Structural Equation Modeling

Chapter 7

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Campbell and Fiske (1959) spelled out the requirements for the Multi-trait Multi-method test of construct validity. There are four requirements:

1. "Entries in the validity matrix diagonal should be significantly different from zero and sufficiently large to encourage further examination of validity." Convergent validity.

2. "...a validity diagonal value should be higher than the values lying in its column and row in the heterotrait-heteromethod triangles." Discriminant validity.

3. "...a variable correlate higher with an independent effort to measure the same trait than with measures designed to get at different traits which happen to employ the same method." Traits should be higher than methods.

4. The fourth method that the patterns of the heterotrait-heteromethod triangles be similar has been criticized.

Kenny (1990) states "Although a variety of statistical procedures have been suggested for use in analyzing the MTMM matrix, confirmatory factor analysis (CFA) has become the predominant analytical technique." Yet there is no accepted method within structural equation modeling to perform the procedure. Consequently, two methods are presented here. Both seem to meet the requirements specified by Campbell and Fiske but both suffer from an exact test because of a problem of degrees of freedom.

Procedure I.

The first procedure following are the steps in computing the Multi-trait Multi-method of construct validity:

1. Compute the model as depicted in Figure 1 (jobstream CAMEMP1A.EQS). This model must fit in order to continue with the analysis (BBN > .90).

2. Compute the model that sets the traits to 0 (jobstream CAMEMP1E.EQS).

3. Compute the model that sets the methods to 0 (jobstream CAMEMP1F.EQS).

4. The following conditions must exist in order to verify MTMM:

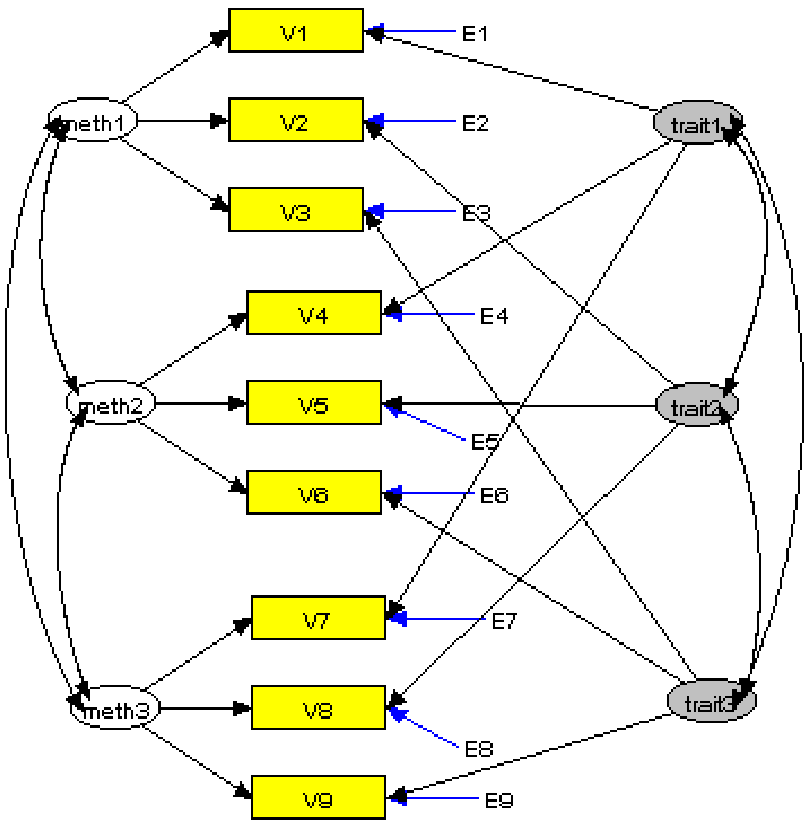
   a. The chi square for the "trait model" must be smaller than that for the "method model".

   b. The differences between the "trait model" and the "method model" must be significant.

The three jobstreams CAMEMP1A.EQS, CAMEMP1E.EQS, and CAMEMP1F.EQS test the following model.

1.0								
.51	1.0							
.38	.37	1.0						
.57	.22	.09	1.0					
.22	.57	.10	.68	1.0				
.11	.11	.46	.59	.58	1.0			
.56	.22	.11	.67	.42	.33	1.0		
.23	.58	.12	.43	.66	.34	.67	1.0	
.11	.11	.45	.34	.32	.58	.58	.60	1.0

[Enter Table 1 from Campbell and Fiske]



]

The data comes from Campbell and Fiske, 1959.

Correlation Data File = camemp1.cv1

```
 1.0
  .51 1.0
  .38  .37 1.0
  .57  .22  .09 1.0
  .22  .57  .10  .68 1.0
  .11  .11  .46  .59  .58 1.0
  .56  .22  .11  .67  .42  .33 1.0
  .23  .58  .12  .43  .66  .34  .67 1.0
  .11  .11  .45  .34  .32  .58  .58  .60 1.0
```

File Name = camemp1a.eqs

```
 /title
 multi-trait multi-method
 /spe
 case=311 ;var=9; me=ml; mat=cor;
 da='camemp1.cv1';
 /labels
 v1 =A1;  v2 =B1; v3 =C1;
 v4 =A2;  v5 =B2; v6 =C2;
 v7 =A3;  v8 =B3; v9 =C3;
 /print
   retest='camemp0.eqs';
 /tec
 itr=30;
/EQUATION
  V1  =   .457*F1   + .892*F4   +1.000 E1;
  V2  =   .412*F1   + .910*F5   +1.000 E2;
  V3  =   .496*F1   + .799*F6   +1.000 E3;
  V4  =   .719*F2   + .651*F4   +1.000 E4;
  V5  =   .708*F2   + .641*F5   +1.000 E5;
  V6  =   .699*F2   + .597*F6   +1.000 E6;
  V7  =   .706*F3   + .627*F4   +1.000 E7;
  V8  =   .728*F3   + .642*F5   +1.000 E8;
  V9  =   .715*F3   + .560*F6   +1.000 E9;
/VARIANCES
    F1  =1.000;E1  =.000*;
```

```
   F2  =1.000;E2  =.000*;
   F3  =1.000;E3  =.114*;
   F4  =1.000;E4  =.050*;
   F5  =1.000;E5  =.088*;
   F6  =1.000;E6  =.159*;
   E7  =.107*;
   E8  =.065*;
   E9  =.174*;
/COVARIANCES
   F2  ,F1  =-.046*;
   F3  ,F1  =.001*;
   F3  ,F2  =.501*;
   F5  ,F4  =.397*;
   F6  ,F4  =.217*;
   F6  ,F5  =.225*;
/END
```

```
 1

 PARAMETER        CONDITION CODE
   E1,E1          CONSTRAINED AT LOWER BOUND
   E2,E2          CONSTRAINED AT LOWER BOUND

 GOODNESS OF FIT SUMMARY

 INDEPENDENCE MODEL CHI-SQUARE =       2590.066 ON     36 DEGREES OF FREEDOM

 INDEPENDENCE AIC =  2518.06637    INDEPENDENCE CAIC =  2347.43382
        MODEL AIC =   -18.68869           MODEL CAIC =   -75.56620

 CHI-SQUARE =         5.311 BASED ON     12 DEGREES OF FREEDOM
 PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS     0.94676
 THE NORMAL THEORY RLS CHI-SQUARE FOR THIS ML SOLUTION IS           5.331.

 BENTLER-BONETT NORMED     FIT INDEX=       0.998
 BENTLER-BONETT NONNORMED FIT INDEX=        1.008
 COMPARATIVE FIT INDEX               =       1.000



 MEASUREMENT EQUATIONS WITH STANDARD ERRORS AND TEST STATISTICS
```

```
A1   =V1  =   .457*F1    + .892*F4    +1.000 E1
              .247          .131
             1.851         6.824

B1   =V2  =   .413*F1    + .910*F5    +1.000 E2
              .262          .120
             1.572         7.574

C1   =V3  =   .497*F1    + .798*F6    +1.000 E3
              .246          .162
             2.023         4.929

A2   =V4  =   .719*F2    + .651*F4    +1.000 E4
              .091          .097
             7.870         6.716

B2   =V5  =   .708*F2    + .641*F5    +1.000 E5
              .076          .094
             9.280         6.824

C2   =V6  =   .699*F2    + .597*F6    +1.000 E6
              .098          .101
             7.159         5.894

A3   =V7  =   .706*F3    + .627*F4    +1.000 E7
              .086          .091
             8.170         6.922

B3   =V8  =   .728*F3    + .642*F5    +1.000 E8
              .074          .092
             9.824         6.945

C3   =V9  =   .715*F3    + .560*F6    +1.000 E9
              .093          .104
             7.710         5.397


STANDARDIZED SOLUTION:


A1   =V1  =   .456*F1    + .890*F4    + .000 E1
B1   =V2  =   .413*F1    + .911*F5    + .000 E2
C1   =V3  =   .497*F1    + .799*F6    + .338 E3
A2   =V4  =   .722*F2    + .654*F4    + .225 E4
```

```
 B2    =V5  =   .708*F2    + .641*F5    + .296 E5
 C2    =V6  =   .698*F2    + .596*F6    + .398 E6
 A3    =V7  =   .706*F3    + .627*F4    + .328 E7
 B3    =V8  =   .725*F3    + .639*F5    + .255 E8
 C3    =V9  =   .715*F3    + .561*F6    + .417 E9

CORRELATIONS AMONG INDEPENDENT VARIABLES
---------------------------------------

            V                          F
           ---                        ---
                      I F2  -   F2           -.046*I
                      I F1  -   F1                I
                      I                           I
                      I F3  -   F3            .002*I
                      I F1  -   F1                I
                      I                           I
                      I F3  -   F3            .501*I
                      I F2  -   F2                I
                      I                           I
                      I F5  -   F5            .397*I
                      I F4  -   F4                I
                      I                           I
                      I F6  -   F6            .217*I
                      I F4  -   F4                I
                      I                           I
                      I F6  -   F6            .225*I
                      I F5  -   F5                I
                      I                           I
```

Name of File = camemp1c.eqs

```
/title
multi-trait multi-method
/spe
case=311 ;var=9; me=ml; mat=cor;
da='camemp1.cv1';
/labels
v1 =meth1a;  v2 =meth1b; v3 =meth1c;
v4 =meth2a;  v5 =meth2b; v6 =meth2c;
v7 =meth3a;  v8 =meth3b; v9 =meth3c;
/print
  retest='camemp0.eqs';
```

```
/tec
itr=30;
/EQUATION
  V1  =    0F1    +  .946*F4    + 1.000 E1;
  V2  =    0F1    +  .947*F5    + 1.000 E2;
  V3  =    0F1    +  .924*F6    + 1.000 E3;
  V4  =    0F2    +  .792*F4    + 1.000 E4;
  V5  =    0F2    +  .782*F5    + 1.000 E5;
  V6  =    0F2    +  .735*F6    + 1.000 E6;
  V7  =    0F3    +  .773*F4    + 1.000 E7;
  V8  =    0F3    +  .785*F5    + 1.000 E8;
  V9  =    0F3    +  .708*F6    + 1.000 E9;
/VARIANCES
    F1  =1.000;E1  =.9000*;
    F2  =1.000;E2  =.9000*;
    F3  =1.000;E3  =.9000*;
    F4  =1.000;E4  =.9000*;
    F5  =1.000;E5  =.9000*;
    F6  =1.000;E6  =.9000*;
E7  =.9000*;
E8  =.9000*;
E9  =.9000*;
/COVARIANCES
    F2  ,F1  =.3*;
    F3  ,F1  =.3*;
    F3  ,F2  =.368*;
    F5  ,F4  =.564*;
    F6  ,F4  =.439*;
    F6  ,F5  =.437*;
/ENd
```

```
1

  PARAMETER         CONDITION CODE
    F2,F1           LINEARLY DEPENDENT ON OTHER PARAMETERS
    F3,F1           LINEARLY DEPENDENT ON OTHER PARAMETERS
    F3,F2           LINEARLY DEPENDENT ON OTHER PARAMETERS
  MAXIMUM LIKELIHOOD SOLUTION (NORMAL DISTRIBUTION THEORY)
    F2,F1           VARIANCE OF PARAMETER ESTIMATE IS SET TO ZERO.
    F3,F1           VARIANCE OF PARAMETER ESTIMATE IS SET TO ZERO.
    F3,F2           VARIANCE OF PARAMETER ESTIMATE IS SET TO ZERO.
```

```
GOODNESS OF FIT SUMMARY

INDEPENDENCE MODEL CHI-SQUARE =       2590.066 ON     36 DEGREES OF FREEDOM

INDEPENDENCE AIC =  2518.06637   INDEPENDENCE CAIC =  2347.43382
       MODEL AIC =  1417.17437          MODEL CAIC =  1317.63871

CHI-SQUARE =     1459.174 BASED ON     21 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001
THE NORMAL THEORY RLS CHI-SQUARE FOR THIS ML SOLUTION IS        1044.982.

BENTLER-BONETT NORMED    FIT INDEX=       0.437
BENTLER-BONETT NONNORMED FIT INDEX=       0.035
COMPARATIVE FIT INDEX             =       0.437



STANDARDIZED SOLUTION:


METH1A  =V1  =   .635*F4   + .772 E1
METH1B  =V2  =   .644*F5   + .765 E2
METH1C  =V3  =   .536*F6   + .844 E3
METH2A  =V4  =   .845*F4   + .534 E4
METH2B  =V5  =   .830*F5   + .558 E5
METH2C  =V6  =   .789*F6   + .615 E6
METH3A  =V7  =   .824*F4   + .566 E7
METH3B  =V8  =   .834*F5   + .551 E8
METH3C  =V9  =   .771*F6   + .637 E9
```

File name = camemp1d.eqs

```
/title
multi-trait multi-method
/spe
case=311 ;var=9; me=ml; mat=cor;
da='camemp1.cv1';
/labels
v1 =meth1a;  v2 =meth1b; v3 =meth1c;
v4 =meth2a;  v5 =meth2b; v6 =meth2c;
v7 =meth3a;  v8 =meth3b; v9 =meth3c;
/print
  retest='camemp0.eqs';
/tec
```

```
itr=30;
/EQUATION
  V1  =   .305*F1   +  0F4   + 1.000 E1;
  V2  =   .297*F1   +  0F5   + 1.000 E2;
  V3  =   .342*F1   +  0F6   + 1.000 E3;
  V4  =   .325*F2   +  0F4   + 1.000 E4;
  V5  =   .339*F2   +  0F5   + 1.000 E5;
  V6  =   .379*F2   +  0F6   + 1.000 E6;
  V7  =   .350*F3   +  0F4   + 1.000 E7;
  V8  =   .339*F3   +  0F5   + 1.000 E8;
  V9  =   .400*F3   +  0F6   + 1.000 E9;
/VARIANCES
    F1  =1.000;E1  =.9000*;
    F2  =1.000;E2  =.9000*;
    F3  =1.000;E3  =.9000*;
    F4  =1.000;E4  =.9000*;
    F5  =1.000;E5  =.9000*;
    F6  =1.000;E6  =.9000*;
E7  =.9000*;
E8  =.9000*;
E9  =.9000*;
/COVARIANCES
    F2  ,F1  =.3*;
    F3  ,F1  =.3*;
    F3  ,F2  =.368*;
    F5  ,F4  =.564*;
    F6  ,F4  =.439*;
    F6  ,F5  =.437*;
/ENd
```

```
PARAMETER          CONDITION CODE
  F5,F4          LINEARLY DEPENDENT ON OTHER PARAMETERS
  F6,F4          LINEARLY DEPENDENT ON OTHER PARAMETERS
  F6,F5          LINEARLY DEPENDENT ON OTHER PARAMETERS
  F5,F4          VARIANCE OF PARAMETER ESTIMATE IS SET TO ZERO.
  F6,F4          VARIANCE OF PARAMETER ESTIMATE IS SET TO ZERO.
  F6,F5          VARIANCE OF PARAMETER ESTIMATE IS SET TO ZERO.


GOODNESS OF FIT SUMMARY


INDEPENDENCE MODEL CHI-SQUARE =        2590.066 ON     36 DEGREES OF FREEDOM
```

```
INDEPENDENCE AIC =  2518.06637   INDEPENDENCE CAIC =  2347.43382
      MODEL AIC =  1447.36148          MODEL CAIC =  1347.82583

CHI-SQUARE =      1489.361 BASED ON     21 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001
THE NORMAL THEORY RLS CHI-SQUARE FOR THIS ML SOLUTION IS        1159.482.

BENTLER-BONETT NORMED     FIT INDEX=        0.425
BENTLER-BONETT NONNORMED FIT INDEX=        0.014
COMPARATIVE FIT INDEX              =        0.425


STANDARDIZED SOLUTION:




METH1A  =V1  =  .724*F1   + .690 E1
METH1B  =V2  =  .726*F1   + .687 E2
METH1C  =V3  =  .492*F1   + .871 E3
METH2A  =V4  =  .837*F2   + .547 E4
METH2B  =V5  =  .830*F2   + .558 E5
METH2C  =V6  =  .684*F2   + .730 E6
METH3A  =V7  =  .820*F3   + .572 E7
METH3B  =V8  =  .840*F3   + .543 E8
METH3C  =V9  =  .688*F3   + .726 E9
```

The above model is tested by following the steps listed at the beginning of the chapter.

1. The full model fits with a BBN of .998 and a chi square of 5.11 and p of .95 .
2. Note that when the traits (CAMEMP1D.EQS) are set to 0 the chi square increases to 1489.36. The difference from the full model of chi square of 5.11 with one degree of freedom is significant.
3. The chi square of the methods removed is <u>LESS</u> than the chi square when the traits are removed (1459.17).
4. Although the difference between the "traits removed" and the "methods removed" appears to be significant this cannot be tested because there are no degrees of freedom.

Procedure II.

In the next procedure the trait factor is constrained to be larger than the method factor. This is accomplished in the "inequalities" section. The weight for the methods factor is taken from the "Measurement Equations with Standard Errors and Test Statistics" section of the original run. The trait factor is then set to be larger than the method factor.

File Name = camemp1z.eqs

```
 /title
 multi-trait multi-method
 /spe
 case=311 ;var=9; me=ml; mat=cor;
 da='camemp1.cv1';
 /labels
 v1 =A1;  v2 =B1; v3 =C1;
 v4 =A2;  v5 =B2; v6 =C2;
 v7 =A3;  v8 =B3; v9 =C3;
 /print
   retest='camemp0.eqs';
 /tec
 itr=30;
/ine
 (v1,f4)>.457;
 (v2,f5)>.412;
 (v3,f6)>.496;
 (v4,f4)>.719;
 (v5,f5)>.708;
 (v6,f6)>.699;
 (v7,f4)>.706;
 (v8,f5)>.728;
 (v9,f6)>.715;
 /EQUATION
   V1  =    .305*F1    +  .946*F4    + 1.000 E1;
   V2  =    .297*F1    +  .947*F5    + 1.000 E2;
   V3  =    .342*F1    +  .924*F6    + 1.000 E3;
   V4  =    .325*F2    +  .792*F4    + 1.000 E4;
   V5  =    .339*F2    +  .782*F5    + 1.000 E5;
   V6  =    .379*F2    +  .735*F6    + 1.000 E6;
   V7  =    .350*F3    +  .773*F4    + 1.000 E7;
   V8  =    .339*F3    +  .785*F5    + 1.000 E8;
   V9  =    .400*F3    +  .708*F6    + 1.000 E9;
 /VARIANCES
     F1  =1.000;E1  =.9000*;
     F2  =1.000;E2  =.9000*;
     F3  =1.000;E3  =.9000*;
     F4  =1.000;E4  =.9000*;
     F5  =1.000;E5  =.9000*;
     F6  =1.000;E6  =.9000*;
E7  =.9000*;
```

```
E8  =.9000*;
E9  =.9000*;
 /COVARIANCES
    F2  ,F1  =.3*;
    F3  ,F1  =.3*;
    F3  ,F2  =.368*;
    F5  ,F4  =.564*;
    F6  ,F4  =.439*;
    F6  ,F5  =.437*;
 /ENd
```

```
 PARAMETER        CONDITION CODE
   F2,F1          CONSTRAINED AT LOWER BOUND
   E1,E1          CONSTRAINED AT LOWER BOUND
   E2,E2          CONSTRAINED AT LOWER BOUND
   V7,F4          CONSTRAINED AT LOWER BOUND
   V8,F5          CONSTRAINED AT LOWER BOUND
   V9,F6          CONSTRAINED AT LOWER BOUND
 MAXIMUM LIKELIHOOD SOLUTION (NORMAL DISTRIBUTION THEORY)


 GOODNESS OF FIT SUMMARY

 INDEPENDENCE MODEL CHI-SQUARE =       2590.066 ON     36 DEGREES OF FREEDOM

 INDEPENDENCE AIC =  2518.06637    INDEPENDENCE CAIC =  2347.43382
        MODEL AIC =   -12.43494           MODEL CAIC =   -69.31246

 CHI-SQUARE =        11.565 BASED ON     12 DEGREES OF FREEDOM
 PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS      0.48121
 THE NORMAL THEORY RLS CHI-SQUARE FOR THIS ML SOLUTION IS          11.082.

 BENTLER-BONETT NORMED     FIT INDEX=        0.996
 BENTLER-BONETT NONNORMED FIT INDEX=       1.001
 COMPARATIVE FIT INDEX              =        1.000


 MEASUREMENT EQUATIONS WITH STANDARD ERRORS AND TEST STATISTICS



  A1    =V1  =     .208*F1    +   .997*F4    +  1.000 E1
                   .053           .026
```

```
              3.964        37.903

B1   =V2  =    .186*F1   +  .998*F5   +  1.000 E2
               .051         .025
              3.634        39.682

C1   =V3  =    .212*F1   +  .972*F6   +  1.000 E3
               .055         .038
              3.890        25.418

A2   =V4  =    .654*F2   +  .722*F4   +  1.000 E4
               .048         .027
             13.564        26.640

B2   =V5  =    .647*F2   +  .715*F5   +  1.000 E5
               .048         .027
             13.440        26.016

C2   =V6  =    .644*F2   +  .703*F6   +  1.000 E6
               .050         .034
             12.755        20.967

A3   =V7  =    .629*F3   +  .706*F4   +  1.000 E7
               .050         .093
             12.586         7.629

B3   =V8  =    .653*F3   +  .728*F5   +  1.000 E8
               .050         .093
             13.079         7.812

C3   =V9  =    .648*F3   +  .715*F6   +  1.000 E9
               .053         .082
             12.217         8.726
```

STANDARDIZED SOLUTION:

```
A1   =V1  =   .204*F1    + .979*F4    + .000 E1
B1   =V2  =   .183*F1    + .983*F5    + .000 E2
C1   =V3  =   .201*F1    + .922*F6    + .332 E3
A2   =V4  =   .654*F2    + .722*F4    + .226 E4
B2   =V5  =   .641*F2    + .709*F5    + .294 E5
C2   =V6  =   .623*F2    + .681*F6    + .386 E6
A3   =V7  =   .629*F3    + .705*F4    + .327 E7
B3   =V8  =   .645*F3    + .720*F5    + .257 E8
C3   =V9  =   .619*F3    + .682*F6    + .390 E9
```

CORRELATIONS AMONG INDEPENDENT VARIABLES

```
---------------------------------------

          V                        F
         ---                      ---
                  I F2  -   F2            -1.000*I
                  I F1  -   F1                   I
                  I                              I
                  I F3  -   F3             -.986*I
                  I F1  -   F1                   I
                  I                              I
                  I F3  -   F3              .390*I
                  I F2  -   F2                   I
                  I                              I
                  I F5  -   F5              .504*I
                  I F4  -   F4                   I
                  I                              I
                  I F6  -   F6              .396*I
                  I F4  -   F4                   I
                  I                              I
                  I F6  -   F6              .388*I
                  I F5  -   F5                   I
                  I                              I
```

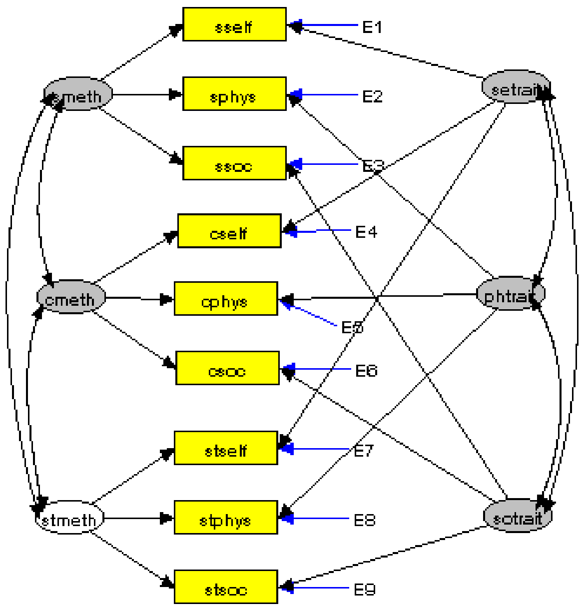
Notice in the original analysis that the Chi Square is 5.311 and there were 12 degrees of freedom and in the present analysis the Chi Square is 11.565 and 12 degrees of freedom. Again there are no degrees of freedom to make an assessment. The following is a method that seems logical but I am not sure that it can be proven mathematically. Whenever a parameter is estimated one degree of freedom is lost. The parameter can range between 0 and 1. If we are estimating a partial parameter (as is the case with "inequalities" we should loose the degrees of freedom for that part that is being estimated. For example, in the case where the "inequality" to be estimated is greater than .457 then the degrees of freedom lost should be the distance between .457 and 1 or 1 minus .457 (.543). Consequently, the calculation for the degrees of freedom for this problem would be:

Beta (Weights from standardized solution)	1 - Beta
0.457	0.543
0.412	0.588
0.496	0.504
0.719	0.281
0.708	0.292
0.699	0.301
0.706	0.294
0.728	0.272
0.715	0.285
5.64	3.36

The difference between 5.311 and 11.565 is 6.455. With a Chi Square of 6.455 and 3.36 degrees of freedom it is not significant. This indicates that the trait factors were larger than the method factors.

File Name = schmtm1.cor

```
1.0
37  1.0
48   .54  1.0
49  -.03  -.03  1.0
22   .77   .33   .14  1.0
11   .35   .37   .06   .54  1.0
61  -.01   .10   .60  -.02  -.05  1.0
23   .73   .42  -.02   .70   .39   .14  1.0
22   .44   .55  -.07   .40   .48   .08   .56  1.0
```



File Name = schmtm1.eqs

/title
multi-trait multi-method
/spe
case=181 ;var=9; me=ml; mat=cor;
da='schmtm1.cor';
/labels
v1 =sself; v2 =sphys; v3 =ssoc; v4 =cself;
v5 =cphys; v6 =csoc; v7 =satself; v8 =satphys;
v9 =satsoc;
/print
 retest= 'schmtm0.eqs';
/tec
itr=200;
/equation

```
 v1  =  *f1  + *f4  +  1.000 e1;
 v2  =  *f1  + *f5  +  1.000 e2;
 v3  =  *f1  + *f6  +  1.000 e3;
 v4  =  *f2  + *f4  +  1.000 e4;
 v5  =  *f2  + *f5  +  1.000 e5;
 v6  =  *f2  + *f6  +  1.000 e6;
 v7  =  *f3  + *f4  +  1.000 e7;
 v8  =  *f3  + *f5  +  1.000 e8;
 v9  =  *f3  + *f6  +  1.000 e9;
/variances
  f1  = 1.000;
  f2  = 1.000;
  f3  = 1.000;
  f4  = 1.000;
  f5  = 1.000;
  f6  = 1.000;
  e1, e2, e3, e4, e5, e6, e7, e8, e9 = *;
/covariances
f2 , f1 =*;
f3 , f1 =*;
f3 , f2 =*;
f4 , f5 =*;
f4 , f6 =*;
f5 , f6 =*;
/end
```

```
1

 *** WARNING *** ANALYZE COVARIANCE MATRIX FROM INPUT CORRELATION MATRIX BUT NO /STANDARD DEVIATION FOUND
                 ANALYSIS=CORRELATION; IS ASSUMED

 PARAMETER ESTIMATES APPEAR IN ORDER,
 NO SPECIAL PROBLEMS WERE ENCOUNTERED DURING OPTIMIZATION.


 GOODNESS OF FIT SUMMARY

 INDEPENDENCE MODEL CHI-SQUARE =        920.183 ON     36 DEGREES OF FREEDOM

 INDEPENDENCE AIC =    848.18294    INDEPENDENCE CAIC =    697.03705
        MODEL AIC =    -13.25843           MODEL CAIC =    -63.64039

 CHI-SQUARE =        10.742 BASED ON     12 DEGREES OF FREEDOM
 PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS      0.55119
```

```
THE NORMAL THEORY RLS CHI-SQUARE FOR THIS ML SOLUTION IS         10.829.

BENTLER-BONETT NORMED    FIT INDEX=      0.988
BENTLER-BONETT NONNORMED FIT INDEX=      1.004
COMPARATIVE FIT INDEX          =      1.000



MEASUREMENT EQUATIONS WITH STANDARD ERRORS AND TEST STATISTICS



SSELF   =V1  =   .821*F1   +  .396*F4   + 1.000 E1
                 .067         .099
               12.213        4.015

SPHYS   =V2  =   .611*F1   +  .737*F5   + 1.000 E2
                 .075         .071
                8.175       10.347

  SSOC  =V3  =   .723*F1   +  .382*F6   + 1.000 E3
                 .079         .105
                9.181        3.624

CSELF   =V4  =   .485*F2   +  .625*F4   + 1.000 E4
                 .099         .088
                4.912        7.074

CPHYS   =V5  =   .682*F2   +  .700*F5   + 1.000 E5
                 .074         .074
                9.264        9.456

  CSOC  =V6  =   .578*F2   +  .479*F6   + 1.000 E6
                 .097         .105
                5.977        4.568

SATSELF =V7  =   .581*F3   +  .718*F4   + 1.000 E7
                 .104         .094
                5.563        7.677

SATPHYS =V8  =   .642*F3   +  .631*F5   + 1.000 E8
                 .072         .077
                8.898        8.196
```

```
SATSOC  =V9  =   .643*F3   +  .529*F6   + 1.000 E9
                 .097         .110
                6.610        4.805
```

```
STANDARDIZED SOLUTION:

SSELF   =V1  =   .820*F1    + .396*F4    + .413 E1
SPHYS   =V2  =   .611*F1    + .737*F5    + .288 E2
  SSOC  =V3  =   .723*F1    + .382*F6    + .575 E3
CSELF   =V4  =   .486*F2    + .627*F4    + .609 E4
CPHYS   =V5  =   .689*F2    + .706*F5    + .163 E5
  CSOC  =V6  =   .574*F2    + .476*F6    + .667 E6
SATSELF =V7  =   .577*F3    + .713*F4    + .400 E7
SATPHYS =V8  =   .641*F3    + .630*F5    + .438 E8
SATSOC  =V9  =   .648*F3    + .533*F6    + .544 E9

 CORRELATIONS AMONG INDEPENDENT VARIABLES
 ---------------------------------------

                V                               F
               ---                             ---
                           I F2  -   F2               .578*I
                           I F1  -   F1                    I
                           I                               I
                           I F3  -   F3               .698*I
                           I F1  -   F1                    I
                           I                               I
                           I F3  -   F3               .573*I
                           I F2  -   F2                    I
                           I                               I
                           I F5  -   F5              -.474*I
                           I F4  -   F4                    I
                           I                               I
                           I F6  -   F6              -.755*I
                           I F4  -   F4                    I
                           I                               I
                           I F6  -   F6               .397*I
                           I F5  -   F5                    I
                           I                               I
```

File Name = schmtm3.eqs

```
/title
multi-trait multi-method
/spe
case=181 ;var=9; me=ml; mat=cor;
da='schmtm1.cor';
/labels
v1 =sself;  v2 =sphys; v3 =ssoc; v4 =cself;
v5 =cphys;  v6 =csoc; v7 =satself; v8 =satphys;
v9 =satsoc;
/print
 retest= 'schmtm0.eqs';
/tec
itr=200;
/equation
  v1  =  *f1  + *f4  +  1.000 e1;
  v2  =  *f1  + *f5  +  1.000 e2;
  v3  =  *f1  + *f6  +  1.000 e3;
  v4  =  *f2  + *f4  +  1.000 e4;
  v5  =  *f2  + *f5  +  1.000 e5;
  v6  =  *f2  + *f6  +  1.000 e6;
  v7  =  *f3  + *f4  +  1.000 e7;
  v8  =  *f3  + *f5  +  1.000 e8;
  v9  =  *f3  + *f6  +  1.000 e9;
/variances
   f1  = 1.000;
   f2  = 1.000;
   f3  = 1.000;
   f4  = 1.000;
   f5  = 1.000;
   f6  = 1.000;
   e1, e2, e3, e4, e5, e6, e7, e8, e9 = *;
/covariances
f2 , f1 =*;
f3 , f1 =*;
f3 , f2 =*;
f4 , f5 =*;
f4 , f6 =*;
f5 , f6 =*;
/ine
 (V1,F4) > .821;
 (V2,f5) > .611;
 (v3,f6) > .723;
 (v4,f4) > .485;
 (v5,f5) > .682;
```

```
 (v6,f6) > .578;
 (v7,f4) > .581;
 (v8,f5) > .642;
 (v9,f6) > .634;
/end

1

  PARAMETER         CONDITION CODE
    F3,F2           CONSTRAINED AT LOWER BOUND
    E5,E5           CONSTRAINED AT LOWER BOUND
    V1,F4           CONSTRAINED AT LOWER BOUND
    V3,F6           CONSTRAINED AT LOWER BOUND

  GOODNESS OF FIT SUMMARY

  INDEPENDENCE MODEL CHI-SQUARE =        920.183 ON     36 DEGREES OF FREEDOM

  INDEPENDENCE AIC =    848.18294    INDEPENDENCE CAIC =    697.03705
         MODEL AIC =     24.25796           MODEL CAIC =    -26.12400
  CHI-SQUARE =        48.258 BASED ON     12 DEGREES OF FREEDOM
  PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001
  THE NORMAL THEORY RLS CHI-SQUARE FOR THIS ML SOLUTION IS          44.185.

  BENTLER-BONETT NORMED     FIT INDEX=        0.948
  BENTLER-BONETT NONNORMED FIT INDEX=        0.877
  COMPARATIVE FIT INDEX              =        0.959

  MEASUREMENT EQUATIONS WITH STANDARD ERRORS AND TEST STATISTICS

 SSELF   =V1  =     .606*F1    +   .821*F4    +  1.000 E1
                  .078           .084
                 7.721          9.743

 SPHYS   =V2  =     .404*F1    +   .824*F5    +  1.000 E2
                  .079           .054
                 5.091         15.195

  SSOC   =V3  =     .562*F1    +   .723*F6    +  1.000 E3
                  .081           .080
```

```
               6.949          9.077

CSELF   =V4  =    .194*F2    +   .795*F4    +  1.000 E4
                .081           .061
               2.398         13.057

CPHYS   =V5  =    .343*F2    +   .965*F5    +  1.000 E5
                .071           .057
               4.843         16.943

  CSOC  =V6  =    .252*F2    +   .760*F6    +  1.000 E6
                .084           .071
               3.016         10.728

SATSELF =V7  =    .278*F3    +   .907*F4    +  1.000 E7
                .084           .061
               3.326         14.917

SATPHYS =V8  =    .329*F3    +   .913*F5    +  1.000 E8
                .086           .062
               3.814         14.838

SATSOC  =V9  =    .228*F3    +   .854*F6    +  1.000 E9
                .084           .069
               2.694         12.446
```

STANDARDIZED SOLUTION:

```
SSELF   =V1  =   .554*F1    + .750*F4    + .361 E1
SPHYS   =V2  =   .404*F1    + .823*F5    + .400 E2
 SSOC   =V3  =   .528*F1    + .679*F6    + .510 E3
CSELF   =V4  =   .190*F2    + .776*F4    + .602 E4
CPHYS   =V5  =   .335*F2    + .942*F5    + .000 E5
 CSOC   =V6  =   .240*F2    + .723*F6    + .648 E6
SATSELF =V7  =   .264*F3    + .859*F4    + .439 E7
SATPHYS =V8  =   .316*F3    + .877*F5    + .363 E8
SATSOC  =V9  =   .216*F3    + .811*F6    + .544 E9
```

CORRELATIONS AMONG INDEPENDENT VARIABLES

```
            V                       F
           ---                     ---
                      I F2  -   F2          -.074*I
                      I F1  -   F1               I
                      I                          I
                      I F3  -   F3           .218*I
                      I F1  -   F1               I
                      I                          I
                      I F3  -   F3         -1.000*I
                      I F2  -   F2               I
                      I                          I
                      I F5  -   F5           .178*I
                      I F4  -   F4               I
                      I                          I
                      I F6  -   F6           .183*I
                      I F4  -   F4               I
                      I                          I
                      I F6  -   F6           .691*I
                      I F5  -   F5               I
                      I                          I
```

Beta (Weights from standardized solution)	1 - Beta
0.82	0.18
0.611	0.389

0.723	0.277
0.486	0.514
0.689	0.311
0.574	0.426
0.577	0.423
0.641	0.359
0.648	0.352
5.769	3.231

The Chi Square in the original analysis is 10.742 and 48.215 in the second analysis with the traits constrained to be larger than the method factors. The difference results in a Chi Square of 37.473 and with 3.231 degrees of freedom the Chi Square is significant at $p < .001$. This indicates that for each variable the trait factors are not larger than the methods factors and does not meet the requirements of convergent and discriminant validity.