Path Model Two for the SENIC Data

```
/* 2201spath2.sas */
title2 'Path Analysis with proc calis';
%include '2201senicdef.sas';
options pagesize=500;

/* Labels can get in the way. Create a new SAS data set without labels */
data without;
     set better;
     label id       = ' '  stay     = ' '  age      = ' '  infrisk  = ' '
           culratio = ' '  xratio   = ' '  nbeds    = ' '  medschl  = ' '
           region   = ' '  census   = ' '  nurses   = ' '  service  = ' ';

proc calis cov vardef=n  singular=2.0e-50;
          /* Analyze the covariance matrix (Default is corr) */
     title2 'Likelihood Methods are Robust: Include categorical IVs' ;
     var infrisk mschool r1-r3 stay nbeds census nurses xratio culratio;
     lineqs              /* Simultaneous equations, separated by commas */
          infrisk = g1 stay + g2 nbeds + g3 census + g4 nurses +
                    g5 mschool + g6 r1 + g7 r2 + g8 r3 + e1,
          xratio = b1 infrisk + e2,
          culratio = b2 infrisk + e3;
     std                /* Variances (not standard deviations) */
          stay nbeds census nurses mschool r1 r2 r3 = v1-v8,
          e1-e3 = psi1-psi3  ;
     cov                   /* Covariances of exogenous variables */
          stay nbeds census nurses mschool r1 r2 r3 = kov1-kov28 ;
     bounds 0.0 < v1-v8 psi1-psi3;

/*  Fit reduced model, no size with lincon (linear constraints). Easier for
    big models like this */

proc calis cov vardef=n singular=2.0e-50;
     title2 'Reduced model for no size using lincon' ;
     var infrisk mschool r1-r3 stay nbeds census nurses xratio culratio;
     lineqs
          infrisk = g1 stay + g2 nbeds + g3 census + g4 nurses +
                    g5 mschool + g6 r1 + g7 r2 + g8 r3 + e1,
          xratio = b1 infrisk + e2,
          culratio = b2 infrisk + e3;
     std
          stay nbeds census nurses mschool r1 r2 r3 = v1-v8,
          e1-e3 = psi1-psi3  ;
     cov
          stay nbeds census nurses mschool r1 r2 r3 = kov1-kov28 ;
     bounds 0.0 < v1-v8 psi1-psi3;
     lincon g2=0, g3=0, g4=0;
```

```
/* Calculate LR test with proc iml. This requires typing in numbers obtained
on an earlier run. */

proc iml;
     title3 'LR test for Hospital Size';
     G = 113 * (0.3867443404-0.2977553108);
     pval = 1-probchi(G,3);
     print G pval;

proc calis cov vardef=n singular=2.0e-50;
     title2 'Reduced model for no region using lincon' ;
     var infrisk mschool r1-r3 stay nbeds census nurses xratio culratio;
     lineqs
          infrisk = g1 stay + g2 nbeds + g3 census + g4 nurses +
                    g5 mschool + g6 r1 + g7 r2 + g8 r3 + e1,
          xratio = b1 infrisk + e2,
          culratio = b2 infrisk + e3;
     std
          stay nbeds census nurses mschool r1 r2 r3 = v1-v8,
          e1-e3 = psi1-psi3  ;
     cov
          stay nbeds census nurses mschool r1 r2 r3 = kov1-kov28 ;
     bounds 0.0 < v1-v8 psi1-psi3;
     lincon g6=0, g7=0, g8=0;

proc iml;
     title3 'LR test for Region';
     G = 113 * (0.3567581106-0.2977553108);
     pval = 1-probchi(G,3);
     print G pval;

/* Wald Test for Region: First, fit the full model again and write out a data
set with the MLE and its asymptotic variance covariance matrix. We don't need
to see the proc calis output for the full model again. */

proc calis cov vardef=n singular=2.0e-50 noprint outest=Abe;
                                          /* Create data set Abe */
     var infrisk mschool r1-r3 stay nbeds census nurses xratio culratio;
     lineqs              /* Simultaneous equations, separated by commas */
          infrisk = g1 stay + g2 nbeds + g3 census + g4 nurses +
                    g5 mschool + g6 r1 + g7 r2 + g8 r3 + e1,
          xratio = b1 infrisk + e2,
          culratio = b2 infrisk + e3;
     std                /* Variances (not standard deviations) */
          stay nbeds census nurses mschool r1 r2 r3 = v1-v8,
          e1-e3 = psi1-psi3  ;
     cov                   /* Covariances of exogenous variables */
          stay nbeds census nurses mschool r1 r2 r3 = kov1-kov28 ;
     bounds 0.0 < v1-v8 psi1-psi3;
```

```
/* There are a lot of parameters in this model, and the asymptotic covariance
matrix is HUGE. It is better to just extract the covariance matrix of the
parameter estimates involved in the test. */

data abe2;    /* Extract the asymptotic covariance matrix, just for g6-g8 */
     set abe; /* Now abe2=abe */
     if _type_='COV'; /* Discard other cases from data set */
     if _name_='g6' then saveit=1;
        else if _name_='g7' then saveit=1;
        else if _name_='g8' then saveit=1;
        else saveit=0;
     if saveit=1;
     keep _type_ _name_ g6 g7 g8; /* Keep just these variables */
proc print;
     title3 'Abe2 has asymptotic covariance matrix, just for g6-g8';

data abe3;   /* Extract the MLEs of g6-g8 */
     set abe;
     if _type_ ='PARMS';
     keep g6 g7 g8;
proc print;
     title3 'Abe3 has parameter estimates for g6-g8';

proc iml;
     title3 'Wald test for region';
     use abe2;
     read all var {g6 g7 g8} into K;
     print "Asymptotic Covariance Matrix"  K;
     use abe3;
     read all var {g6 g7 g8} into T;
     print "Parameter Estimates";
     print T ;
     print "   g6       g7       g8";
     thetahat = T`; print thetahat;
     C = {1  0  0,
          0  1  0,
          0  0  1};
     W = (C*thetahat)` * inv(C*K*C`) * (C*thetahat);
     pval = 1-probchi(W,3);
     print "Wald Test for region"; print W pval;
```

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

LINEQS Model Statement

		Matrix	Rows	Columns	------Matrix Type-------	
Term 1	1	_SEL_	11	14	SELECTION	
	2	_BETA_	14	14	EQSBETA	IMINUSINV
	3	_GAMMA_	14	11	EQSGAMMA	
	4	_PHI_	11	11	SYMMETRIC	

The 3 Endogenous Variables

Manifest	infrisk	xratio	culratio
Latent			

The 11 Exogenous Variables

Manifest	mschool	r1	r2	r3	stay
	nbeds	census	nurses		
Latent					
Error	e1	e2	e3		

Skipping ….

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Observations	113	Model Terms	1
Variables	11	Model Matrices	4
Informations	66	Parameters	49

Variable	Mean	Std Dev
infrisk	4.35487	1.33496
mschool	0.15044	0.35750
r1	0.25664	0.43678
r2	0.28319	0.45055
r3	0.14159	0.34863
stay	9.64832	1.90298
nbeds	252.17699	191.98996
census	191.37168	153.07770
nurses	173.24779	138.64780
xratio	81.63009	19.28085
culratio	15.68407	10.13789

Set Covariances of Exogenous Manifest Variables

mschool r1 r2 r3 stay nbeds census nurses

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

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Vector of Initial Estimates

	Parameter	Estimate	Type
1	b1	8.38121	Matrix Entry: _BETA_[2:1]
2	b2	4.30152	Matrix Entry: _BETA_[3:1]
3	g5	-0.27798	Matrix Entry: _GAMMA_[1:1]
4	g6	0.24444	Matrix Entry: _GAMMA_[1:2]
5	g7	0.29569	Matrix Entry: _GAMMA_[1:3]
6	g8	0.86102	Matrix Entry: _GAMMA_[1:4]
7	g1	0.37893	Matrix Entry: _GAMMA_[1:5]
8	g2	-0.00100	Matrix Entry: _GAMMA_[1:6]
9	g3	-0.00151	Matrix Entry: _GAMMA_[1:7]
10	g4	0.00453	Matrix Entry: _GAMMA_[1:8]
11	v5	0.12781	Matrix Entry: _PHI_[1:1]
12	kov15	0.01449	Matrix Entry: _PHI_[2:1]
13	v6	0.19077	Matrix Entry: _PHI_[2:2]
14	kov20	0.01934	Matrix Entry: _PHI_[3:1]
15	kov21	-0.07268	Matrix Entry: _PHI_[3:2]
16	v7	0.20299	Matrix Entry: _PHI_[3:3]
17	kov26	-0.00360	Matrix Entry: _PHI_[4:1]
18	kov27	-0.03634	Matrix Entry: _PHI_[4:2]
19	kov28	-0.04010	Matrix Entry: _PHI_[4:3]
20	v8	0.12154	Matrix Entry: _PHI_[4:4]
21	kov7	0.20202	Matrix Entry: _PHI_[5:1]
22	kov11	0.36140	Matrix Entry: _PHI_[5:2]
23	kov16	0.00995	Matrix Entry: _PHI_[5:3]
24	kov22	-0.21728	Matrix Entry: _PHI_[5:4]
25	v1	3.62133	Matrix Entry: _PHI_[5:5]
26	kov8	40.57514	Matrix Entry: _PHI_[6:1]
27	kov12	4.56520	Matrix Entry: _PHI_[6:2]
28	kov17	7.79944	Matrix Entry: _PHI_[6:3]
29	kov23	-9.03391	Matrix Entry: _PHI_[6:4]
30	kov1	149.51755	Matrix Entry: _PHI_[6:5]
31	v2	36860	Matrix Entry: _PHI_[6:6]
32	kov9	33.64320	Matrix Entry: _PHI_[7:1]
33	kov13	7.01081	Matrix Entry: _PHI_[7:2]
34	kov18	4.97439	Matrix Entry: _PHI_[7:3]
35	kov24	-9.11457	Matrix Entry: _PHI_[7:4]
36	kov2	138.04461	Matrix Entry: _PHI_[7:5]
37	kov3	28831	Matrix Entry: _PHI_[7:6]

38	v3	23433	Matrix Entry: _PHI_[7:7]
39	kov10	29.15741	Matrix Entry: _PHI_[8:1]
40	kov14	6.05145	Matrix Entry: _PHI_[8:2]
41	kov19	3.46965	Matrix Entry: _PHI_[8:3]
42	kov25	-3.62801	Matrix Entry: _PHI_[8:4]
43	kov4	89.80378	Matrix Entry: _PHI_[8:5]
44	kov5	24370	Matrix Entry: _PHI_[8:6]
45	kov6	19269	Matrix Entry: _PHI_[8:7]
46	v4	19223	Matrix Entry: _PHI_[8:8]
47	psi1	1.09707	Matrix Entry: _PHI_[9:9]
48	psi2	301.36247	Matrix Entry: _PHI_[10:10]
49	psi3	68.32201	Matrix Entry: _PHI_[11:11]

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Dual Quasi-Newton Optimization

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

Parameter Estimates	49
Functions (Observations)	66
Lower Bounds	11
Upper Bounds	0

Optimization Start

Active Constraints 0 Objective Function 0.328967156
Max Abs Gradient Element 38.467337762

Iter	Rest arts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Step Size	Slope Search Direc
1	0	6	0	0.31811	0.0109	0.7724	0.00006	-394.1
2	0	9	0	0.31799	0.000112	0.2400	36.028	-621E-8
3	0	11	0	0.31796	0.000037	0.0217	3.496	-214E-7
4	0	13	0	0.31796	2.598E-8	0.0546	0.304	-171E-9
5	0	19	0	0.31609	0.00187	0.0506	2207.4	-17E-7
6	0	21	0	0.31609	1.881E-6	0.0477	1.240	-303E-8
7	0	25	0	0.31566	0.000433	0.0356	983.1	-957E-9
8	0	27	0	0.31560	0.000059	0.3562	26.903	-441E-8
9	0	28	0	0.31550	0.000093	0.0384	1.551	-0.0001
10	0	29	0	0.31538	0.000119	0.4460	3.466	-0.0001
11	0	30	0	0.31522	0.000159	0.0443	2.651	-0.0001
12	0	32	0	0.31520	0.000027	0.2499	5.291	-101E-7
13	0	36	0	0.29994	0.0153	0.2585	688.4	-442E-7
14	0	38	0	0.29991	0.000036	0.0300	1.034	-0.0001
15	0	40	0	0.29991	6.785E-7	0.0296	2.609	-518E-9
16	0	43	0	0.29987	0.000035	0.2323	89.830	-769E-9
17	0	45	0	0.29985	0.000022	0.0277	1.202	-365E-7

18	0	47	0	0.29982	0.000033	0.0274	24.250	-274E-8
19	0	49	0	0.29982	2.368E-6	0.0399	2.727	-175E-8
20	0	52	0	0.29976	0.000054	0.0713	41.697	-284E-8
21	0	54	0	0.29976	4.493E-6	0.0803	2.164	-417E-8
22	0	56	0	0.29976	3.383E-7	0.0131	1.267	-533E-9
23	0	58	0	0.29976	1.169E-6	0.0130	30.113	-78E-9
24	0	59	0	0.29975	1.89E-6	0.0515	5.804	-504E-9
25	0	61	0	0.29975	3.788E-6	0.0239	4.417	-214E-8
26	0	63	0	0.29970	0.000047	0.0885	16.449	-567E-8
27	0	65	0	0.29947	0.000235	0.0840	5.506	-0.0001
28	0	67	0	0.29777	0.00170	0.3862	13.550	-0.0003
29	0	69	0	0.29776	0.000011	0.0148	1.097	-208E-7
30	0	71	0	0.29776	6.602E-7	0.0130	5.476	-241E-9
31	0	73	0	0.29776	1.371E-7	0.00239	1.432	-191E-9
32	0	75	0	0.29776	4.873E-9	0.000586	1.284	-76E-10
33	0	76	0	0.29776	2.902E-9	0.000989	10.000	-45E-11

Optimization Results

Iterations	33	Function Calls	77
Gradient Calls	60	Active Constraints	0
Objective Function	0.2977553108	Max Abs Gradient Element	0.0009893738
Slope of Search Direction	-4.46653E-10		

GCONV convergence criterion satisfied.

SENIC data 6

Likelihood Methods are Robust: Include categorical IVs

23:47 Saturday, February 25, 2006

The CALIS Procedure

Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Function	0.2978
Goodness of Fit Index (GFI)	0.9484
GFI Adjusted for Degrees of Freedom (AGFI)	0.7995
Root Mean Square Residual (RMR)	77.1220
Parsimonious GFI (Mulaik, 1989)	0.2931
Chi-Square	33.3486
Chi-Square DF	17
Pr > Chi-Square	0.0102
Independence Model Chi-Square	921.98
Independence Model Chi-Square DF	55
RMSEA Estimate	0.0927
RMSEA 90% Lower Confidence Limit	0.0441
RMSEA 90% Upper Confidence Limit	0.1390
ECVI Estimate	1.2778
ECVI 90% Lower Confidence Limit	1.1637
ECVI 90% Upper Confidence Limit	1.4701
Probability of Close Fit	0.0692
Bentler's Comparative Fit Index	0.9811
Normal Theory Reweighted LS Chi-Square	33.4191
Akaike's Information Criterion	-0.6514
Bozdogan's (1987) CAIC	-64.0170
Schwarz's Bayesian Criterion	-47.0170
McDonald's (1989) Centrality	0.9302

Bentler & Bonett's (1980) Non-normed Index	0.9390
Bentler & Bonett's (1980) NFI	0.9638
James, Mulaik, & Brett (1982) Parsimonious NFI	0.2979
Z-Test of Wilson & Hilferty (1931)	2.3169
Bollen (1986) Normed Index Rho1	0.8830
Bollen (1988) Non-normed Index Delta2	0.9819
Hoelter's (1983) Critical N	94

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Estimates

```
 infrisk  =  -0.2780*mschool  +  0.2444*r1       +  0.2958*r2
 Std Err      0.3600 g5          0.2942 g6          0.2615 g7
 t Value     -0.7721             0.8306             1.1310

+  0.8610*r3       +  0.3789*stay     +-0.00043*nbeds    +-0.00151*census
   0.3301 g8          0.0706 g1          0.00295 g2         0.00382 g3
   2.6080             5.3690            -0.1449            -0.3938

                   + 0.00453*nurses   +  1.0000 e1
                     0.00186 g4
                      2.4351

 xratio   =   6.5469*infrisk  +  1.0000 e2
 Std Err      1.2288 b1
 t Value      5.3281

 culratio =   4.3981*infrisk  +  1.0000 e3
 Std Err      0.5851 b2
 t Value      7.5172
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
mschool	v5	0.12781	0.01708	7.48
r1	v6	0.19077	0.02549	7.48
r2	v7	0.20299	0.02713	7.48
r3	v8	0.12154	0.01624	7.48
stay	v1	3.62133	0.48392	7.48
nbeds	v2	36860	4926	7.48
census	v3	23433	3131	7.48
nurses	v4	19223	2569	7.48
e1	psi1	1.08499	0.14499	7.48
e2	psi2	301.36087	40.27104	7.48
e3	psi3	68.32244	9.12997	7.48

Covariances Among Exogenous Variables

Var1	Var2	Parameter	Estimate	Standard Error	t Value
mschool	r1	kov15	0.01449	0.01482	0.98
mschool	r2	kov20	0.01934	0.01533	1.26
r1	r2	kov21	-0.07268	0.01982	-3.67
mschool	r3	kov26	-0.00360	0.01178	-0.31
r1	r3	kov27	-0.03634	0.01479	-2.46
r2	r3	kov28	-0.04010	0.01532	-2.62
mschool	stay	kov7	0.20202	0.06706	3.01
r1	stay	kov11	0.36141	0.08564	4.22
r2	stay	kov16	0.00995	0.08102	0.12
r3	stay	kov22	-0.21728	0.06597	-3.29
mschool	nbeds	kov8	40.57514	7.53407	5.39
r1	nbeds	kov12	4.56520	7.93546	0.58
r2	nbeds	kov17	7.79944	8.20667	0.95
r3	nbeds	kov23	-9.03391	6.38202	-1.42
stay	nbeds	kov1	149.51755	37.30165	4.01
mschool	census	kov9	33.64320	6.07010	5.54
r1	census	kov13	7.01081	6.35239	1.10
r2	census	kov18	4.97439	6.53384	0.76
r3	census	kov24	-9.11457	5.11581	-1.78
stay	census	kov2	138.04461	30.45989	4.53
nbeds	census	kov3	28831	3890	7.41
mschool	nurses	kov10	29.15741	5.43389	5.37
r1	nurses	kov14	6.05145	5.75071	1.05
r2	nurses	kov19	3.46965	5.91169	0.59
r3	nurses	kov25	-3.62801	4.58028	-0.79
stay	nurses	kov4	89.80378	26.33546	3.41
nbeds	nurses	kov5	24370	3410	7.15
census	nurses	kov6	19269	2709	7.11

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Standardized Estimates

```
     infrisk  =  -0.0744*mschool  +  0.0799*r1       +  0.0998*r2
                          g5                g6                g7

  +  0.2249*r3       +  0.5402*stay     + -0.0615*nbeds    + -0.1726*census
           g8                 g1                 g2                 g3

                     +  0.4703*nurses   +  0.7803 e1
                              g4

     xratio   =   0.4497*infrisk  +  0.8932 e2
                          b1




     culratio =   0.5791*infrisk  +  0.8153 e3
                          b2
```


The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

LINEQS Model Statement

		Matrix	Rows	Columns	------Matrix Type-------	
Term 1	1	_SEL_	11	14	SELECTION	
	2	_BETA_	14	14	EQSBETA	IMINUSINV
	3	_GAMMA_	14	11	EQSGAMMA	
	4	_PHI_	11	11	SYMMETRIC	

The 3 Endogenous Variables

Manifest	infrisk	xratio	culratio
Latent			

The 11 Exogenous Variables

Manifest	mschool	r1	r2	r3	stay
	nbeds	census	nurses		
Latent					
Error	e1	e2	e3		

Skipping quite a bit of output …

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

NOTE: Initial point was changed to be feasible for boundary and linear constraints.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Dual Quasi-Newton Optimization

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

Parameter Estimates	49
Functions (Observations)	66
Lower Bounds	14
Upper Bounds	3

Optimization Start

Active Constraints	3	Objective Function	0.4401340309	
Max Abs Gradient Element	0.24591917			

Iter	Rest arts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Step Size	Slope Search Direc
1	0	3	3	0.43196	0.00818	0.0926	3.540	-0.0046
2	0	5	3	0.41575	0.0162	0.0524	7.245	-0.0041
3	0	7	3	0.40433	0.0114	0.0199	2.043	-0.0112

```
                          Optimization Results

Iterations                           50  Function Calls                      98
Gradient Calls                       70  Active Constraints                   3
Objective Function        0.3867443404  Max Abs Gradient Element  7.0013871E-6
Slope of Search Direction -1.316835E-8

ABSGCONV convergence criterion satisfied.

WARNING: There are 3 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.
```

Skip all the rest of this output.

```
                              SENIC data                                  18
                   Reduced model for no size using lincon
                          LR test for Hospital Size
                                        23:47 Saturday, February 25, 2006

                                    G      PVAL

                                10.05576 0.0180981
```

```
                              SENIC data                                  19
                   Reduced model for no region using lincon
```

Skipping …

```
                          Optimization Results

Iterations                           99  Function Calls                     230
Gradient Calls                      141  Active Constraints                   3
Objective Function        0.3567581106  Max Abs Gradient Element  2.5807055E-6
Slope of Search Direction -5.994375E-9

ABSGCONV convergence criterion satisfied.

WARNING: There are 3 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.
```

Reduced model for no region using lincon
LR test for Region
23:47 Saturday, February 25, 2006

G	PVAL
6.6673164	0.0832924

Abe2 has asymptotic covariance matrix, just for g6-g8
23:47 Saturday, February 25, 2006

Obs	_TYPE_	_NAME_	g6	g7	g8
1	COV	g6	0.086549	0.035727	0.02734
2	COV	g7	0.035727	0.068397	0.03230
3	COV	g8	0.027338	0.032298	0.10899

Abe3 has parameter estimates for g6-g8
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Obs	g6	g7	g8
1	0.24435	0.29579	0.86102

K

Asymptotic Covariance Matrix 0.0865493 0.0357274 0.0273381
0.0357274 0.068397 0.0322982
0.0273381 0.0322982 0.1089945

Parameter Estimates

T

0.2443524 0.2957893 0.8610189

g6 g7 g8

THETAHAT

0.2443524
0.2957893
0.8610189

Wald Test for region

W PVAL

6.8311315 0.0774795