c23.1

seq.2 <- specifyEquations()
 x1 = b12*x2 + b13.2*x3
 x4 = b41.2*x1 + b43*x3
 V(x1) = ev1.2
 V(x4) = ev4.2
 V(x2) = v2.2
 V(x3) = v3.2
 C(x2,x3) = c23.2

mg.seq <- multigroupModel(seq.1, seq.2, groups=c("1","0"))
d1$work <- factor(d1$work, levels=c(1,0))
sem.mg.seq <- sem(mg.seq, data=d1, group="work")
```

パス係数の検定

H0：$\beta 13.1 = \beta 13.2$　など

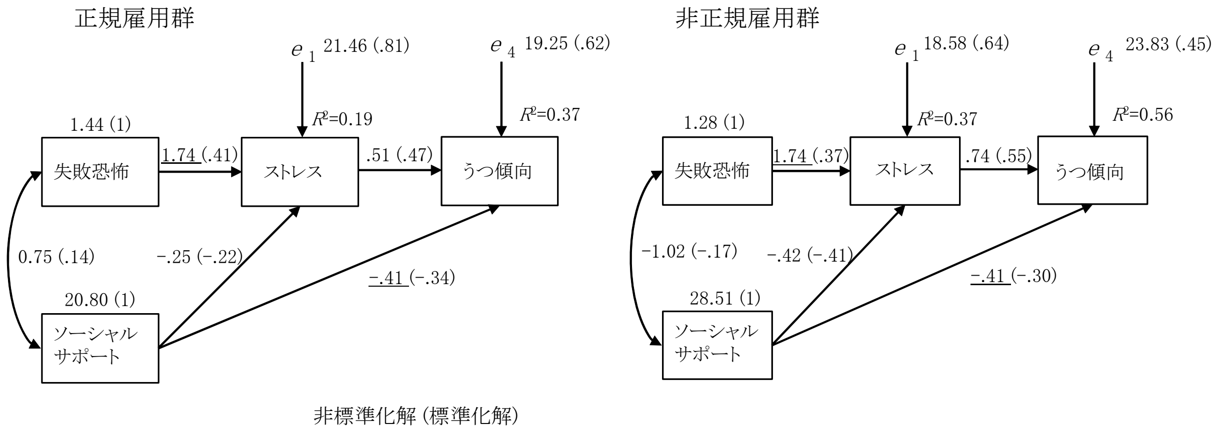
```
# パス係数の差の値
(vb <- sem.mg.seq$coeff)
(vb1 <- vb[c("b12.1","b13.1","b41.1","b43.1")])
(vb2 <- vb[c("b12.2","b13.2","b41.2","b43.2")])
(vbd <- vb1-vb2)

# パス係数の差の標準誤差の推定
(vse <- sqrt(diag(sem.mg.seq$vcov)))
(vve <- diag(sem.mg.seq$vcov))
(vve1 <- vve[c("b12.1","b13.1","b41.1","b43.1")])
(vve2 <- vve[c("b12.2","b13.2","b41.2","b43.2")])
(vse12 <- sqrt(vve1 + vve2))

# 検定
(vz <- (vb1 - vb2)/ vse12)
2*(1-pnorm(abs(vz)))

# 信頼区間の推定
(z0 <- qnorm(.975))
(vL <- (vb1 - vb2) - z0*vse12)
(vU <- (vb1 - vb2) + z0*vse12)
```

```
> setwd("i:¥¥Rdocuments¥¥scripts¥¥")
> d1 <- read.table("回帰分析データ.csv", header=TRUE, sep=",")
> head(d1)
  id stress kyoufu support utsu work result
1  1     20    2.2      17   18    0      0
2  2     23    4.8      18   21    1      0
3  3     30    5.8      12   29    1      1
4  4     25    5.2      18   29    0      1
5  5     26    2.0       8   22    1      0
6  6     21    5.0      26   19    1      0
>
>
> # 群別データ
> d11 <- d1[d1$work==1, colnames(d1) %in% c("work")==F]
> d10 <- d1[d1$work==0, colnames(d1) %in% c("work")==F]
```

```
>
> # 記述統計量
> dtmp <- d11[,c(-1)]
> ntmp <- nrow(dtmp)
> mtmp <- colMeans(dtmp)
> stmp <- apply(dtmp, 2, sd)
> ctmp <- cor(dtmp)
> ktmp <- round(data.frame(ntmp, mtmp, stmp, ctmp),2)
> colnames(ktmp) <- c("N","Mean","SD",colnames(ctmp))
> ktmp
          N  Mean   SD stress kyoufu support  utsu result
stress  122 23.10 5.08   1.00   0.35   -0.17  0.53   0.33
kyoufu  122  4.17 1.20   0.35   1.00    0.14  0.27   0.17
support 122 18.25 4.56  -0.17   0.14    1.00 -0.38  -0.31
utsu    122 20.44 5.49   0.53   0.27   -0.38  1.00   0.75
result  122  0.22 0.42   0.33   0.17   -0.31  0.75   1.00
>
> dtmp <- d10[,c(-1)]
> ntmp <- nrow(dtmp)
> mtmp <- colMeans(dtmp)
> stmp <- apply(dtmp, 2, sd)
> ctmp <- cor(dtmp)
> ktmp <- round(data.frame(ntmp, mtmp, stmp, ctmp),2)
> colnames(ktmp) <- c("N","Mean","SD",colnames(ctmp))
> ktmp
          N  Mean   SD stress kyoufu support  utsu result
stress  123 22.78 5.43   1.00   0.46   -0.47  0.69   0.54
kyoufu  123  3.93 1.13   0.46   1.00   -0.17  0.35   0.25
support 123 18.59 5.34  -0.47  -0.17    1.00 -0.59  -0.45
utsu    123 20.13 7.38   0.69   0.35   -0.59  1.00   0.79
result  123  0.29 0.46   0.54   0.25   -0.45  0.79   1.00
>
>
> #変数名の変更（式を書くのにはこのほうが簡単）
> # x1:ストレス  x2:失敗恐怖  x3:ソーシャルサポート  x4:うつ傾向
> colnames(d1) <- c("id", "x1", "x2", "x3", "x4","work","result")
> head(d1)
  id x1  x2 x3 x4 work result
1  1 20 2.2 17 18    0      0
2  2 23 4.8 18 21    1      0
3  3 30 5.8 12 29    1      1
4  4 25 5.2 18 29    0      1
5  5 26 2.0  8 22    1      0
6  6 21 5.0 26 19    1      0
>
>
> # 多母集団分析
> library(sem)
> opt <- options(fit.indices = c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI", "IFI", "SRM
R", "AIC", "AICc", "BIC", "CAIC"))
>
>
> # 制約モデル
> seq.1 <- specifyEquations()
1:  x1 = b12*x2 + b13.1*x3
2:  x4 = b41.1*x1 + b43*x3
3:  V(x1) = ev1.1
4:  V(x4) = ev4.1
5:  V(x2) = v2.1
6:  V(x3) = v3.1
7:  C(x2,x3) = c23.1
8:
Read 7 items
> seq.2 <- specifyEquations()
1:  x1 = b12*x2 + b13.2*x3
2:  x4 = b41.2*x1 + b43*x3
3:  V(x1) = ev1.2
4:  V(x4) = ev4.2
5:  V(x2) = v2.2
6:  V(x3) = v3.2
7:  C(x2,x3) = c23.2
8:
```

```
Read 7 items

> mg.seq <- multigroupModel(seq.1, seq.2, groups=c("1","0"))
> d1$work <- factor(d1$work, levels=c(1,0))
> sem.mg.seq <- sem(mg.seq, data=d1, group="work")
> summary(sem.mg.seq)

 Model Chisquare = 7.154842  Df = 4  Pr(>Chisq) = 0.1279283
 Chisquare (null model) = 246.2831  Df = 12
 Goodness-of-fit index = 0.9856524
 Adjusted goodness-of-fit index = 0.9426097
 RMSEA index = 0.0805695 90% CI: (NA, 0.1744588)
 Bentler-Bonett NFI = 0.9709487
 Tucker-Lewis NNFI = 0.9596022
 Bentler CFI = 0.9865341
 Bentler RNI =  0.9865341
 Bollen IFI =  0.9869787
 SRMR = 0.03869427
 AIC = 39.15484
 AICc = 9.540807
 BIC = -14.85019

Iterations: initial fits, 0 0   final fit, 41


  work: 1

 Model Chisquare =  5.676078   Df =  1 Pr(>Chisq) = 0.01719777
 Goodness-of-fit index =  0.9770847
 Adjusted goodness-of-fit index =  0.7708467
 RMSEA index =  0.196584   90% CI: (0.06622647, 0.3661187)
 Bentler-Bonett NFI =  0.9326746
 Tucker-Lewis NNFI =  0.6417169
 Bentler CFI =  0.9402862
 Bentler RNI =  0.9402862
 Bollen IFI =  0.9438701
 SRMR =  0.05046779
 AIC =  23.67608
 AICc =  7.283221
 BIC =  0.8720571
 CAIC =  -0.1279429

 Normalized Residuals
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-0.3399 -0.1436  0.0000  0.1575  0.1087  1.5250

 R-square for Endogenous Variables
    x1     x4
0.1896 0.3830

 Parameter Estimates
      Estimate   Std Error  z value   Pr(>|z|)
b12     1.7380842 0.24885864  6.984223 2.864368e-12 x1 <--- x2
b13.1 -0.2516773 0.09277849 -2.712668 6.674387e-03 x1 <--- x3
b41.1  0.5067888 0.07808442  6.490268 8.568370e-11 x4 <--- x1
b43   -0.4107062 0.06435925 -6.381464 1.754034e-10 x4 <--- x3
ev1.1 21.4625255 2.75932679  7.778175 7.357848e-15 x1 <--> x1
ev4.1 19.2480001 2.47461661  7.778175 7.357848e-15 x4 <--> x4
v2.1   1.4446416 0.18573016  7.778175 7.357848e-15 x2 <--> x2
v3.1  20.8026690 2.67449242  7.778175 7.357848e-15 x3 <--> x3
c23.1  0.7534345 0.50304910  1.497736 1.342020e-01 x3 <--> x2

  work: 0

 Model Chisquare =  1.478764   Df =  1 Pr(>Chisq) = 0.223968
 Goodness-of-fit index =  0.9941505
 Adjusted goodness-of-fit index =  0.9415052
 RMSEA index =  0.06264419   90% CI: (NA, 0.2589937)
 Bentler-Bonett NFI =  0.9908704
 Tucker-Lewis NNFI =  0.981583
 Bentler CFI =  0.9969305
 Bentler RNI =  0.9969305
```

```
 Bollen IFI =  0.9970258
 SRMR =  0.02701648
 AIC =  19.47876
 AICc =  3.071684
 BIC =  -3.33342
 CAIC =  -4.33342

 Normalized Residuals
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-0.33150  0.00000  0.05265  0.11760  0.23190  0.68640

 R-square for Endogenous Variables
    x1     x4
0.3562 0.5501

 Parameter Estimates
       Estimate   Std Error  z value   Pr(>|z|)
b12     1.7380842 0.24885864  6.984223 2.864368e-12 x1 <--- x2
b13.2 -0.4164422 0.08832617 -4.714822 2.419219e-06 x1 <--- x3
b41.2  0.7443567 0.07362779 10.109726 5.002392e-24 x4 <--- x1
b43   -0.4107062 0.06435925 -6.381464 1.754034e-10 x4 <--- x3
ev1.2 18.5789349 2.37878885  7.810250 5.707481e-15 x1 <--> x1
ev4.2 23.8340009 3.05163111  7.810250 5.707481e-15 x4 <--> x4
v2.2   1.2784699 0.16369130  7.810250 5.707481e-15 x2 <--> x2
v3.2  28.5069972 3.64994698  7.810250 5.707481e-15 x3 <--> x3
c23.2 -1.0180328 0.55428088 -1.836673 6.625817e-02 x3 <--> x2

> stdCoef(sem.mg.seq)

 Group:  1
          Std. Estimate
1   b12      0.4059282 x1 <--- x2
2 b13.1     -0.2230498 x1 <--- x3
3 b41.1      0.4669772 x4 <--- x1
4   b43     -0.3353959 x4 <--- x3
5 ev1.1      0.8103589 x1 <--> x1
6 ev4.1      0.6170487 x4 <--> x4
7  v2.1      1.0000000 x2 <--> x2
8  v3.1      1.0000000 x3 <--> x3
9 c23.1      0.1374377 x3 <--> x2


 Group:  0
          Std. Estimate
1   b12      0.3658290 x1 <--- x2
2 b13.2     -0.4138973 x1 <--- x3
3 b41.2      0.5494062 x4 <--- x1
4   b43     -0.3012877 x4 <--- x3
5 ev1.2      0.6437911 x1 <--> x1
6 ev4.2      0.4499310 x4 <--> x4
7  v2.2      1.0000000 x2 <--> x2
8  v3.2      1.0000000 x3 <--> x3
9 c23.2     -0.1686323 x3 <--> x2
>
>
>
>
```



非標準化解（標準化解）

X^2=7.15, df=4, p=0.128,
AGFI=0.94, RMSEA=0.08, CFI=0.99, AIC=39.15

```
> # パス係数の検定
> # パス係数
> (vb <- sem.mg.seq$coeff)
       b12       b13.1       b41.1         b43       ev1.1       ev4.1        v2.1        v3.1 
 1.7380842  -0.2516773   0.5067888  -0.4107062  21.4625255  19.2480001   1.4446416  20.8026690 
     c23.1       b13.2       b41.2       ev1.2       ev4.2        v2.2        v3.2       c23.2 
 0.7534345  -0.4164422   0.7443567  18.5789349  23.8340009   1.2784699  28.5069972  -1.0180328 

> 関心のあるパス係数の取り出し
> (vb1 <- vb[,c("b12.1","b13.1","b41.1","b43.1")])
      <NA>      b13.1      b41.1       <NA> 
        NA -0.2516773  0.5067888         NA 

> (vb2 <- vb[,c("b12.2","b13.2","b41.2","b43.2")])
      <NA>      b13.2      b41.2       <NA> 
        NA -0.4164422  0.7443567         NA 

> # パス係数の差
> (vbd <- vb1-vb2)
      <NA>      b13.1      b41.1       <NA> 
        NA  0.1647649 -0.2375679         NA 
>
> # パス係数の標準誤差
> (vse <- sqrt(diag(sem.mg.seq$vcov)))
       b12       b13.1       b41.1         b43       ev1.1       ev4.1        v2.1        v3.1 
0.24919533  0.09277965  0.07917452  0.06467567  2.76178042  2.47910233  0.18576895  2.67505003 
     c23.1       b13.2       b41.2       ev1.2       ev4.2        v2.2        v3.2       c23.2 
0.50304583  0.07362920  0.08675249  2.38087824  3.05715764  0.16372405  3.65067675  0.55428201 

> # パス係数の標準誤差の2乗
> (vve <- diag(sem.mg.seq$vcov))
          b12          b13.1          b41.1            b43          ev1.1          ev4.1           v2.1 
  0.062098310    0.008608063    0.006268604    0.004182942    7.627431081    6.145948342    0.034510101 
         v3.1          c23.1          b13.2          b41.2          ev1.2          ev4.2           v2.2 
  7.155892678    0.253055110    0.005421260    0.007525994    5.668581192    9.346212836    0.026805563 
         v3.2          c23.2 
 13.327440737    0.307228541 

> # 関心のあるパス係数の標準誤差の2乗の取り出し
> (vve1 <- vve[,c("b12.1","b13.1","b41.1","b43.1")])
       <NA>       b13.1       b41.1        <NA> 
         NA 0.008608063 0.006268604          NA 

> (vve2 <- vve[,c("b12.2","b13.2","b41.2","b43.2")])
       <NA>       b13.2       b41.2        <NA> 
         NA 0.005421260 0.007525994          NA 

> #パス係数の差の標準誤差
> (vse12 <- sqrt(vve1 + vve2))
     <NA>     b13.1     b41.1      <NA> 
       NA 0.1184454 0.1174504        NA 

> # 検定統計量
> (vz <- (vb1 - vb2)/ vse12)
     <NA>     b13.1     b41.1      <NA> 
       NA  1.391062 -2.022709        NA 

> # p-value
> 2*(1-pnorm(abs(vz)))
     <NA>     b13.1     b41.1      <NA> 
       NA 0.1642067 0.0431032        NA 
>
> # 信頼区間の推定
> z0 <- qnorm(.975)

> (vL <- (vb1 - vb2) - z0*vse12)
       <NA>       b13.1       b41.1        <NA> 
         NA -0.06738386 -0.46776651          NA 

> (vU <- (vb1 - vb2) + z0*vse12)
        <NA>        b13.1        b41.1         <NA> 
          NA  0.396913743 -0.007369375           NA 
```