# STA431 Handout 9

# Double Measurement Regression on the BMI Data

```
/********************** bmi5.sas *************************/
options linesize=79 pagesize = 500 noovp formdlim='-';
title 'BMI and Health: Double measurement Regression';

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;
   /* Analyze the covariance matrix (Default is corr). */
     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,
          cholest1 = Fcholest + eps11,
          diastol1 = Fdiastol + eps12,
          age2     = Fage     + delta21,
          bmi2     = Fbmi     + delta22,
          fat2     = Ffat     + delta23,
          cholest2 = Fcholest + eps21,
          diastol2 = Fdiastol + eps22;
     std   /* Variances (not standard deviations). Colon means fill
              in the numbers. */
          Fage Fbmi Ffat = 3 * phi: ,
          e1 e2 = 2 * psi: ,
          delta11 delta12 delta13 eps11 eps12 = 5 * omega1_: ,
          delta21 delta22 delta23 eps21 eps22 = 5 * omega2_: ;
     cov   /* Covariances: If not mentioned, it's zero.  */
          Fage Ffat Fbmi = 3 * phi_ij: , e1 e2 = psi12 ,
          delta11 delta12 delta13 eps11 eps12 = 10 * omega1_ij: ,
          delta21 delta22 delta23 eps21 eps22 = 10 * omega2_ij: ;
     bounds 0.0 < phi1-phi3 psi1 psi2 omega1_1-omega1_5 omega2_1-omega2_5;
             /* Variances are positive */

/*  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 psummary;
     title2 'Reduced Model for testing H0: gamma12 = gamma22 = 0';
     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,
          cholest1 = Fcholest + eps11,
          diastol1 = Fdiastol + eps12,
          age2     = Fage     + delta21,
          bmi2     = Fbmi     + delta22,
          fat2     = Ffat     + delta23,
          cholest2 = Fcholest + eps21,
          diastol2 = Fdiastol + eps22;
     std
          Fage Fbmi Ffat = 3 * phi: ,
          e1 e2 = 2 * psi: ,
          delta11 delta12 delta13 eps11 eps12 = 5 * omega1_: ,
          delta21 delta22 delta23 eps21 eps22 = 5 * omega2_: ;
     cov
          Fage Ffat Fbmi = 3 * phi_ij: , e1 e2 = psi12 ,
          delta11 delta12 delta13 eps11 eps12 = 10 * omega1_ij: ,
          delta21 delta22 delta23 eps21 eps22 = 10 * omega2_ij: ;
     bounds 0.0 < phi1-phi3 psi1 psi2 omega1_1-omega1_5 omega2_1-omega2_5;
     lincon gamma12=0, gamma22=0; /* Constrain model to obey this H0 */

     /* Using lincon is 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;
     /* Difference between chisquares (copied from the printout) */
     pval = 1 - probchi(G,2);
     print G,pval;
     print "  ";

/* You could also do this with R or a calculator. */
```

---

Log file says

```
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.
```

Some parts of the list file are skipped.

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

                BMI and Health: Double measurement Regression                1
                                 Full Model


                          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

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

                BMI and Health: Double measurement Regression                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      13.01257
                      bmi1           25.43580       4.55383
                      fat1           18.79000       7.76001
                      cholest1      262.02740      52.55520
                      diastol1       88.42400      19.29136
                      age2           44.40600      12.43005
                      bmi2           25.51760       3.72919
                      fat2           18.90280       7.57154
                      cholest2      261.24560      53.92955
                      diastol2       88.70000      13.09921

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

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Dual Quasi-Newton Optimization

Dual Broyden - Fletcher - Goldfarb - Shanno Update (DBFGS)

| | |
|---|---|
| Parameter Estimates | 45 |
| Functions (Observations) | 55 |
| Lower Bounds | 15 |
| Upper Bounds | 0 |

Optimization Start

| | | | |
|---|---|---|---|
| Active Constraints | 0 | Objective Function | 0.3271903962 |
| Max Abs Gradient Element | 0.0797311211 | | |

| Iter | Rest arts | Func Calls | Act Con | Objective Function | Obj Fun Change | Max Abs Gradient Element | Step Size | Slope Search Direc |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 3 | 0 | 0.30497 | 0.0222 | 0.2449 | 0.0466 | -1.030 |
| 2 | 0 | 4 | 0 | 0.28490 | 0.0201 | 0.1134 | 0.320 | -0.173 |
| 3 | 0 | 5 | 0 | 0.26879 | 0.0161 | 0.0925 | 1.000 | -0.0413 |

skipping ...

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 165 | 0 | 291 | 0 | 0.03788 | 0.000016 | 0.000727 | 72.118 | -457E-9 |
| 166 | 0 | 293 | 0 | 0.03788 | 1.362E-6 | 0.000013 | 1.026 | -265E-8 |
| 167 | 0 | 295 | 0 | 0.03788 | 4.984E-8 | 0.000036 | 3.287 | -3E-8 |
| 168 | 0 | 296 | 0 | 0.03788 | 4.69E-8 | 0.000015 | 3.018 | -41E-9 |
| 169 | 0 | 298 | 0 | 0.03788 | 4.252E-9 | 9.062E-6 | 1.135 | -75E-10 |

Optimization Results

| | | | |
|---|---|---|---|
| Iterations | 169 | Function Calls | 299 |
| Gradient Calls | 240 | Active Constraints | 0 |
| Objective Function | 0.0378778957 | Max Abs Gradient Element | 9.0624024E-6 |
| Slope of Search Direction | -7.494794E-9 | | |

ABSGCONV convergence criterion satisfied.

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) | 19.5113 |
| 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 |
| RMSEA 90% Lower Confidence Limit | 0.0081 |
| RMSEA 90% Upper Confidence Limit | 0.0711 |
| ECVI Estimate | 0.2223 |
| ECVI 90% Lower Confidence Limit | 0.2051 |
| ECVI 90% Upper Confidence Limit | 0.2554 |
| Probability of Close Fit | 0.6316 |
| Bentler's Comparative Fit Index | 0.9978 |
| Normal Theory Reweighted LS Chi-Square | 18.6927 |
| Akaike's Information Criterion | -1.0989 |
| Bozdogan's (1987) CAIC | -53.2450 |
| Schwarz's Bayesian Criterion | -43.2450 |
| McDonald's (1989) Centrality | 0.9911 |
| Bentler & Bonett's (1980) Non-normed Index | 0.9899 |
| Bentler & Bonett's (1980) NFI | 0.9953 |
| James, Mulaik, & Brett (1982) Parsimonious NFI | 0.2212 |
| Z-Test of Wilson & Hilferty (1931) | 1.7350 |
| Bollen (1986) Normed Index Rho1 | 0.9788 |
| Bollen (1988) Non-normed Index Delta2 | 0.9978 |
| Hoelter's (1983) Critical N | 485 |

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with 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: 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      0.2269               -0.2674               6.2090

                           +  1.0000 e2
```

Variances of Exogenous Variables

| Variable | Parameter | Estimate | Standard Error | t Value |
|---|---|---|---|---|
| Fage | phi1 | 148.42528 | 9.81374 | 15.12 |
| Fbmi | phi2 | 12.56690 | 0.94238 | 13.34 |
| Ffat | phi3 | 47.09143 | 3.29507 | 14.29 |
| e1 | psi1 | 2396 | 161.85535 | 14.81 |
| e2 | psi2 | 75.84924 | 8.80013 | 8.62 |
| eps11 | omega1_4 | 196.19717 | 54.14132 | 3.62 |
| eps12 | omega1_5 | 208.12976 | 15.27861 | 13.62 |
| eps21 | omega2_4 | 336.70368 | 56.85898 | 5.92 |
| eps22 | omega2_5 | 25.25689 | 7.68825 | 3.29 |
| delta11 | omega1_1 | 22.35003 | 3.22668 | 6.93 |
| delta12 | omega1_2 | 8.62777 | 0.71848 | 12.01 |
| delta13 | omega1_3 | 13.98305 | 1.72274 | 8.12 |
| delta21 | omega2_1 | 6.31681 | 2.90687 | 2.17 |
| delta22 | omega2_2 | 1.28742 | 0.48644 | 2.65 |
| delta23 | omega2_3 | 11.48662 | 1.67843 | 6.84 |

Covariances Among Exogenous Variables

| Var1 | Var2 | Parameter | Estimate | Standard Error | t Value |
|---|---|---|---|---|---|
| Fage | Fbmi | phi_ij2 | 8.55218 | 2.14675 | 3.98 |
| Fage | Ffat | phi_ij1 | 28.72995 | 4.21197 | 6.82 |
| Fbmi | Ffat | phi_ij3 | 21.11231 | 1.59012 | 13.28 |
| e1 | e2 | psi12 | 27.04719 | 23.18142 | 1.17 |
| eps11 | eps12 | omega1_ij10 | 2.37831 | 17.47881 | 0.14 |
| eps21 | eps22 | omega2_ij10 | 10.57885 | 12.16913 | 0.87 |
| eps11 | delta11 | omega1_ij4 | 1.46892 | 9.30486 | 0.16 |
| eps12 | delta11 | omega1_ij7 | 5.51726 | 4.26881 | 1.29 |
| eps11 | delta12 | omega1_ij5 | -1.69104 | 4.06349 | -0.42 |
| eps12 | delta12 | omega1_ij8 | 8.24458 | 2.39020 | 3.45 |
| delta11 | delta12 | omega1_ij1 | 2.41623 | 1.00309 | 2.41 |
| eps11 | delta13 | omega1_ij6 | -1.68245 | 6.64325 | -0.25 |
| eps12 | delta13 | omega1_ij9 | 0.90754 | 3.58593 | 0.25 |
| delta11 | delta13 | omega1_ij2 | -1.23971 | 1.62508 | -0.76 |
| delta12 | delta13 | omega1_ij3 | 8.09346 | 0.97038 | 8.34 |
| eps21 | delta21 | omega2_ij4 | 0.83367 | 9.04174 | 0.09 |
| eps22 | delta21 | omega2_ij7 | 2.25362 | 2.79309 | 0.81 |
| eps21 | delta22 | omega2_ij5 | 0.09766 | 3.35074 | 0.03 |
| eps22 | delta22 | omega2_ij8 | 2.97847 | 1.44756 | 2.06 |
| delta21 | delta22 | omega2_ij1 | 0.26709 | 0.76879 | 0.35 |
| eps21 | delta23 | omega2_ij6 | -4.04534 | 6.67275 | -0.61 |
| eps22 | delta23 | omega2_ij9 | 2.33950 | 2.56766 | 0.91 |
| delta21 | delta23 | omega2_ij2 | 1.97628 | 1.52225 | 1.30 |
| delta22 | delta23 | omega2_ij3 | 0.06910 | 0.74472 | 0.09 |

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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.

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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) | 19.8115 |
| 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 |

skipping ...

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| G |
|---|
| 0.6298 |

| PVAL |
|---|
| 0.7298619 |