Example 5.2 (with 3SLS Extensions)
Seemingly Unrelated Regression Estimation and 3SLS

A survey of 206 people was conducted on the campus of Purdue University in the Fall of 2007. One of the key questions of the survey was to find out how fast people drove on interstate highways with speed limits of 55 mph, 65 mph and 70 mph.

Your task is to first estimate a seemingly unrelated regression model to determine the normal driving speed of individuals in this data sample. The equation system:

\[
\begin{align*}
\text{Speed}_{70} &= \beta_{70}Z + \alpha_{70}X + \epsilon_{70} \\
\text{Speed}_{65} &= \beta_{65}Z + \alpha_{65}X + \epsilon_{65} \\
\text{Speed}_{55} &= \beta_{55}Z + \alpha_{55}X + \epsilon_{55}
\end{align*}
\]

In these equations, Speed_{70}, Speed_{65} and Speed_{55} are the number of miles per hour respondents normally drive above the speed limit (with little traffic) for 70, 65, and 55 mph speed limits, respectively. These variables can take on positive values if respondents normally drive above the speed limit and negative values if they normally drive below it. Also in these equations, Z is a vector of driver and driver-household characteristics, X is a vector of vector of driver preferences and opinions, βs, αs, are vectors of estimable parameters, and εs are disturbance terms.

Next, estimate the same modeling system using three-stage least squares (3SLS), that is:

\[
\begin{align*}
\text{Speed}_{70} &= \lambda_{70-65}\text{Speed}_{65} + \beta_{70}Z + \alpha_{70}X + \epsilon_{70} \\
\text{Speed}_{65} &= \lambda_{65-70}\text{Speed}_{70} + \lambda_{65-55}\text{Speed}_{55} + \beta_{65}Z + \alpha_{65}X + \epsilon_{65} \\
\text{Speed}_{55} &= \lambda_{55-65}\text{Speed}_{65} + \beta_{55}Z + \alpha_{55}X + \epsilon_{55}
\end{align*}
\]

Then, provide a write up to include:

1. The results of your best model specification.

2. A discussion of the logical process that led you to the selection of your final specification (the theory behind the inclusion of your selected variables). Include t-statistics and justify the signs of your variables.
Section A: Your Opinions and Preferences

1. On an interstate with a 70mph speed limit and little traffic, about how fast do you normally drive? _____ mph
2. On an interstate with a 65mph speed limit and little traffic, about how fast do you normally drive? _____ mph
3. On an interstate with a 55mph speed limit and little traffic, about how fast do you normally drive? _____ mph
4. About how many miles per year do you drive? ______ miles/yr
5. How many vehicle accidents have you had (while driving) in the last 5 years? ______ years
6. When braking quickly to avoid a collision do you usually?
   1. Brake and steer  2. Brake only  3. Not sure/Depends on situation
7. Do you have?
   1. An engineering background  2. No engineering background
8. When putting on socks and shoes do you normally?
   1. Put both socks on then both shoes  2. One sock, one shoe  3. Not sure/Varies
9. When waking up in the morning, what leg reaches the floor first from bed?
   1. Right  2. Left  3. Both legs at the same time  4. Not sure/Varies
10. Do you prefer to buy online or in a store?
    1. Online  2. Store  3. No preference
11. Do you think Britney Spears should get full custody of her kids?
    1. Yes  2. No  3. Don't care
12. Do you prefer an automatic or manual transmission in your vehicle?
13. Do you sometimes smoke cigarettes?
    1. Yes  2. No
14. Do you prefer to text or talk on a cell phone?
    1. Text  2. Talk  3. No preference
15. At Purdue (West Lafayette), what is your favorite season?
16. During severe winter weather (snow) do you use your car or bus?
17. In money matters (investments, gambling, etc) do you consider yourself?
18. What is the first thing you drink in the morning?
19. Do you normally skip breakfast?
    1. Yes  2. No

(Please Turn Over)
Section A: Continued
20. What drives your decision to accept a job offer?
   1  Compensation  2  Career progression opportunities  3  Job location  4  Not sure
21. When showering, do you normally use: 1  Body wash  2  Bar soap  3  Unsure
22. While driving and using your cell phone, do you:
   1  Use a headset  2  Use one hand on the phone - one hand on wheel  3  Other
   4  Do not use phone while driving
23. When your car is the first in line at a traffic signal (dry road) and the light turns green do you normally:
   1  Accelerate briskly  2  Accelerate moderately  3  Accelerate slowly
24. What is the fastest that you (as a driver) have ever driven on an interstate, rural or urban road?
   1  Less than 70 mph  2  70-79 mph  3  80-89 mph  4  90-99 mph  5  100-109 mph
   6  110-119 mph  7  120-129 mph  8  130-139 mph  9  More than 140 mph

Section B: Additional Questions About Yourself
25. Are you?  1  Female  2  Male
26. Are you?  1  Married  2  Single  3  Separated  4  Divorced  5  Other
27. What is your age? ______
28. Are you currently?
   1  Not affiliated with Purdue  2  Purdue undergraduate  3  Purdue graduate
   4  Purdue faculty  5  Purdue staff (other than RA/TA/faculty)
29. What is your highest completed level of education?
   1  Some high school  2  High school diploma  3  Technical college degree (A.A.)
   4  College degree  5  Post graduate degree
30. Please indicate your Race/Ethnicity
   1  African American  2  American Indian  3  Asian  4  Caucasian
   5  Hispanic/White  6  Hispanic/Non-white  7  Other  8  I would rather not answer
31. What is the approximate annual household income of the household you consider home?
   1  No income  2  Under $10,000  3  $10,000-$19,999  4  $20,000-$29,999
   5  $30,000-$39,999  6  $40,000-$49,999  7  $50,000-$59,999  8  $60,000-$74,999
   9  $75,000-$100,000  10  Over $100,000
32. Including yourself, how many people live in the household you consider home? ______
33. How many children, in the household you consider home, are under age 6? ______
34. How many children, in the household you consider home, are aged 6 to 16? ______
35. How many people living in the household you consider home, work outside the home? ______
36. How many licensed and operable motor vehicles does your "home" household have? ______
37. Are you a licensed driver?  1  Yes  2  No
38. If you are licensed to drive, how many years have you had a license? ______ years
39. Did you lie about your response to any of the previous questions on this survey?  1  Yes  2  No
40. STUDENT ID (Thank you)
-- > RESET
-- > read;nvar=40;nob=206;file=D:\old_drive_d\Book\Book2e-Data\Ex5-2.txt$
-- > skip
-- > create;ageL=x27-x38$
-- > create;if(ageL>17)late=1$
-- > create;if(x25=2)male=1$
-- > create;if(x26=1)married=1$
-- > create;if(x23=1)brisk=1$
-- > create;mo70=x1-70$
-- > create;mo65=x2-65$
-- > create;mo55=x3-55$
-- > dstat;rhs=mo70,mo65,mo55$
Descriptive Statistics
All results based on nonmissing observations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Cases Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>MO70</td>
<td>5.45366</td>
<td>7.08727</td>
<td>-30.0000</td>
<td>20.0000</td>
<td>205 1</td>
</tr>
<tr>
<td>MO65</td>
<td>5.69024</td>
<td>7.15568</td>
<td>-25.0000</td>
<td>25.0000</td>
<td>205 1</td>
</tr>
<tr>
<td>MO55</td>
<td>6.24757</td>
<td>7.66951</td>
<td>-40.0000</td>
<td>25.0000</td>
<td>206 0</td>
</tr>
</tbody>
</table>

--> reject;x1=-999$
--> reject;x2=-999$
--> reject;x3=-999$
--> reject;x27=-999$
--> reject;x38=-999$
--> reject;x25=-999$
--> reject;x37=2$
-- > Sure;lhs=mo70,mo65,mo55
  ;eq1=one,x27,x32,late,brisk,x24
  ;eq2=one,male,x27,x32,late,brisk,x24
  ;eq3=one,x33,late,brisk,x24$

************************************************************************
* NOTE: Deleted 3 observations with missing data. N is now 191 *
************************************************************************

Criterion function for GLS is log-likelihood.
Iteration 0, GLS = -1587.460
Iteration 1, GLS = -1585.073
Iteration 2, GLS = -1585.073
Iteration 3, GLS = -1585.073
GLS has converged.
Estimates for equation: MO70
Generalized least squares regression
Model was estimated Sep 13, 2012 at 09:31:08AM
LHS=MO70
Mean = 5.748691
Standard deviation = 6.822539
WTS=none
Number of observs. = 191
Model size
Parameters = 6
Degrees of freedom = 185
Residuals
Sum of squares = 7071.643
Standard error of e = 6.182645
Fit
R-squared = .1744634
Adjusted R-squared = .1521516
Model test
F[  5,  185] (prob) = 7.82 (.0000)
Diagnostic
Log likelihood = -615.9227
Restricted(b=0) = -637.2802
Chi-sq [  5] (prob) = 42.72 (.0000)
Info criter.
LogAmemiya Prd. Crt. = 3.674423
Akaike Info. Criter. = 3.674402

Not using OLS or no constant. Rsqd & F may be < 0.
Log|W| 8.0840 Log-Likelihood = -1585.0730
Durbin-Watson 1.549 Autocorrelation = .2255

| Variable | Coefficient | Standard Error | b/St.Er. | P[|Z|>z] | Mean of X |
|----------|-------------|----------------|----------|--------|----------|
| Constant | 1.03937387  | 1.57273427     | .661     | .5087  |
| X27      | -0.02485828 | 0.02481934     | -1.002   | .3166  |
| X32      | 0.12286014  | 0.20565573     | .597     | .5502  |
| LATE     | -1.00489400 | 0.90224677     | -1.114   | .2654  |
| BRISK    | -0.06583367 | 1.15896419     | -0.057   | .9547  |
| X24      | 1.29620039  | 0.21742426     | 5.962    | .0000  |

Estimates for equation: MO65
Generalized least squares regression
Model was estimated Sep 13, 2012 at 09:31:08AM
LHS=MO65
Mean = 5.850785
Standard deviation = 7.007514
WTS=none
Number of observs. = 191
Model size
Parameters = 7
Degrees of freedom = 184
Residuals
Sum of squares = 7614.406
Standard error of e = 6.432934
Fit
R-squared = .1528310
Adjusted R-squared = .1252059
Model test
F[  6,  184] (prob) = 5.53 (.0000)
Diagnostic
Log likelihood = -622.9848
Restricted(b=0) = -642.3897
Chi-sq [  6] (prob) = 38.81 (.0000)
Info criter.
LogAmemiya Prd. Crt. = 3.758855
Akaike Info. Criter. = 3.758822

Not using OLS or no constant. Rsqd & F may be < 0.
Log|W| 8.0840 Log-Likelihood = -1585.0730
Durbin-Watson 1.522 Autocorrelation = .2390
| Variable | Coefficient | Standard Error | b/St.Er. | P[|Z|>z] | Mean of X |
|----------|-------------|----------------|----------|--------|----------|
| Constant | 2.77846956  | 1.50616043     | 1.845    | .0651  |          |
| MALE     | -.08593715  | .36576014      | -.235    | .8142  | .62827225|
| X27      | -.01630271  | .02089760      | -.780    | .4353  | 31.4136126|
| X32      | -.16336038  | .17645812      | -.926    | .3546  | 2.83246073|
| LATE     | -2.06350679 | .93873401      | -2.198   | .0279  | .45549738 |
| BRISK    | -.22663173  | 1.20641004     | -1.88    | .8510  | .18848168 |
| X24      | 1.17412675  | .22757164      | 5.159    | .0000  | 4.32984293|

Estimates for equation: MO55
Generalized least squares regression
Model was estimated Sep 13, 2012 at 09:31:08AM
LHS=MO55
Mean = 6.649215
Standard deviation = 6.953037
WTS=none
Number of observs. = 191
Model size
Parameters = 5
Degrees of freedom = 186
Residuals
Sum of squares = 7682.128
Standard error of e = 6.426645
Fit
R-squared = .1411856
Adjusted R-squared = .1227165
Model test
F[ 4, 186] (prob) = 7.64 (.0000)
Diagnostic
Log likelihood = -623.8304
Restricted(b=0) = -640.8991
Chi-sq [ 4] (prob) = 34.14 (.0000)
Info criter.
LogAmemiya Prd. Crt. = 3.746746
Akaike Info. Criter. = 3.746735
Not using OLS or no constant. Rsqd & F may be < 0.
Log|W| = 8.0840
Log-Likelihood = -1585.0730
Durbin-Watson = 1.598
Autocorrelation = .2012
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--> 3sls;lhs=mo70,mo65,mo55
;eq1=one,mo65,x27,x32,late,brisk,x24
;eq2=one,mo70,mo55,male,x27,x32,late,brisk,x24
;eq3=one,mo65,x33,late,brisk,x24
;Inst= male,married,late,brisk,x4,x5,x24,x27,x28,x29,x31,x32,x34,x35,x37$

************************************************************************
* NOTE: Deleted 26 observations with missing data. N is now 168 *
************************************************************************

Criterion function is max(abs(%chg in b(i))).
Iteration 0, 3SLS = 1.000000
Iteration 1, 3SLS = 6.239083
Iteration 2, 3SLS = .9998302
| Variable | Coefficient | Standard Error | b/St.Er. | P[Z>|z|] | Mean of X |
|----------|-------------|----------------|---------|----------|-----------|
| Constant | -1.42182312 | 1.01987119     | -1.394  | .1633    |           |
| MO65     | 1.07969977  | .07140781      | 15.120  | .0000    | 5.89583333 |
| X27      | -.01269818  | .01974662      | -.643   | .5202    | 31.7976190 |
| X32      | .22939908   | .15877944      | 1.445   | .1485    | 2.76785714 |
| LATE     | .95744540   | .46918529      | 2.041   | .0413    | .47023810  |
| BRISK    | .60038783   | .60306851      | .996    | .3195    | .18452381  |
| X24      | .01939998   | .13720854      | .141    | .8876    | 4.39880952  |

Estimates for equation: MO65
InstVar/GLS least squares regression
Model was estimated Sep 13, 2012 at 09:40:38AM
LHS=MO65
Mean = 5.895833
Standard deviation = 6.998472
WTS=none
Number of observs. = 168
Model size
Parameters = 9
Degrees of freedom = 159
Residuals
Sum of squares = 745.1716
Standard error of e = 2.164859
Fit
R-squared = .9037401
Adjusted R-squared = .8988968
Model test
F[ 8, 159] (prob) = 186.60 (.0000)
Diagnostic
Log likelihood = -363.5123
Restricted(b=0) = -564.7564
Chi-sq [ 8] (prob) = 402.49 (.0000)
Info criter.
LogAmemiya Prd. Crt. = 2.199130
Akaike Info. Criter. = 2.199082
Not using OLS or no constant. Rsqd & F may be < 0.
Durbin-Watson 1.655 Autocorrelation = .1723

Estimates for equation: MO70
InstVar/GLS least squares regression
Model was estimated Sep 13, 2012 at 09:40:38AM
LHS=MO70
Mean = 5.821429
Standard deviation = 6.869460
WTS=none
Number of observs. = 168
Model size
Parameters = 7
Degrees of freedom = 161
Residuals
Sum of squares = 1393.693
Standard error of e = 2.942190
Fit
R-squared = .8154607
Adjusted R-squared = .8085834
Model test
F[ 6, 161] (prob) = 118.57 (.0000)
Diagnostic
Log likelihood = -416.1046
Restricted(b=0) = -561.6305
Chi-sq [ 6] (prob) = 291.05 (.0000)
Info criter.
LogAmemiya Prd. Crt. = 2.199130
Akaike Info. Criter. = 2.199082
Not using OLS or no constant. Rsqd & F may be < 0.
Durbin-Watson 1.655 Autocorrelation = .1723
| Variable | Coefficient | Standard Error | b/St.Er. | P[|Z|>z] | Mean of X |
|----------|-------------|----------------|----------|---------|-----------|
| Constant | .18583962   | .64708195      | .287     | .7740   |           |
| MO70     | .58726659   | .00062856      | 934.310  | .0000   | 5.82142857|
| MO55     | .39836223   | .00064488      | 617.730  | .0000   | 6.67261905|
| MALE     | .314238D-07 | .00096143      | .000     | 1.0000  | .63690476 |
| X27      | .00745723   | .01159661      | .643     | .5202   | 31.7976190|
| X32      | -.13471812  | .09324695      | -1.445   | .1485   | 2.76785714|
| LATE     | -.16141096  | .33534949      | -1.481   | .6303   | .47023810 |
| BRISK    | -.77759065  | .43730921      | -1.778   | .0754   | .18452381 |
| X24      | -.00266262  | .07984093      | -1.033   | .9734   | 4.39880952|

Estimates for equation: MO55
InstVar/GLS least squares regression
Model was estimated Sep 13, 2012 at 09:40:38AM
LHS=MO55
Mean = 6.672619
Standard deviation = 7.063864
WTS=none
Number of observs. = 168
Model size
Parameters = 6
Degrees of freedom = 162
Residuals
Sum of squares = 1743.601
Standard error of e = 3.280696
Fit
R-squared = .7830097
Adjusted R-squared = .7763125
Model test
F[ 5, 162] (prob) = 116.92 (.0000)
Diagnostic
Log likelihood = -434.9201
Restricted(b=0) = -566.3189
Chi-sq [ 5] (prob) = 262.80 (.0000)
Info criter.
LogAmemiya Prd. Crt. = 2.411203
Akaike Info. Criter. = 2.411172
Not using OLS or no constant. Rsqd & F may be < 0.
Durbin-Watson 2.095 Autocorrelation = -.0476