Example 15 — Higher-order CFA

Description   Remarks and examples   Reference   Also see

Description

sem can be used to estimate higher-order confirmatory factor analysis models.

```
. use https://www.stata-press.com/data/r19/sem_hcfa1
(Higher-order CFA)

. ssd describe

  Summary statistics data from
  https://www.stata-press.com/data/r19/sem_hcfa1.dta
  Observations:            251          Higher-order CFA
     Variables:             16          25 May 2024 11:26
                                        (_dta has notes)
  ------------------------------------------------------------------------
  Variable name                   Variable label
  ------------------------------------------------------------------------
  phyab1                          Physical ability 1
  phyab2                          Physical ability 2
  phyab3                          Physical ability 3
  phyab4                          Physical ability 4
  appear1                         Appearance 1
  appear2                         Appearance 2
  appear3                         Appearance 3
  appear4                         Appearance 4
  peerrel1                        Relationship w/ peers 1
  peerrel2                        Relationship w/ peers 2
  peerrel3                        Relationship w/ peers 3
  peerrel4                        Relationship w/ peers 4
  parrel1                         Relationship w/ parent 1
  parrel2                         Relationship w/ parent 2
  parrel3                         Relationship w/ parent 3
  parrel4                         Relationship w/ parent 4
  ------------------------------------------------------------------------

. notes

_dta:
  1.  Summary statistics data from Marsh, H. W. and Hocevar, D., 1985,
      "Application of confirmatory factor analysis to the study of
      self-concept: First- and higher order factor models and their invariance
      across groups", _Psychological Bulletin_, 97: 562-582.
  2.  Summary statistics based on 251 students from Sydney, Australia in Grade
      5.
  3.  Data collected using the Self-Description Questionnaire and includes
      sixteen subscales designed to measure nonacademic traits: four intended
      to measure physical ability, four intended to measure physical
      appearance, four intended to measure relations with peers, and four
      intended to measure relations with parents.
```

See *Higher-order CFA models* in [SEM] **Intro 5** for background.

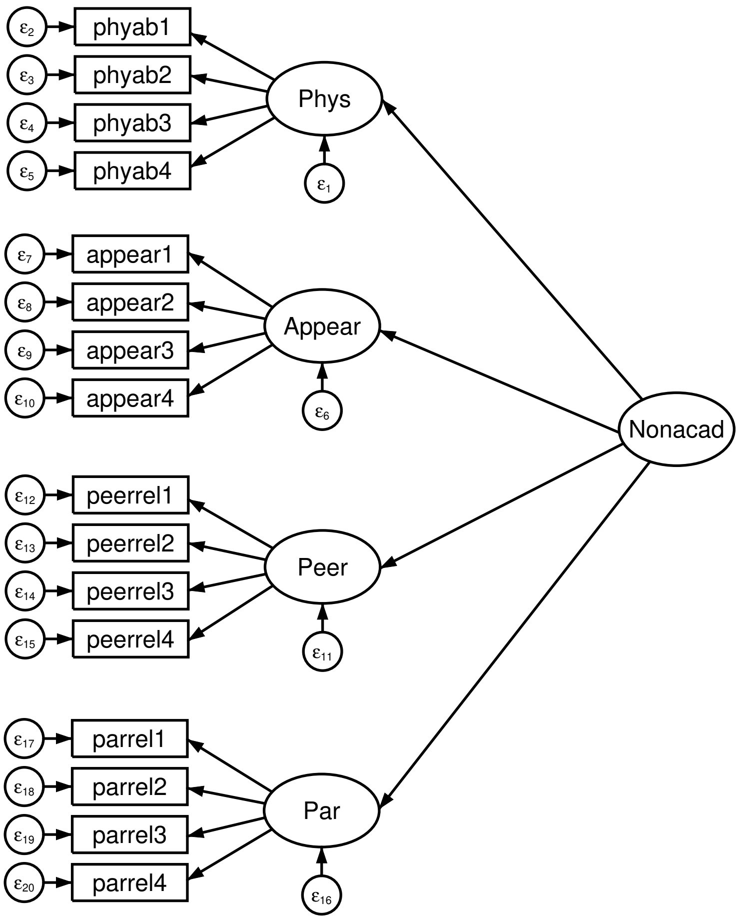
Remarks and examples

Remarks are presented under the following headings:

Fitting the model
Fitting the model with the Builder

Fitting the model

We fit the following model:



```
. sem (Phys -> phyab1 phyab2 phyab3 phyab4)
>     (Appear -> appear1 appear2 appear3 appear4)
>     (Peer -> peerrel1 peerrel2 peerrel3 peerrel4)
>     (Par -> parrel1 parrel2 parrel3 parrel4)
>     (Nonacad -> Phys Appear Peer Par)
Endogenous variables
  Measurement: phyab1 phyab2 phyab3 phyab4 appear1 appear2 appear3 appear4
               peerrel1 peerrel2 peerrel3 peerrel4 parrel1 parrel2 parrel3
               parrel4
  Latent:      Phys Appear Peer Par
Exogenous variables
  Latent: Nonacad
Fitting target model:
Iteration 0:  Log likelihood = -7686.6699  (not concave)
Iteration 1:  Log likelihood = -7643.7387  (not concave)
Iteration 2:  Log likelihood = -7616.2966  (not concave)
Iteration 3:  Log likelihood = -7597.6133
Iteration 4:  Log likelihood = -7588.9515
Iteration 5:  Log likelihood = -7585.3162
Iteration 6:  Log likelihood = -7584.8125
Iteration 7:  Log likelihood = -7584.7885
Iteration 8:  Log likelihood = -7584.7881
Structural equation model                              Number of obs = 251
Estimation method: ml
Log likelihood = -7584.7881
 ( 1)  [phyab1]Phys = 1
 ( 2)  [appear1]Appear = 1
 ( 3)  [peerrel1]Peer = 1
 ( 4)  [parrel1]Par = 1
 ( 5)  [Phys]Nonacad = 1
------------------------------------------------------------------------------
             |                 OIM
             | Coefficient  std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
Structural   |
  Phys       |
     Nonacad |          1  (constrained)
  -----------+----------------------------------------------------------------
  Appear     |
     Nonacad |   2.202491   .3975476     5.54   0.000     1.423312     2.98167
  -----------+----------------------------------------------------------------
  Peer       |
     Nonacad |   1.448035   .2921383     4.96   0.000     .8754549    2.020616
  -----------+----------------------------------------------------------------
  Par        |
     Nonacad |    .569956   .1382741     4.12   0.000     .2989437    .8409683
-------------+----------------------------------------------------------------
Measurement  |
  phyab1     |
        Phys |          1  (constrained)
       _cons |        8.2   .1159065    70.75   0.000     7.972827    8.427173
  -----------+----------------------------------------------------------------
  phyab2     |
        Phys |   .9332477   .1285726     7.26   0.000       .68125    1.185245
       _cons |       8.23    .122207    67.34   0.000     7.990479    8.469521
```

phyab3						
Phys	1.529936	.1573845	9.72	0.000	1.221468	1.838404
_cons	8.17	.1303953	62.66	0.000	7.91443	8.42557
phyab4						
Phys	1.325641	.1338053	9.91	0.000	1.063387	1.587894
_cons	8.56	.1146471	74.66	0.000	8.335296	8.784704
appear1						
Appear	1	(constrained)				
_cons	7.41	.1474041	50.27	0.000	7.121093	7.698907
appear2						
Appear	1.0719	.0821893	13.04	0.000	.9108121	1.232988
_cons	7	.1644123	42.58	0.000	6.677758	7.322242
appear3						
Appear	1.035198	.0893075	11.59	0.000	.8601581	1.210237
_cons	7.17	.1562231	45.90	0.000	6.863808	7.476192
appear4						
Appear	.9424492	.0860848	10.95	0.000	.7737262	1.111172
_cons	7.4	.1474041	50.20	0.000	7.111093	7.688907
peerrel1						
Peer	1	(constrained)				
_cons	8.81	.1077186	81.79	0.000	8.598875	9.021125
peerrel2						
Peer	1.214379	.1556051	7.80	0.000	.9093989	1.51936
_cons	7.94	.1215769	65.31	0.000	7.701714	8.178286
peerrel3						
Peer	1.667829	.190761	8.74	0.000	1.293944	2.041714
_cons	7.52	.1373248	54.76	0.000	7.250848	7.789152
peerrel4						
Peer	1.363627	.159982	8.52	0.000	1.050068	1.677186
_cons	8.29	.1222066	67.84	0.000	8.050479	8.529521
parrel1						
Par	1	(constrained)				
_cons	9.35	.0825215	113.30	0.000	9.188261	9.511739
parrel2						
Par	1.159754	.184581	6.28	0.000	.7979822	1.521527
_cons	9.13	.0988998	92.32	0.000	8.93616	9.32384
parrel3						
Par	2.035143	.2623826	7.76	0.000	1.520882	2.549403
_cons	8.67	.1114983	77.76	0.000	8.451467	8.888533
parrel4						
Par	1.651802	.2116151	7.81	0.000	1.237044	2.06656
_cons	9	.0926003	97.19	0.000	8.818507	9.181493
var(e.phyab1)	2.07466	.2075636			1.705244	2.524103
var(e.phyab2)	2.618638	.252693			2.167386	3.163841
var(e.phyab3)	1.231013	.2062531			.8864333	1.70954
var(e.phyab4)	1.019261	.1600644			.7492262	1.386621

var(e.appe~1)	1.986955	.2711164	1.520699	2.596169
var(e.appe~2)	2.801673	.3526427	2.189162	3.585561
var(e.appe~3)	2.41072	.300262	1.888545	3.077276
var(e.appe~4)	2.374508	.2872554	1.873267	3.009868
var(e.peer~1)	1.866632	.18965	1.529595	2.277933
var(e.peer~2)	2.167766	.2288099	1.762654	2.665984
var(e.peer~3)	1.824346	.2516762	1.392131	2.390749
var(e.peer~4)	1.803918	.212599	1.431856	2.272659
var(e.parr~1)	1.214141	.1195921	1.000982	1.472692
var(e.parr~2)	1.789125	.1748043	1.477322	2.166738
var(e.parr~3)	1.069717	.1767086	.7738511	1.478702
var(e.parr~4)	.8013735	.121231	.5957527	1.077963
var(e.Phys)	.911538	.1933432	.6014913	1.381403
var(e.Appear)	1.59518	.3704939	1.011838	2.514828
var(e.Peer)	.2368108	.1193956	.0881539	.6361528
var(e.Par)	.3697854	.0915049	.2276755	.600597
var(Nonacad)	.3858166	.1237638	.2057449	.7234903

```
LR test of model vs. saturated: chi2(100) = 219.48         Prob > chi2 = 0.0000
```

Notes:

1. The idea behind this model is that physical ability, appearance, and relationships with peers and parents may be determined by a latent variable containing nonacademic traits. This model was suggested by Bollen (1989, 315).

2. `sem` automatically provided normalization constraints for the first-order factors `Phys`, `Appear`, `Peer`, and `Par`. Their path coefficients were set to 1.

3. `sem` automatically provided a normalization constraint for the second-order factor `Nonacad`. Its path coefficient was set to 1.

Fitting the model with the Builder

Use the diagram above for reference.

1. Open the dataset.

   In the Command window, type

   ```
   . use https://www.stata-press.com/data/r19/sem_hcfa1
   ```

2. Open a new Builder diagram.

   Select menu item **Statistics > SEM (structural equation modeling) > Model building and estimation**.

3. Enlarge the size of the canvas to accommodate the length of the diagram.

   Click on the **Adjust canvas size** button, , in the Standard Toolbar, change the second size to 7 (inches), and then click on **OK**.

4. Change the size of the observed variables' rectangles.

   a. In the SEM Builder menu, select **Settings > Variables > All observed...**.

   b. In the resulting dialog box, change the second size to `.25` and click on **OK**.

5. Create the measurement component for physical ability.

   Select the Add measurement component tool, . Then using the darker one-inch grid lines in the background as a guide, click in the diagram about two inches in from the left and one inch down from the top.

   In the resulting dialog box,

   a. change the *Latent variable name* to `Phys`;
   b. select `phyab1`, `phyab2`, `phyab3`, and `phyab4` by using the *Measurement variables* control;
   c. select `Left` in the *Measurement direction* control;
   d. click on **OK**.

   If you wish, move the component by clicking on any variable and dragging it.

6. Create the remaining first-order measurement components.

   a. Repeat the process from item 5, but place the measurement component on the grid line two inches in from the left and about two and one-half inches down from the top. Label the latent variable `Appear`, and select measurement variables `appear1`, `appear2`, `appear3`, and `appear4`.
   b. Repeat the process from item 5, but place the measurement component on the grid line two inches in from the left and about four inches down from the top. Label the latent variable `Peer`, and select measurement variables `peerrel1`, `peerrel2`, `peerrel3`, and `peerrel4`.
   c. Repeat the process from item 5, but place the measurement component on the grid line two inches in from the left and about five and one-half inches down from the top. Label the latent variable `Par`, and select measurement variables `parrel1`, `parrel2`, `parrel3`, and `parrel4`.

7. Create the second-order latent variable.

   a. Select the Add latent variable tool, , and then click in the diagram about two inches in from the right and vertically centered between the `Appear` and `Peer` latent variables.
   b. In the Contextual Toolbar, type `Nonacad` in the *Name* control and press *Enter*.

8. Create paths from `Nonacad` to each of the first-order latent variables.

   a. Select the Add path tool, .
   b. Click in the upper-left quadrant of the `Nonacad` oval (it will highlight when you hover over it), and drag a path to the lower-left quadrant of the `Phys` oval (it will highlight when you can release to connect the path).
   c. Continuing with the tool, create the following paths by clicking first on the left side of the `Nonacad` variable and dragging to the right side of the first-order latent variable.

```
Nonacad -> Appear
Nonacad -> Peer
Nonacad -> Par
```

9. Clean up the direction of the errors.

   We want the errors for each of the latent variables to be below the latent variable. The errors for `Phys`, `Appear`, and `Peer` are likely to have been created in other directions.

   a. Choose the Select tool, .

  b. Click in the `Phys` oval.

  c. Click on one of the **Error rotation** buttons, , in the Contextual Toolbar until the error is below the latent variable.

  Repeat this for all errors on latent variables that are not below the latent variable.

10. Clean up the paths.

    If you do not like where a path has been connected to its variable, use the Select tool, , to click on the path, and then simply click on where it connects to an oval and drag the endpoint.

11. Estimate.

    Click on the **Estimate** button, , in the Standard Toolbar, and then click on **OK** in the resulting *SEM estimation options* dialog box.

Tip: See the tips of [SEM] **Example 9** to make creating paths somewhat easier than described above.

You can open a completed diagram in the Builder by typing

```
. webgetsem sem_hcfa1
```

Reference

Bollen, K. A. 1989. *Structural Equations with Latent Variables*. New York: Wiley. https://doi.org/10.1002/9781118619179.

Also see

[SEM] **sem** — Structural equation model estimation command