Instrumental variables regression on the Poverty data

```
/********************* poverty2.sas *************************/
options linesize=79 noovp formdlim='-' nodate;
title 'UN Poverty Data: Instrumental variables regression';

data misery;
     infile 'poverty.data';
     input birthrat deathrat infmort lifexM lifexF gnp group country $;
     avelife  = (lifexM + lifexF)/2;
     lifediff = lifexM - lifexF;
     gnp2 = gnp/100;

proc calis cov; /* Analyze the covariance matrix (Default is corr) */
     var gnp avelife birthrat infmort; /* 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
          gnp = Fgnp + delta,
          avelife  = gamma1 Fgnp + e1,
          birthrat = gamma2 Fgnp + e2,
          infmort  = gamma3 Fgnp + e3;
     std                    /* Variances (not standard deviations) */
          Fgnp = phi,
          delta = tdelta,
          e1 = psi1,
          e2 = psi2,
          e3 = psi3;
     /* The cov statement would specify covariances. */
     bounds                 /* Variances are positive */
          0.0 < phi, 0.0 < tdelta, 0.0 < psi1, 0.0 < psi2 , 0.0 < psi3;

/* Suspect numerical problems because of big variance for GNP */

proc calis;
     title2 'Analyze the correlation matrix';
     var gnp avelife birthrat infmort;
     lineqs
          gnp = Fgnp + delta,
          avelife  = gamma1 Fgnp + e1,
          birthrat = gamma2 Fgnp + e2,
          infmort  = gamma3 Fgnp + e3;
     std
          Fgnp = phi,
          delta = tdelta,
          e1 = psi1,
          e2 = psi2,
          e3 = psi3;
     bounds
          0.0 < phi, 0.0 < tdelta, 0.0 < psi1, 0.0 < psi2 , 0.0 < psi3;
```

```
proc calis cov; /* Analyze the covariance matrix (Default is corr) */
     title2 'Use re-scaled GNP (Divide by 100)';
     var gnp2 avelife birthrat infmort;
     lineqs
          gnp2 = Fgnp + delta,
          avelife  = gamma1 Fgnp + e1,
          birthrat = gamma2 Fgnp + e2,
          infmort  = gamma3 Fgnp + e3;
     std
          Fgnp = phi,
          delta = tdelta,
          e1 = psi1,
          e2 = psi2,
          e3 = psi3;
     bounds
          0.0 < phi, 0.0 < tdelta, 0.0 < psi1, 0.0 < psi2 , 0.0 < psi3;
```

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

              UN Poverty Data: Instrumental variables regression            1

                              The CALIS Procedure
           Covariance Structure Analysis: Pattern and Initial Values

                            LINEQS Model Statement


                       Matrix      Rows    Columns    ------Matrix Type-------

Term 1            1    _SEL_          4          9    SELECTION
                  2    _BETA_         9          9    EQSBETA        IMINUSINV
                  3    _GAMMA_        9          5    EQSGAMMA
                  4    _PHI_          5          5    SYMMETRIC


                          The 4 Endogenous Variables

    Manifest        gnp       avelife   birthrat  infmort
    Latent


                          The 5 Exogenous Variables

    Manifest
    Latent          Fgnp
    Error           e1        e2        e3        delta

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

              UN Poverty Data: Instrumental variables regression            2

                              The CALIS Procedure
           Covariance Structure Analysis: Pattern and Initial Values
```

```
          Manifest Variable Equations with Initial Estimates

            gnp      =   1.0000 Fgnp     +  1.0000 delta
            avelife  =        .*Fgnp     +  1.0000 e1
                              gamma1
            birthrat =        .*Fgnp     +  1.0000 e2
                              gamma2
            infmort  =        .*Fgnp     +  1.0000 e3
                              gamma3


                   Variances of Exogenous Variables

                   Variable Parameter      Estimate

                   Fgnp     phi                   .
                   e1       psi1                  .
                   e2       psi2                  .
                   e3       psi3                  .
                   delta    tdelta                .
```

```
          UN Poverty Data: Instrumental variables regression            3

                            The CALIS Procedure
       Covariance Structure Analysis: Maximum Likelihood Estimation

         Observations          91    Model Terms              1
         Variables              4    Model Matrices           4
         Informations          10    Parameters               8


                 Variable          Mean       Std Dev

                 gnp               5741          8094
                 avelife       63.70582      10.38232
                 birthrat      29.46044      13.69912
                 infmort       55.28132      46.30232

NOTE: Some initial estimates computed by instrumental variable method.
```

```
          UN Poverty Data: Instrumental variables regression            4

                            The CALIS Procedure
       Covariance Structure Analysis: Maximum Likelihood Estimation
```

Vector of Initial Estimates

	Parameter	Estimate	Type
1	gamma1	0.01000	Matrix Entry: _GAMMA_[2:1]
2	gamma2	-0.01000	Matrix Entry: _GAMMA_[3:1]
3	gamma3	-0.01000	Matrix Entry: _GAMMA_[4:1]
4	phi	27910197	Matrix Entry: _PHI_[1:1]
5	psi1	1849	Matrix Entry: _PHI_[2:2]
6	psi2	1704	Matrix Entry: _PHI_[3:3]
7	psi3	382.18752	Matrix Entry: _PHI_[4:4]
8	tdelta	37597457	Matrix Entry: _PHI_[5:5]

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Levenberg-Marquardt Optimization

Scaling Update of More (1978)

Parameter Estimates	8
Functions (Observations)	10
Lower Bounds	5
Upper Bounds	0

Optimization Start

Active Constraints	0	Objective Function	8.2440087478
Max Abs Gradient Element	112.91787916	Radius	34433.201204

Iter	Restarts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Lambda	Actual Over Pred Change
1	0	2	0	5.30908	2.9349	169.8	0	3.071
2	0	3	0	1.92138	3.3877	259.8	0	3.621
3	0	4	0	0.16640	1.7550	149.9	0	2.847
4	0	5	0	0.03181	0.1346	2.3446	0	1.442
5	0	6	0	0.03103	0.000779	0.8293	0	1.031
6	0	7	0	0.03102	3.679E-6	0.0177	0	0.957
7	0	8	0	0.03102	3.256E-8	0.00650	0	0.908
8	0	9	0	0.03102	3.96E-10	0.000514	0	0.888
9	0	10	0	0.03102	5.35E-12	0.000075	0	0.883

Optimization Results

Iterations	9	Function Calls	11
Jacobian Calls	10	Active Constraints	0
Objective Function	0.0310245835	Max Abs Gradient Element	0.0000754344
Lambda	0	Actual Over Pred Change	0.8831579839
Radius	0.0000143073		

```
GCONV convergence criterion satisfied.

          NOTE: Moore-Penrose inverse is used in covariance matrix.


NOTE: Covariance matrix for the estimates is not full rank.

NOTE: Small diagonal element in covariance matrix for phi.
NOTE: Small diagonal element in covariance matrix for tdelta.

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

              UN Poverty Data: Instrumental variables regression            6

                            The CALIS Procedure
         Covariance Structure Analysis: Maximum Likelihood Estimation

         Fit Function                                           0.0310
         Goodness of Fit Index (GFI)                            0.9852
         GFI Adjusted for Degrees of Freedom (AGFI)             0.9259
         Root Mean Square Residual (RMR)                     3239.8846
         Parsimonious GFI (Mulaik, 1989)                        0.3284
         Chi-Square                                             2.7922
         Chi-Square DF                                               2
         Pr > Chi-Square                                        0.2476
         Independence Model Chi-Square                          399.83
         Independence Model Chi-Square DF                            6
         RMSEA Estimate                                         0.0663
         RMSEA 90% Lower Confidence Limit                            .
         RMSEA 90% Upper Confidence Limit                       0.2304
         ECVI Estimate                                          0.2193
         ECVI 90% Lower Confidence Limit                             .
         ECVI 90% Upper Confidence Limit                        0.3204
         Probability of Close Fit                               0.3226
         Bentler's Comparative Fit Index                        0.9980
         Normal Theory Reweighted LS Chi-Square                 2.7091
         Akaike's Information Criterion                        -1.2078
         Bozdogan's (1987) CAIC                                -8.2295
         Schwarz's Bayesian Criterion                          -6.2295
         McDonald's (1989) Centrality                           0.9957
         Bentler & Bonett's (1980) Non-normed Index             0.9940
         Bentler & Bonett's (1980) NFI                          0.9930
         James, Mulaik, & Brett (1982) Parsimonious NFI         0.3310
         Z-Test of Wilson & Hilferty (1931)                     0.6863
         Bollen (1986) Normed Index Rho1                        0.9790
         Bollen (1988) Non-normed Index Delta2                  0.9980
         Hoelter's (1983) Critical N                               195

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

              UN Poverty Data: Instrumental variables regression            7

                            The CALIS Procedure
         Covariance Structure Analysis: Maximum Likelihood Estimation

                  Manifest Variable Equations with Estimates
```

```
gnp      =   1.0000 Fgnp     +  1.0000 delta
avelife  =  0.00195*Fgnp     +  1.0000 e1
Std Err    0.000128 gamma1
t Value     15.2015
birthrat = -0.00231*Fgnp     +  1.0000 e2
Std Err    0.000193 gamma2
t Value    -12.0153
infmort  = -0.00837*Fgnp     +  1.0000 e3
Std Err    0.000600 gamma3
t Value    -13.9577
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
Fgnp	phi	27992866	4.93933E-6	5.67E12
e1	psi1	1.69803	1.73450	0.98
e2	psi2	37.86868	6.18412	6.12
e3	psi3	180.85450	41.79798	4.33
delta	tdelta	37514788	0.0000101	3.71E12

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Standardized Estimates

```
gnp      =   0.6537 Fgnp     +  0.7568 delta
avelife  =   0.9921*Fgnp     +  0.1255 e1
                    gamma1
birthrat =  -0.8934*Fgnp     +  0.4492 e2
                    gamma2
infmort  =  -0.9569*Fgnp     +  0.2904 e3
                    gamma3
```

Squared Multiple Correlations

	Variable	Error Variance	Total Variance	R-Square
1	gnp	37514788	65507654	0.4273
2	avelife	1.69803	107.79249	0.9842
3	birthrat	37.86868	187.66597	0.7982
4	infmort	180.85450	2144	0.9156

Part of the output is skipped here. We've already seen it.

```
                    The CALIS Procedure
   Covariance Structure Analysis: Maximum Likelihood Estimation

               Levenberg-Marquardt Optimization

                 Scaling Update of More (1978)

          Parameter Estimates                      8
          Functions (Observations)                10
          Lower Bounds                             5
          Upper Bounds                             0

                     Optimization Start

Active Constraints                      0  Objective Function        0.0689138038
Max Abs Gradient Element     2.2714411201  Radius                     25.71390391
```

Iter	Restarts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Lambda	Actual Over Pred Change
1	0	2	0	0.03117	0.0377	0.1251	0	1.228
2	0	3	0	0.03103	0.000149	0.0111	0	1.023
3	0	4	0	0.03102	6.842E-7	0.000569	0	0.966
4	0	5	0	0.03102	5.738E-9	0.000085	0	0.913
5	0	6	0	0.03102	6.78E-11	6.477E-6	0	0.890

```
                    Optimization Results

Iterations                              5  Function Calls                        7
Jacobian Calls                          6  Active Constraints                    0
Objective Function           0.0310245835  Max Abs Gradient Element   6.4769144E-6
Lambda                                  0  Actual Over Pred Change    0.8899971846
Radius                       0.0000510193

GCONV convergence criterion satisfied.
```

Exactly the same "objective function" value as before, but no complaints about a singular matrix. Also, same chi-square on the following page.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Function	0.0310
Goodness of Fit Index (GFI)	0.9852
GFI Adjusted for Degrees of Freedom (AGFI)	0.9259
Root Mean Square Residual (RMR)	0.0161
Parsimonious GFI (Mulaik, 1989)	0.3284
Chi-Square	2.7922
Chi-Square DF	2
Pr > Chi-Square	0.2476
Independence Model Chi-Square	399.83
Independence Model Chi-Square DF	6
RMSEA Estimate	0.0663
RMSEA 90% Lower Confidence Limit	.
RMSEA 90% Upper Confidence Limit	0.2304
ECVI Estimate	0.2193
ECVI 90% Lower Confidence Limit	.
ECVI 90% Upper Confidence Limit	0.3204
Probability of Close Fit	0.3226
Bentler's Comparative Fit Index	0.9980
Normal Theory Reweighted LS Chi-Square	2.7091
Akaike's Information Criterion	-1.2078
Bozdogan's (1987) CAIC	-8.2295
Schwarz's Bayesian Criterion	-6.2295
McDonald's (1989) Centrality	0.9957
Bentler & Bonett's (1980) Non-normed Index	0.9940
Bentler & Bonett's (1980) NFI	0.9930
James, Mulaik, & Brett (1982) Parsimonious NFI	0.3310
Z-Test of Wilson & Hilferty (1931)	0.6863
Bollen (1986) Normed Index Rho1	0.9790
Bollen (1988) Non-normed Index Delta2	0.9980
Hoelter's (1983) Critical N	195

Manifest Variable Equations with Estimates

```
gnp      =   1.0000 Fgnp     +  1.0000 delta
avelife  =   1.5177*Fgnp     +  1.0000 e1
Std Err      0.1886 gamma1
t Value      8.0478
birthrat =  -1.3667*Fgnp     +  1.0000 e2
Std Err      0.1830 gamma2
t Value     -7.4672
infmort  =  -1.4638*Fgnp     +  1.0000 e3
Std Err      0.1859 gamma3
t Value     -7.8737
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
Fgnp	phi	0.42732	0.12286	3.48
e1	psi1	0.01575	0.01612	0.98
e2	psi2	0.20179	0.03296	6.12
e3	psi3	0.08436	0.01951	4.32
delta	tdelta	0.57268	0.08631	6.64

Skipping the standardized estimates ...

UN Poverty Data: Instrumental variables regression 17
Use re-scaled GNP (Divide by 100)

Skipping initial part ...

UN Poverty Data: Instrumental variables regression 21
Use re-scaled GNP (Divide by 100)

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Levenberg-Marquardt Optimization

Scaling Update of More (1978)

Parameter Estimates	8
Functions (Observations)	10
Lower Bounds	5
Upper Bounds	0

Optimization Start

Active Constraints	0	Objective Function	0.2835732124
Max Abs Gradient Element	0.4443450073	Radius	8.4702560074

Iter	Restarts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Lambda	Actual Over Pred Change
1	0	2	0	0.03207	0.2515	0.0893	0	1.604
2	0	3	0	0.03103	0.00104	0.00240	0	1.020
3	0	4	0	0.03102	5.183E-6	0.000819	0	0.948
4	0	5	0	0.03102	4.912E-8	0.000047	0	0.903
5	0	6	0	0.03102	6.11E-10	8.388E-6	0	0.887

```
                            Optimization Results

Iterations                             5  Function Calls                        7
Jacobian Calls                         6  Active Constraints                    0
Objective Function          0.0310245835  Max Abs Gradient Element   8.3877773E-6
Lambda                                 0  Actual Over Pred Change    0.8872828041
Radius                      0.0001531357

ABSGCONV convergence criterion satisfied.
```

Same objective function value again.

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

              UN Poverty Data: Instrumental variables regression            22
                       Use re-scaled GNP (Divide by 100)

                             The CALIS Procedure
         Covariance Structure Analysis: Maximum Likelihood Estimation

         Fit Function                                              0.0310
         Goodness of Fit Index (GFI)                               0.9852
         GFI Adjusted for Degrees of Freedom (AGFI)                0.9259
         Root Mean Square Residual (RMR)                          32.4001
         Parsimonious GFI (Mulaik, 1989)                           0.3284
         Chi-Square                                                2.7922
         Chi-Square DF                                                  2
         Pr > Chi-Square                                           0.2476
         Independence Model Chi-Square                             399.83
         Independence Model Chi-Square DF                               6
         RMSEA Estimate                                            0.0663
         RMSEA 90% Lower Confidence Limit                               .
         RMSEA 90% Upper Confidence Limit                          0.2304
         ECVI Estimate                                             0.2193
         ECVI 90% Lower Confidence Limit                                .
         ECVI 90% Upper Confidence Limit                           0.3204
         Probability of Close Fit                                  0.3226
         Bentler's Comparative Fit Index                           0.9980
         Normal Theory Reweighted LS Chi-Square                    2.7091
         Akaike's Information Criterion                           -1.2078
         Bozdogan's (1987) CAIC                                   -8.2295
         Schwarz's Bayesian Criterion                             -6.2295
         McDonald's (1989) Centrality                              0.9957
         Bentler & Bonett's (1980) Non-normed Index                0.9940
         Bentler & Bonett's (1980) NFI                             0.9930
         James, Mulaik, & Brett (1982) Parsimonious NFI            0.3310
         Z-Test of Wilson & Hilferty (1931)                        0.6863
         Bollen (1986) Normed Index Rho1                           0.9790
         Bollen (1988) Non-normed Index Delta2                     0.9980
         Hoelter's (1983) Critical N                                  195

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

```
                     The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

         Manifest Variable Equations with Estimates


     gnp2     =   1.0000 Fgnp     +  1.0000 delta
     avelife  =   0.1947*Fgnp     +  1.0000 e1
     Std Err      0.0242 gamma1
     t Value      8.0478
     birthrat =  -0.2313*Fgnp     +  1.0000 e2
     Std Err      0.0310 gamma2
     t Value     -7.4672
     infmort  =  -0.8374*Fgnp     +  1.0000 e3
     Std Err      0.1064 gamma3
     t Value     -7.8737


              Variances of Exogenous Variables

                                            Standard
Variable Parameter      Estimate               Error    t Value

Fgnp     phi                2799       804.84791       3.48
e1       psi1            1.69800         1.73789       0.98
e2       psi2           37.86864         6.18496       6.12
e3       psi3          180.85526        41.83153       4.32
delta    tdelta             3751       565.38707       6.64
```

Same "t" values as when we analyzed the correlation matrix.
