SAS Example 4: Instrumental variables

```
/* card1.sas */
options linesize=79 pagesize=500 noovp formdlim='_' ;
title 'Instrumental variables on credit card data (Card1)';

data math;
     infile 'card1.data'  firstobs=2;
     input id income ccdebt auto house;
     label income = 'Annual income in thousands'
           ccdebt = 'Credit card debtin thousands'
           auto   = 'Book value of car in thousands'
           house  = 'Assessed value of home in thousands';
     house2 = house/10;

/* Exclude some output you really don't want to see. */
ods exclude
     Calis.ModelSpec.LINEQSEqInit               (persist)
     Calis.ModelSpec.LINEQSVarExogInit          (persist)
     Calis.ModelSpec.LINEQSCovExogInit          (persist)
     Calis.ML.SqMultCorr                        (persist)
     Calis.StandardizedResults.LINEQSEqStd      (persist)
     Calis.StandardizedResults.LINEQSVarExogStd (persist)
     Calis.StandardizedResults.LINEQSCovExogStd (persist)  ;

proc calis cov ; /* Analyze the covariance matrix (Default is corr) */
     title2 'Original scaling: Numerical trouble';
     var income ccdebt auto house; /* Declare observed vars */
     lineqs                /* Simultaneous equations, separated by commas */
          income = Fincome + e1,
          ccdebt = beta1 Fincome + epsilon1,
          auto   = beta2 Fincome + epsilon2,
          house  = beta3 Fincome + epsilon3;
     std                        /* Variances (not standard deviations) */
          Fincome  = phi,
          e1       = omega,
          epsilon1 = psi1,
          epsilon2 = psi2,
          epsilon3 = psi3;
     bounds 0.0 < phi,    0.0 < omega,
            0.0 < psi1,   0.0 < psi2,
            0.0 < psi3;

proc calis cov ; /* Analyze the covariance matrix (Default is corr) */
     title2 'With house re-scaled (Express in tens of thousands)';
     var income ccdebt auto house2; /* Declare observed vars */
     lineqs                /* Simultaneous equations, separated by commas */
          income = Fincome + e1,
          ccdebt = beta1 Fincome + epsilon1,
          auto   = beta2 Fincome + epsilon2,
          house2 = beta3 Fincome + epsilon3;
     std                        /* Variances (not standard deviations) */
          Fincome  = phi,
          e1       = omega,
          epsilon1 = psi1,
          epsilon2 = psi2,
          epsilon3 = psi3;
     bounds 0.0 < phi,    0.0 < omega,
            0.0 < psi1,   0.0 < psi2,
            0.0 < psi3;
```

The CALIS Procedure
Covariance Structure Analysis: Model and Initial Values

Modeling Information

Data Set	WORK.MATH
N Records Read	250
N Records Used	250
N Obs	250
Model Type	LINEQS
Analysis	Covariances

Variables in the Model

Endogenous	Manifest	auto ccdebt house income
	Latent	
Exogenous	Manifest	
	Latent	Fincome
	Error	epsilon2 epsilon1 epsilon3 e1

Number of Endogenous Variables = 4
Number of Exogenous Variables = 5

The CALIS Procedure
Covariance Structure Analysis: Descriptive Statistics

Simple Statistics

Variable		Mean	Std Dev
income	Annual income in thousands	39.69936	37.86792
ccdebt	Credit card debtin thousands	22.25002	22.35506
auto	Book value of car in thousands	9.72028	9.69018
house	Assessed value of home in thousands	195.36020	192.84725

The CALIS Procedure
Covariance Structure Analysis: Optimization

Initial Estimation Methods

1	Instrumental Variables Method
2	McDonald Method

Optimization Start
Parameter Estimates

N	Parameter	Estimate	Gradient	Lower Bound	Upper Bound
1	beta1	-0.33283	0.01262	.	.
2	beta2	0.11425	-0.05556	.	.
3	beta3	4.95652	0.0009388	.	.
4	phi	1150	-8.3528E-7	0	.
5	omega	284.11786	-2.9972E-7	0	.
6	psi1	372.37439	0.0000122	0	.
7	psi2	78.89085	0.0000828	0	.
8	psi3	8941	-1.8106E-7	0	.

Value of Objective Function = 0.0072682132

Original scaling: Numerical trouble

The CALIS Procedure
Covariance Structure Analysis: Optimization

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	0.0072682132
Max Abs Gradient Element	0.0555611064	Radius	1

Iter	Rest arts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Lambda	Actual Over Pred Change
1	0	4	0	0.00714	0.000129	0.000645	0	0.991
2	0	6	0	0.00714	1.687E-7	0.000056	0	1.025
3	0	8	0	0.00714	7.56E-10	1.109E-6	0	1.076

Optimization Results

Iterations	3	Function Calls	11
Jacobian Calls	5	Active Constraints	0
Objective Function	0.0071385725	Max Abs Gradient Element	1.1092758E-6
Lambda	0	Actual Over Pred Change	1.075612413
Radius	0.0001835928		

Convergence criterion (ABSGCONV=0.00001) satisfied.

NOTE: The Moore-Penrose inverse is used in computing the covariance matrix for parameter estimates.

WARNING: Standard errors and t values might not be accurate with the use of the Moore-Penrose inverse.

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

NOTE: The variance of some parameter estimates is zero or some parameter estimates are linearly related to other parameter estimates as shown in the following equations:

```
psi3       =     5090966120   -     899.687347   *   beta1      +
                  311.873127   *   beta2      +          27104
                 *   beta3      -        5833633   *   phi
                 +         5833633   *   omega      -
                       39554   *   psi1       -    4580.388613
                 *   psi2
```

Original scaling: Numerical trouble

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Summary

Modeling Info	N Observations	250
	N Variables	4
	N Moments	10
	N Parameters	8
	N Active Constraints	0
	Baseline Model Function Value	1.3604
	Baseline Model Chi-Square	338.7482
	Baseline Model Chi-Square DF	6
	Pr > Baseline Model Chi-Square	<.0001
Absolute Index	Fit Function	0.0071
	Chi-Square	1.7775
	Chi-Square DF	2
	Pr > Chi-Square	0.4112
	Z-Test of Wilson & Hilferty	0.2177
	Hoelter Critical N	840
	Root Mean Square Residual (RMSR)	9.6633
	Standardized RMSR (SRMSR)	0.0203
	Goodness of Fit Index (GFI)	0.9965
Parsimony Index	Adjusted GFI (AGFI)	0.9824
	Parsimonious GFI	0.3322
	RMSEA Estimate	0.0000
	RMSEA Lower 90% Confidence Limit	0.0000
	RMSEA Upper 90% Confidence Limit	0.1212
	Probability of Close Fit	0.6028
	ECVI Estimate	0.0727
	ECVI Lower 90% Confidence Limit	0.0738
	ECVI Upper 90% Confidence Limit	0.1034
	Akaike Information Criterion	17.7775
	Bozdogan CAIC	53.9492
	Schwarz Bayesian Criterion	45.9492

	McDonald Centrality	1.0004
Incremental Index	Bentler Comparative Fit Index	1.0000
	Bentler-Bonett NFI	0.9948
	Bentler-Bonett Non-normed Index	1.0020
	Bollen Normed Index Rho1	0.9843
	Bollen Non-normed Index Delta2	1.0007
	James et al. Parsimonious NFI	0.3316

Original scaling: Numerical trouble

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Linear Equations

```
income  =    1.0000 Fincome  +  1.0000 e1
ccdebt  =   -0.3351*Fincome  +  1.0000 epsilon1
Std Err      0.0409 beta1
t Value     -8.2017
auto    =    0.1164*Fincome  +  1.0000 epsilon2
Std Err      0.0183 beta2
t Value      6.3770
house   =    4.9428*Fincome  +  1.0000 epsilon3
Std Err      0.2779 beta3
t Value     17.7889
```

Estimates for Variances of Exogenous Variables

Variable Type	Variable	Parameter	Estimate	Standard Error	t Value
Latent	Fincome	phi	1152	134.43701	8.56952
Error	e1	omega	281.91910	53.48372	5.27112
	epsilon1	psi1	370.36712	34.80880	10.64004
	epsilon2	psi2	78.28021	7.20424	10.86586
	epsilon3	psi3	9044	4.73269	1911

The CALIS Procedure
Covariance Structure Analysis: Model and Initial Values

Modeling Information

Data Set	WORK.MATH
N Records Read	250
N Records Used	250
N Obs	250
Model Type	LINEQS
Analysis	Covariances

Variables in the Model

Endogenous	Manifest	auto ccdebt house2 income
	Latent	
Exogenous	Manifest	
	Latent	Fincome
	Error	epsilon2 epsilon1 epsilon3 e1

Number of Endogenous Variables = 4
Number of Exogenous Variables = 5

The CALIS Procedure
Covariance Structure Analysis: Descriptive Statistics

Simple Statistics

	Variable	Mean	Std Dev
income	Annual income in thousands	39.69936	37.86792
ccdebt	Credit card debtin thousands	22.25002	22.35506
auto	Book value of car in thousands	9.72028	9.69018
house2		19.53602	19.28472

The CALIS Procedure
Covariance Structure Analysis: Optimization

Initial Estimation Methods

1	Instrumental Variables Method
2	McDonald Method

Optimization Start
Parameter Estimates

N	Parameter	Estimate	Gradient	Lower Bound	Upper Bound
1	beta1	-0.33283	0.00943	.	.
2	beta2	0.11425	-0.05053	.	.
3	beta3	0.49565	0.01423	.	.
4	phi	1155	7.25142E-7	0	.
5	omega	279.42311	-0.0000250	0	.
6	psi1	371.85434	7.66355E-6	0	.
7	psi2	78.82957	0.0000712	0	.
8	psi3	88.25978	-0.0001104	0	.

Value of Objective Function = 0.0073905528

Instrumental variables on credit card data (Card1) 10
With house re-scaled (Express in tens of thousands)

The CALIS Procedure
Covariance Structure Analysis: Optimization

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	0.0073905528
Max Abs Gradient Element	0.0505279998	Radius	1

Iter	Rest arts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Lambda	Actual Over Pred Change
1	0	4	0	0.00714	0.000252	0.000989	0	0.971
2	0	6	0	0.00714	2.659E-7	0.000071	0	1.002
3	0	8	0	0.00714	8.31E-10	9.603E-7	0	1.060

Optimization Results

Iterations	3	Function Calls	11
Jacobian Calls	5	Active Constraints	0
Objective Function	0.0071385725	Max Abs Gradient Element	9.6028445E-7
Lambda	0	Actual Over Pred Change	1.0602958128
Radius	0.0001803962		

Convergence criterion (ABSGCONV=0.00001) satisfied.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Summary

Modeling Info	N Observations	250
	N Variables	4
	N Moments	10
	N Parameters	8
	N Active Constraints	0
	Baseline Model Function Value	1.3604
	Baseline Model Chi-Square	338.7482
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	Pr > Baseline Model Chi-Square	<.0001
Absolute Index	Fit Function	0.0071
	Chi-Square	1.7775
	Chi-Square DF	2
	Pr > Chi-Square	0.4112
	Z-Test of Wilson & Hilferty	0.2177
	Hoelter Critical N	840
	Root Mean Square Residual (RMSR)	4.5296
	Standardized RMSR (SRMSR)	0.0203
	Goodness of Fit Index (GFI)	0.9965
Parsimony Index	Adjusted GFI (AGFI)	0.9824
	Parsimonious GFI	0.3322
	RMSEA Estimate	0.0000
	RMSEA Lower 90% Confidence Limit	0.0000
	RMSEA Upper 90% Confidence Limit	0.1212
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	James et al. Parsimonious NFI	0.3316

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Linear Equations

```
income  =    1.0000 Fincome  +  1.0000 e1
ccdebt  =   -0.3351*Fincome  +  1.0000 epsilon1
Std Err      0.0419 beta1
t Value     -7.9944
auto    =    0.1164*Fincome  +  1.0000 epsilon2
Std Err      0.0185 beta2
t Value      6.2785
house2  =    0.4943*Fincome  +  1.0000 epsilon3
Std Err      0.0396 beta3
t Value     12.4903
```

Estimates for Variances of Exogenous Variables

Variable Type	Variable	Parameter	Estimate	Standard Error	t Value
Latent	Fincome	phi	1152	147.57348	7.80669
Error	e1	omega	281.91909	80.85949	3.48653
	epsilon1	psi1	370.36709	34.81126	10.63929
	epsilon2	psi2	78.28020	7.20440	10.86562
	epsilon3	psi3	90.44139	20.46328	4.41969

For comparison, before re-scaling

Linear Equations

```
income  =    1.0000 Fincome  +  1.0000 e1
ccdebt  =   -0.3351*Fincome  +  1.0000 epsilon1
Std Err      0.0409 beta1
t Value     -8.2017
auto    =    0.1164*Fincome  +  1.0000 epsilon2
Std Err      0.0183 beta2
t Value      6.3770
house   =    4.9428*Fincome  +  1.0000 epsilon3
Std Err      0.2779 beta3
t Value     17.7889
```

Estimates for Variances of Exogenous Variables

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