BMI Measurement Error Regression: Make it shorter

```
/********************* bmi3.sas ************************/
options linesize=79 pagesize = 500 noovp formdlim='-' nodate;
title 'BMI and Health: Like bmi2.sas, but try to make it shorter';

data health;
     infile 'bmihealth.data';
     input age1 bmi1 fat1 cholest1 diastol1
           age2 bmi2 fat2 cholest2 diastol2;
           /* fat1 and fat2 are percent body fat */
     age = (age1+age2)/2; bmi = (bmi1+bmi2)/2; fat = (fat1+fat2)/2;
     cholest = (cholest1+cholest2)/2 ; diastol = (diastol1+diastol2)/2;

proc calis cov vardef=n;
   /* Analyze the covariance matrix (Default is corr). Divide by n to
      get true MLE of covariance matrix. */
     title2 'Full Model';
     var age1 -- diastol2; /* Name the observed variables */
     /* Now give simultaneous equations, separated by commas. Latent
        variables begin with F for factor. Error terms begin with
        E for error or D for disturbance. SAS is not case sensitive.
        You must name all the parameters. Optional starting values in
        parentheses may be given after the parameters. */
     lineqs
          Fcholest = gamma11 Fage + gamma12 Fbmi + gamma13 Ffat + e1,
          Fdiastol = gamma21 Fage + gamma22 Fbmi + gamma23 Ffat + e2,
          age1     = Fage + delta11,
          bmi1     = Fbmi + delta12,
          fat1     = Ffat + delta13,
          age2     = Fage + delta21,
          bmi2     = Fbmi + delta22,
          fat2     = Ffat + delta23,
          cholest1 = Fcholest + eps11,
          diastol1 = Fdiastol + eps12,
          cholest2 = Fcholest + eps21,
          diastol2 = Fdiastol + eps22;
     std   /* Variances (not standard deviations) will be
              called V-something. Colon means fill in the numbers. */
          Fage Fbmi Ffat e1 e2
          delta11 delta12 delta13 delta21 delta22 delta23
          eps11 eps12 eps21 eps22 = v: ;
     cov   /* Covariances: If not mentioned, it's zero.  */
          Fage Ffat Fbmi = phi: , e1 e2 = psi: ,
          delta11 delta12 delta13 eps11 eps12 = TED1_: ,
          delta21 delta22 delta23 eps21 eps22 = TED2_: ;
     bounds 0.0 < v1-v15;  /* Variances are positive */

/* Note: These std and cov statements will generate warnings saying
         "Shorter parameter list than variable list ..." These can be
          ignored. There would be no warnings if we specified the
          number of parameters, as in    15 * v:  and
          delta11 delta12 delta13 eps11 eps12 = 10 * TED1_:   etc.
          But it's more convenient not to have to count parameters. */
```

```
/*  Now fit a reduced model to test H0: gamma12 = gamma22 = 0,
    meaning BMI is unrelated to either cholesterol or blood pressure
    if we allow for age and percent body fat.  Use psummary to see
    just the minimal output needed for a likelihood ratio test. */

proc calis cov vardef=n psummary;
     title2 'Reduced Model for testing BMI on both DVs at once';
     var age1 -- diastol2;
     lineqs
          Fcholest = gamma11 Fage + gamma12 Fbmi + gamma13 Ffat + e1,
          Fdiastol = gamma21 Fage + gamma22 Fbmi + gamma23 Ffat + e2,
          age1     = Fage + delta11,
          bmi1     = Fbmi + delta12,
          fat1     = Ffat + delta13,
          age2     = Fage + delta21,
          bmi2     = Fbmi + delta22,
          fat2     = Ffat + delta23,
          cholest1 = Fcholest + eps11,
          diastol1 = Fdiastol + eps12,
          cholest2 = Fcholest + eps21,
          diastol2 = Fdiastol + eps22;
     std
          Fage Fbmi Ffat e1 e2
          delta11 delta12 delta13 delta21 delta22 delta23
          eps11 eps12 eps21 eps22 = v: ;
     cov
          Fage Ffat Fbmi = phi: , e1 e2 = psi: ,
          delta11 delta12 delta13 eps11 eps12 = TED1_: ,
          delta21 delta22 delta23 eps21 eps22 = TED2_: ;
     bounds 0.0 < v1-v15;
     lincon gamma12=0, gamma22=0; /* Constrain model to obey this H0 */
     /* Much safer than fitting a model with the variables just missing
        in the regression equations. However, SAS will warn us that
        "There are 2 active constraints at the solution," and carry on
        in a pretty menacing way. The warning can be ignored, in this
        particular case where the linear constraints are setting
        parameters exactly equal to zero. Do NOT ignore the warning
        if an inequality is involved.   */

proc iml;
     title2 'Calculate Likelihood ratio test of H0: gamma12=gamma22=0';
     G = (19.5309 - 18.9011) * 500/499 ;
     /* Difference between chisquares (corrected) */
     pval = 1 - probchi(G,2);
     print G,pval;
```

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

LINEQS Model Statement

		Matrix	Rows	Columns	------Matrix Type-------	
Term 1	1	_SEL_	10	27	SELECTION	
	2	_BETA_	27	27	EQSBETA	IMINUSINV
	3	_GAMMA_	27	15	EQSGAMMA	
	4	_PHI_	15	15	SYMMETRIC	

The 12 Endogenous Variables

```
Manifest        age1      bmi1      fat1      cholest1  diastol1  age2
                bmi2      fat2      cholest2  diastol2
Latent          Fcholest  Fdiastol
```

The 15 Exogenous Variables

```
Manifest
Latent          Fage      Fbmi      Ffat
Error           e1        e2        eps11     eps12     eps21
                eps22     delta11   delta12   delta13   delta21
                delta22   delta23
```

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

Manifest Variable Equations with Initial Estimates

```
age1     =   1.0000 Fage     +  1.0000 delta11
bmi1     =   1.0000 Fbmi     +  1.0000 delta12
fat1     =   1.0000 Ffat     +  1.0000 delta13
cholest1 =   1.0000 Fcholest +  1.0000 eps11
diastol1 =   1.0000 Fdiastol +  1.0000 eps12
age2     =   1.0000 Fage     +  1.0000 delta21
bmi2     =   1.0000 Fbmi     +  1.0000 delta22
fat2     =   1.0000 Ffat     +  1.0000 delta23
cholest2 =   1.0000 Fcholest +  1.0000 eps21
diastol2 =   1.0000 Fdiastol +  1.0000 eps22
```

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

Latent Variable Equations with Initial Estimates

```
Fcholest =        .*Fage     +       .*Fbmi     +       .*Ffat
                    gamma11            gamma12            gamma13

                      +  1.0000 e1


Fdiastol =        .*Fage     +       .*Fbmi     +       .*Ffat
                    gamma21            gamma22            gamma23

                      +  1.0000 e2
```

Variances of Exogenous Variables

Variable	Parameter	Estimate
Fage	v1	.
Fbmi	v2	.
Ffat	v3	.
e1	v4	.
e2	v5	.
eps11	v12	.
eps12	v13	.
eps21	v14	.
eps22	v15	.
delta11	v6	.
delta12	v7	.
delta13	v8	.
delta21	v9	.
delta22	v10	.
delta23	v11	.

Covariances Among Exogenous Variables

Var1	Var2	Parameter	Estimate
Fage	Fbmi	phi2	.
Fage	Ffat	phi1	.
Fbmi	Ffat	phi3	.
e1	e2	psi1	.
eps11	eps12	TED1_10	.
eps21	eps22	TED2_10	.
eps11	delta11	TED1_4	.
eps12	delta11	TED1_7	.
eps11	delta12	TED1_5	.
eps12	delta12	TED1_8	.

```
               delta11  delta12  TED1_1               .
               eps11    delta13  TED1_6               .
               eps12    delta13  TED1_9               .
               delta11  delta13  TED1_2               .
               delta12  delta13  TED1_3               .
               eps21    delta21  TED2_4               .
               eps22    delta21  TED2_7               .
               eps21    delta22  TED2_5               .
               eps22    delta22  TED2_8               .
               delta21  delta22  TED2_1               .
               eps21    delta23  TED2_6               .
               eps22    delta23  TED2_9               .
               delta21  delta23  TED2_2               .
               delta22  delta23  TED2_3               .
```

```
           BMI and Health: Like bmi2.sas, but try to make it shorter          4
                                  Full Model

                              The CALIS Procedure
          Covariance Structure Analysis: Maximum Likelihood Estimation

             Observations         500    Model Terms              1
             Variables             10    Model Matrices           4
             Informations          55    Parameters              45


                     Variable          Mean       Std Dev

                     age1          43.08800      12.99955
                     bmi1          25.43580       4.54927
                     fat1          18.79000       7.75224
                     cholest1     262.02740      52.50262
                     diastol1      88.42400      19.27206
                     age2          44.40600      12.41762
                     bmi2          25.51760       3.72546
                     fat2          18.90280       7.56396
                     cholest2     261.24560      53.87560
                     diastol2      88.70000      13.08610

NOTE: Some initial estimates computed by two-stage LS method.
```

Now we get the (automatic) starting values of all the parameters. Skip it.

```
                              Optimization Start

Active Constraints                      0  Objective Function       0.3271903962
Max Abs Gradient Element  0.0798909029


                                                          Max Abs              Slope
         Rest   Func       Act     Objective   Obj Fun  Gradient      Step    Search
 Iter    arts  Calls       Con      Function    Change   Element      Size     Direc

    1       0      3         0       0.30488    0.0223    0.2450    0.0467    -1.031
    2       0      4         0       0.28493    0.0200    0.1155     0.321    -0.174
    3       0      5         0       0.26868    0.0163    0.0924     1.000   -0.0414
    4       0      7         0       0.21790    0.0508    0.2954     2.854   -0.0371
    5       0      8         0       0.19763    0.0203    0.1178     1.000   -0.0295
    6       0     10         0       0.18967   0.00796    0.0603     1.110   -0.0139
    7       0     12         0       0.18633   0.00334    0.0332     1.482   -0.0039
    8       0     13         0       0.18070   0.00563    0.0151     1.517   -0.0055
```

It goes on and on for 164 iterations. Skipping ...

```
                             Optimization Results

Iterations                            164  Function Calls                       293
Gradient Calls                        232  Active Constraints                     0
Objective Function           0.0378779129  Max Abs Gradient Element  9.0354545E-6
Slope of Search Direction -5.202293E-7

ABSGCONV convergence criterion satisfied.

-------------------------------------------------------------------------------

           BMI and Health: Like bmi2.sas, but try to make it shorter          7
                                 Full Model

                              The CALIS Procedure
         Covariance Structure Analysis: Maximum Likelihood Estimation

         Fit Function                                             0.0379
         Goodness of Fit Index (GFI)                              0.9926
         GFI Adjusted for Degrees of Freedom (AGFI)               0.9591
         Root Mean Square Residual (RMR)                         19.4718
         Parsimonious GFI (Mulaik, 1989)                          0.2206
         Chi-Square                                              18.9011
         Chi-Square DF                                                10
         Pr > Chi-Square                                          0.0415
         Independence Model Chi-Square                            4015.9
         Independence Model Chi-Square DF                             45
         RMSEA Estimate                                           0.0422
```

Skipping again ...

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Latent Variable Equations with Estimates

```
Fcholest =   0.1480*Fage     + -1.2703*Fbmi     +  2.2271*Ffat
Std Err      0.2128 gamma11     1.6550 gamma12     0.8974 gamma13
t Value      0.6957            -0.7675             2.4818

                       +  1.0000 e1


Fdiastol =   0.0104*Fage     + -0.1054*Fbmi     +  1.2692*Ffat
Std Err      0.0458 gamma21     0.3941 gamma22     0.2044 gamma23
t Value      0.2268            -0.2675             6.2090

                       +  1.0000 e2
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
Fage	v1	148.12838	9.79411	15.12
Fbmi	v2	12.54181	0.94050	13.34
Ffat	v3	46.99750	3.28849	14.29
e1	v4	2391	161.53168	14.81
e2	v5	75.69775	8.78257	8.62
eps11	v12	195.80618	54.03321	3.62
eps12	v13	207.71308	15.24803	13.62
eps21	v14	336.03140	56.74542	5.92
eps22	v15	25.20654	7.67288	3.29
delta11	v6	22.30517	3.22022	6.93
delta12	v7	8.61051	0.71704	12.01
delta13	v8	13.95514	1.71930	8.12
delta21	v9	6.30433	2.90105	2.17
delta22	v10	1.28485	0.48547	2.65
delta23	v11	11.46363	1.67508	6.84

Covariances Among Exogenous Variables

Var1	Var2	Parameter	Estimate	Standard Error	t Value
Fage	Fbmi	phi2	8.53524	2.14246	3.98
Fage	Ffat	phi1	28.67293	4.20356	6.82
Fbmi	Ffat	phi3	21.07021	1.58695	13.28
e1	e2	psi1	26.99445	23.13516	1.17
eps11	eps12	TED1_10	2.37369	17.44389	0.14
eps21	eps22	TED2_10	10.55839	12.14484	0.87

```
     eps11    delta11  TED1_4          1.46571       9.28626       0.16
     eps12    delta11  TED1_7          5.50639       4.26027       1.29
     eps11    delta12  TED1_5         -1.68780       4.05537      -0.42
     eps12    delta12  TED1_8          8.22814       2.38542       3.45
     delta11  delta12  TED1_1          2.41139       1.00109       2.41
     eps11    delta13  TED1_6         -1.67949       6.62998      -0.25
     eps12    delta13  TED1_9          0.90570       3.57876       0.25
     delta11  delta13  TED1_2         -1.23726       1.62183      -0.76
     delta12  delta13  TED1_3          8.07727       0.96844       8.34
     eps21    delta21  TED2_4          0.83261       9.02367       0.09
     eps22    delta21  TED2_7          2.24903       2.78751       0.81
     eps21    delta22  TED2_5          0.09756       3.34404       0.03
     eps22    delta22  TED2_8          2.97256       1.44467       2.06
     delta21  delta22  TED2_1          0.26655       0.76726       0.35
     eps21    delta23  TED2_6         -4.03672       6.65942      -0.61
     eps22    delta23  TED2_9          2.33466       2.56252       0.91
     delta21  delta23  TED2_2          1.97235       1.51921       1.30
     delta22  delta23  TED2_3          0.06895       0.74323       0.09
```

Skip the "standardized estimates." Next comes the output from the reduced model. The `psummary` option makes it very short. Note the scary warnings, which can be ignored.

```
           BMI and Health: Like bmi2.sas, but try to make it shorter         12
               Reduced Model for testing BMI on both DVs at once

                              The CALIS Procedure
         Covariance Structure Analysis: Maximum Likelihood Estimation

WARNING: There are 2 active constraints at the solution.  The standard errors
         and Chi-Square test statistic assume the solution is located in the
         interior of the parameter space and hence do not apply if it is
         likely that some different set of inequality constraints could be
         active.


NOTE: The degrees of freedom are increased by the number of active constraints
      (see Dijkstra, 1992). The number of parameters in calculating fit
      indices is decreased by the number of active constraints. To turn off
      the adjustment, use the NOADJDF option.
```

Reduced Model for testing BMI on both DVs at once

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Function	0.0391
Goodness of Fit Index (GFI)	0.9924
GFI Adjusted for Degrees of Freedom (AGFI)	0.9650
Root Mean Square Residual (RMR)	19.7718
Parsimonious GFI (Mulaik, 1989)	0.2646
Chi-Square	19.5309
Chi-Square DF	12
Pr > Chi-Square	0.0765
Independence Model Chi-Square	4015.9
Independence Model Chi-Square DF	45
RMSEA Estimate	0.0355
RMSEA 90% Lower Confidence Limit	.
RMSEA 90% Upper Confidence Limit	0.0630
ECVI Estimate	0.2154
ECVI 90% Lower Confidence Limit	.
ECVI 90% Upper Confidence Limit	0.2482
Probability of Close Fit	0.7834
Bentler's Comparative Fit Index	0.9981
Normal Theory Reweighted LS Chi-Square	19.2565
Akaike's Information Criterion	-4.4691
Bozdogan's (1987) CAIC	-67.0444
Schwarz's Bayesian Criterion	-55.0444
McDonald's (1989) Centrality	0.9925
Bentler & Bonett's (1980) Non-normed Index	0.9929
Bentler & Bonett's (1980) NFI	0.9951
James, Mulaik, & Brett (1982) Parsimonious NFI	0.2654
Z-Test of Wilson & Hilferty (1931)	1.4315
Bollen (1986) Normed Index Rho1	0.9818
Bollen (1988) Non-normed Index Delta2	0.9981
Hoelter's (1983) Critical N	539

Calculate Likelihood ratio test of H0: gamma12=gamma22=0

G

0.6310621

PVAL

0.7294014