Mixed Models for Longitudinal Ordinal and Nominal Outcomes

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Hedeker, D. (2008). Multilevel models for ordinal and nominal variables. In J. de Leeuw & E. Meijer (Eds.), Handbook of Multilevel Analysis. Springer, New York.

Hedeker, D. & Gibbons, R.D. (2006). Longitudinal Data Analysis, chapters 10 & 11. Wiley.

Hedeker, D. (2014). Methods for multilevel ordinal data in prevention research. *Prevention Science*.

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Why analyze as ordinal?

- Efficiency: Armstrong & Sloan (1989, Amer Jrn of Epid) and Strömberg (1996, Amer Jrn of Epid) report efficiency losses between 49% to 87% when dichotomizing an ordinal outcome with five categories.

- Bias: continuous model can yield correlated residuals and regressors when used for ordinal outcomes; continuous model does not take into account the ceiling and floor effects of the ordinal outcome. Results in biased estimates of regression coefficients and is most critical when the ordinal variables is highly skewed (see Bauer & Sterba, 2011, Psych Methods)

- Logic: continuous model can yield predicted values outside of the range of the ordinal variable.

Ordinal Logistic Regression Model (aka Proportional Odds or Cumulative Logit Model) - McCullagh (1980)

$$\log\left[\frac{P(Y \leq c)}{1 - P(Y \leq c)}\right] = \gamma_c - \boldsymbol{x}'\boldsymbol{\beta}$$

$$\begin{aligned} c &= 1, \ldots, C-1 \text{ for the } C \text{ categories of the ordinal outcome} \\ \boldsymbol{x} &= \text{vector of explanatory variables (plus the intercept)} \\ \gamma_c &= \text{threshold parameters; reflect cumulative logits when } \boldsymbol{x} = 0 \\ &\quad \text{(for identification: } \gamma_1 = 0 \text{ or } \beta_0 = 0\text{)} \end{aligned}$$

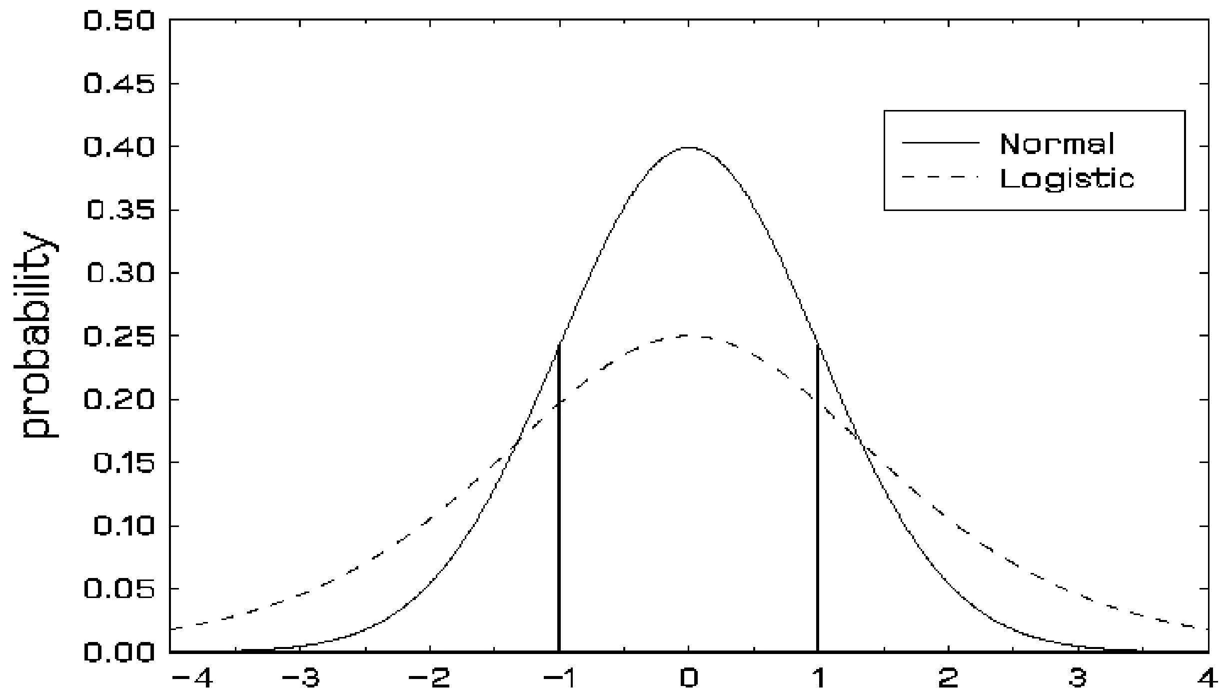
- positive association between explanatory variable x and ordinal outcome variable Y is reflected by β
- x is assumed to have the same effect on each cumulative logit (proportional odds assumption)

Ordinal Response and Threshold Concept

Continuous y_i - unobservable latent variable - related to ordinal response Y_i via "threshold concept"

- threshold values $\gamma_1, \gamma_2, \ldots, \gamma_{C-1}$ ($\gamma_0 = -\infty$ and $\gamma_C = \infty$)
- C = number of ordered categories

Response occurs in category c, $\quad Y_i = c \quad$ if $\quad \gamma_{c-1} < y_i < \gamma_c$



The Threshold Concept in Practice

"How was your day?"
(what is your level of satisfaction today?)

- Satisfaction may be continuous, but we sometimes emit an ordinal response:

Model for Latent Continuous Responses

Consider the model with p covariates for the latent response strength y_i ($i = 1, 2, \ldots, N$):

$$y_i = \boldsymbol{x}_i' \boldsymbol{\beta} + \varepsilon_i$$

- probit: $\varepsilon_i \sim$ standard normal (mean=0, variance=1)
- logistic: $\varepsilon_i \sim$ standard logistic (mean=0, variance=$\pi^2/3$)

$\Rightarrow \boldsymbol{\beta}$ estimates from logistic regression are larger (in abs. value) than from probit regression by approximately $\sqrt{\pi^2/3} = 1.8$

Underlying latent variable

- useful way of thinking of the problem
- not an essential assumption of the model

Mixed-effects ordinal logistic regression model

(Hedeker & Gibbons, 1994, 1996)

- $i = 1, \ldots N$ level-2 units (clusters or subjects)
- $j = 1, \ldots, n_i$ level-1 units (subjects or repeated observations)
- $c = 1, 2, \ldots, C$ response categories
- Y_{ij} = ordinal response of level-2 unit i and level-1 unit j

How was your day? (asked repeatedly each day for a week)

Mixed-effects ordinal logistic regression model

$$\lambda_{ijc} = \log\left[\frac{P_{ijc}}{(1-P_{ijc})}\right] = \gamma_c - (\boldsymbol{x}'_{ij}\boldsymbol{\beta} + \boldsymbol{z}'_{ij}\boldsymbol{\upsilon}_i)$$

- $P_{ijc} = \Pr\left(Y_{ij} \leq c \mid \boldsymbol{\upsilon}\,;\, \gamma_c, \boldsymbol{\beta}, \boldsymbol{\Sigma}_\upsilon\right) \;=\; \frac{1}{1+\exp(-\lambda_{ijc})}$
- $p_{ijc} = \Pr\left(Y_{ij} = c \mid \boldsymbol{\upsilon}\,;\, \gamma_c, \boldsymbol{\beta}, \boldsymbol{\Sigma}_\upsilon\right) \;=\; P_{ijc} - P_{ijc-1}$

- $C-1$ strictly increasing model thresholds γ_c
- $\boldsymbol{x}_{ij} = p \times 1$ covariate vector
- $\boldsymbol{z}_{ij} = r \times 1$ design vector for random effects
- $\boldsymbol{\beta} = p \times 1$ fixed regression parameters
- $\boldsymbol{\upsilon}_i = r \times 1$ random effects for level-2 unit $i \quad \sim N(\mathbf{0}, \boldsymbol{\Sigma}_\upsilon)$

Model for Latent Continuous Responses

Model with p covariates for the latent response strength y_{ij}:

$$y_{ij} = \boldsymbol{x}'_{ij}\boldsymbol{\beta} + \upsilon_{0i} + \varepsilon_{ij}$$

where $\upsilon_{0i} \sim N(0, \sigma_\upsilon^2)$, and assuming

- $\varepsilon_{ij} \sim$ standard normal (mean 0 and $\sigma^2 = 1$) leads to mixed-effects ordinal probit regression
- $\varepsilon_{ij} \sim$ standard logistic (mean 0 and $\sigma^2 = \pi^2/3$) leads to mixed-effects ordinal logistic regression

Underlying latent variable

- not an essential assumption of the model
- useful for obtaining intra-class correlation (r)

$$r = \frac{\sigma_v^2}{\sigma_v^2 + \sigma^2}$$

and for design effect (d)

$$d = \frac{\sigma_v^2 + \sigma^2}{\sigma^2} = 1/(1-r)$$

ratio of actual variance to the variance that would be obtained by simple random sampling (holding sample size constant)

Scaling of regression coefficients

Fixed-effects model

$\boldsymbol{\beta}$ estimates from logistic regression are larger (in abs. value) than from probit regression by approximately

$$\sqrt{\frac{\pi^2/3}{1}} = 1.8$$

because

- $V(y) = \sigma^2 = \pi^2/3$ for logistic
- $V(y) = \sigma^2 = 1$ for probit

Mixed-effects model

$\boldsymbol{\beta}$ estimates from mixed-effects (random intercepts) model are larger (in abs. value) than from fixed-effects model by approximately

$$\sqrt{d} = \sqrt{\frac{\sigma_v^2 + \sigma^2}{\sigma^2}}$$

because

- $V(y) = \sigma_v^2 + \sigma^2$ in mixed-effects (random intercepts) model
- $V(y) = \sigma^2$ in fixed-effects model

- difference depends on size of random-effects variance σ_v^2
- more complex for models with multiple random effects

Treatment-Related Change Across Time

Data from the NIMH Schizophrenia collaborative study on treatment related changes in overall severity. IMPS item 79, *Severity of Illness*, was scored as:

1	=	normal or borderline mentally ill
2	=	mildly or moderately ill
3	=	markedly ill
4	=	severely or among the most extremely ill

The experimental design and corresponding sample sizes:

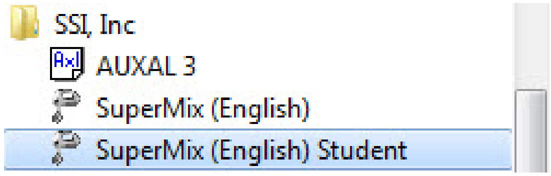
	Sample size at Week							
Group	0	1	2	3	4	5	6	*completers*
PLC (n=108)	107	105	5	87	2	2	70	65%
DRUG (n=329)	327	321	9	287	9	7	265	81%

Drug = Chlorpromazine, Fluphenazine, or Thioridazine

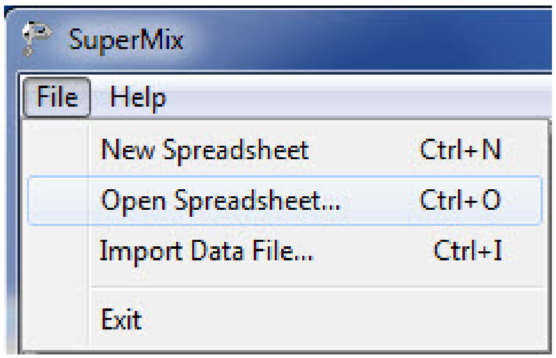
Main question of interest:

- Was there differential improvement for the drug groups relative to the control group?

- Under SSI, Inc > "SuperMix (English)" or "SuperMix (English) Student"



- Under "File" click on "Open Spreadsheet"



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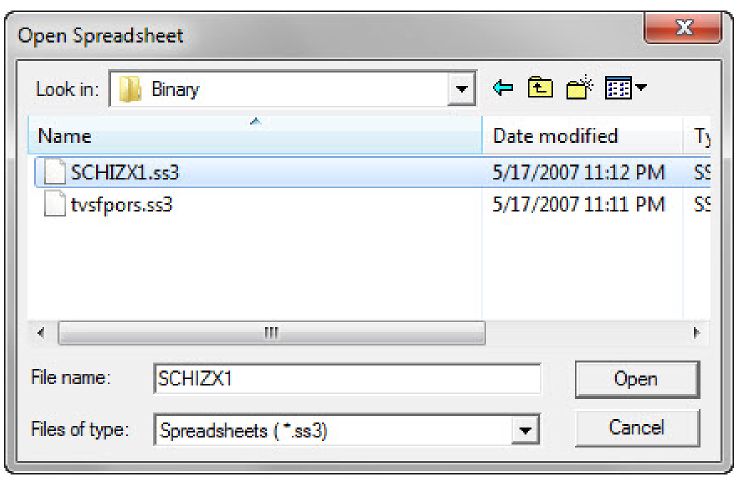
  (or C:\SuperMixEn Student Examples\Workshop\Binary\SCHIZX1.ss3)



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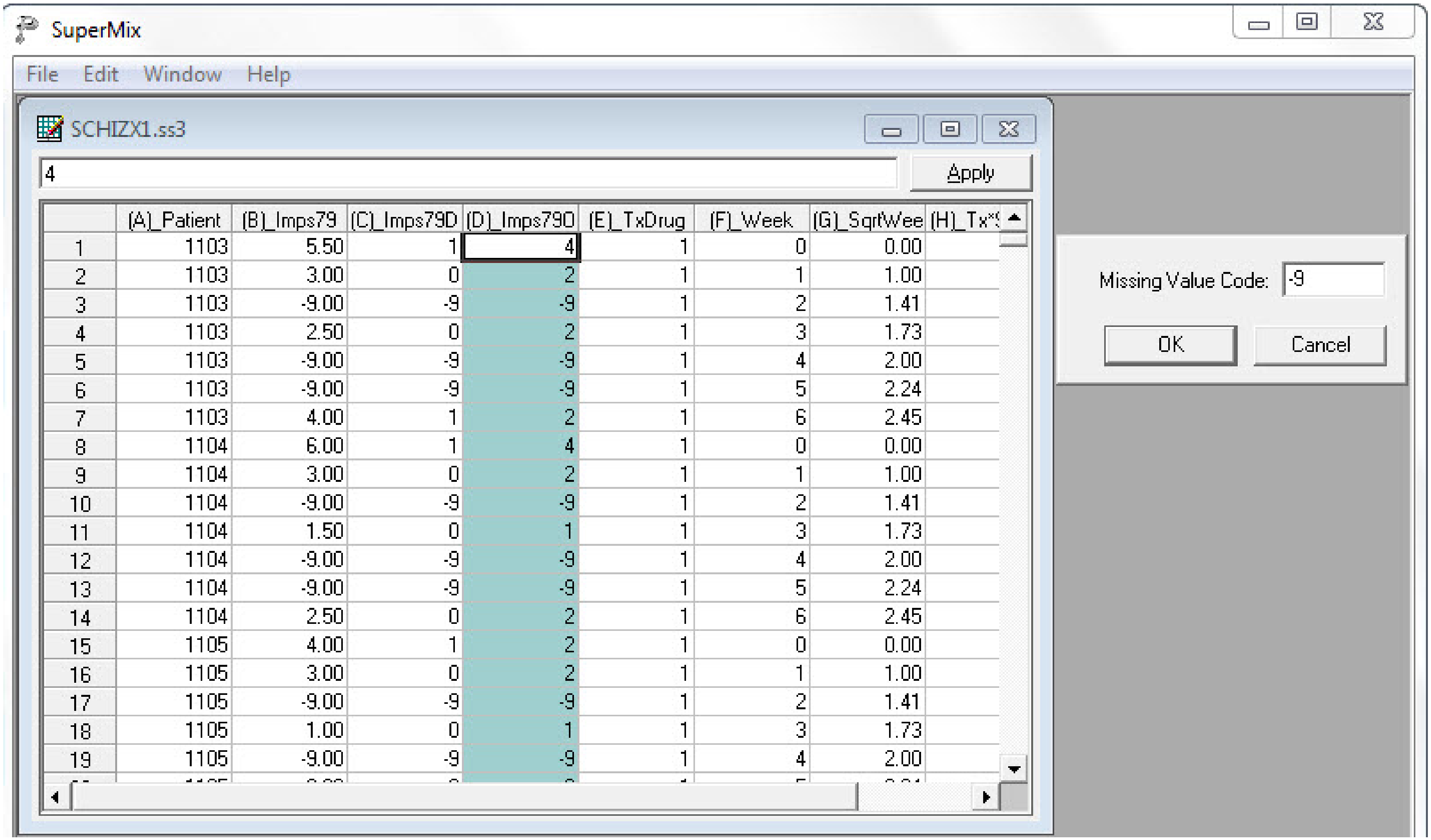
SCHIZX1.ss3

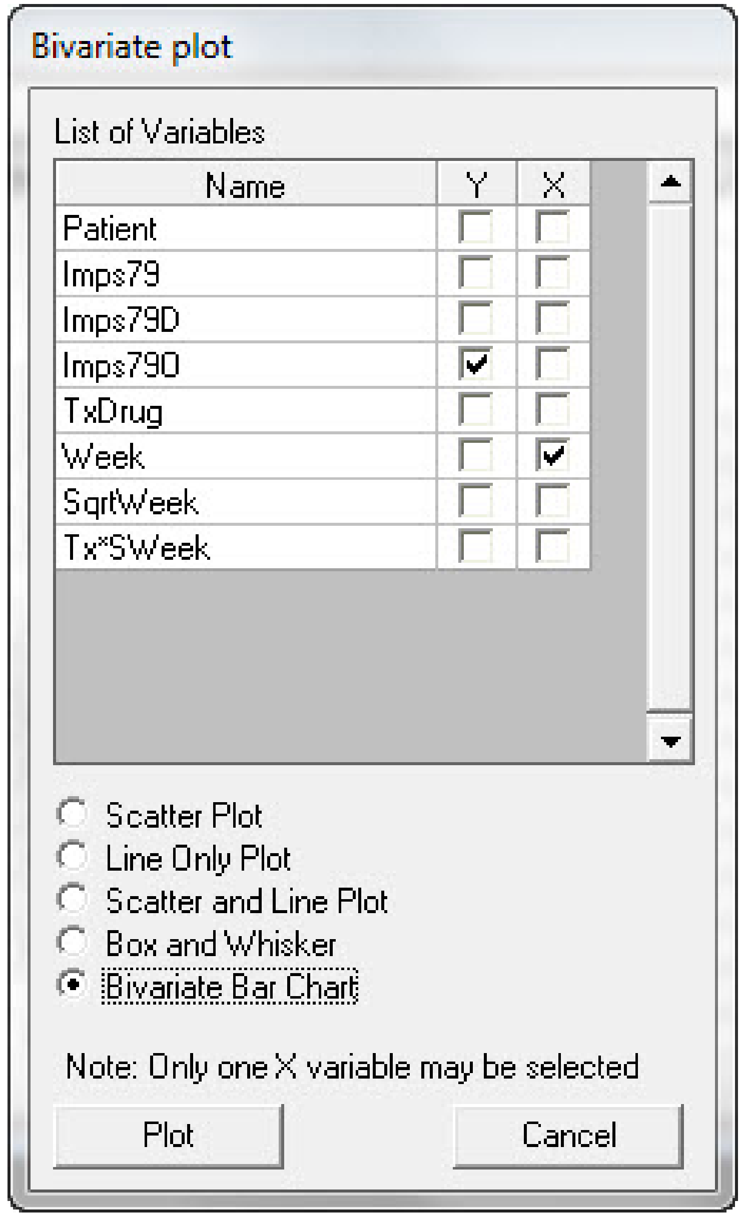
1103 Apply

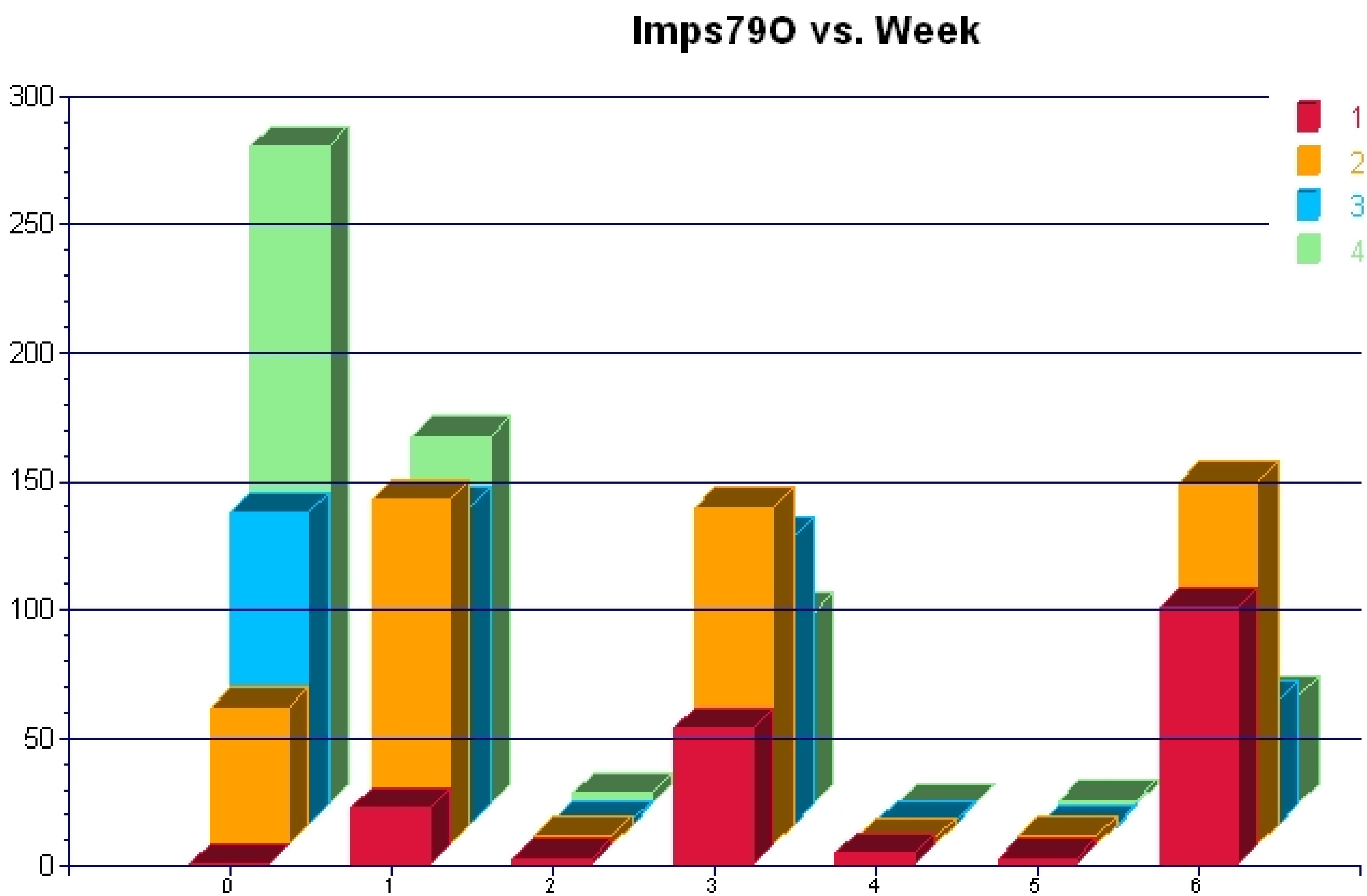
	(A)_Patient	(B)_Imps79	(C)_Imps79D	(D)_Imps79O	(E)_TxDrug	(F)_Week	(G)_SqrtWee	(H)_Tx*SWe
1	1103	5.50	1	4	1	0	0.00	0.00
2	1103	3.00	0	2	1	1	1.00	1.00
3	1103	-9.00	-9	-9	1	2	1.41	1.41
4	1103	2.50	0	2	1	3	1.73	1.73
5	1103	-9.00	-9	-9	1	4	2.00	2.00
6	1103	-9.00	-9	-9	1	5	2.24	2.24
7	1103	4.00	1	2	1	6	2.45	2.45
8	1104	6.00	1	4	1	0	0.00	0.00
9	1104	3.00	0	2	1	1	1.00	1.00
10	1104	-9.00	-9	-9	1	2	1.41	1.41
11	1104	1.50	0	1	1	3	1.73	1.73
12	1104	-9.00	-9	-9	1	4	2.00	2.00
13	1104	-9.00	-9	-9	1	5	2.24	2.24
14	1104	2.50	0	2	1	6	2.45	2.45
15	1105	4.00	1	2	1	0	0.00	0.00
16	1105	3.00	0	2	1	1	1.00	1.00
17	1105	-9.00	-9	-9	1	2	1.41	1.41
18	1105	1.00	0	1	1	3	1.73	1.73
19	1105	-9.00	-9	-9	1	4	2.00	2.00
20	1105	-9.00	-9	-9	1	5	2.24	2.24
21	1105	-9.00	-9	-9	1	6	2.45	2.45
22	1106	3.00	0	2	1	0	0.00	0.00
23	1106	1.00	0	1	1	1	1.00	1.00
24	1106	-9.00	-9	-9	1	2	1.41	1.41
25	1106	1.50	0	1	1	3	1.73	1.73
26	1106	-9.00	-9	-9	1	4	2.00	2.00
27	1106	-9.00	-9	-9	1	5	2.24	2.24
28	1106	1.00	0	1	1	6	2.45	2.45

Select **`Imps790`** column, then “Edit” > “Set Missing Value”



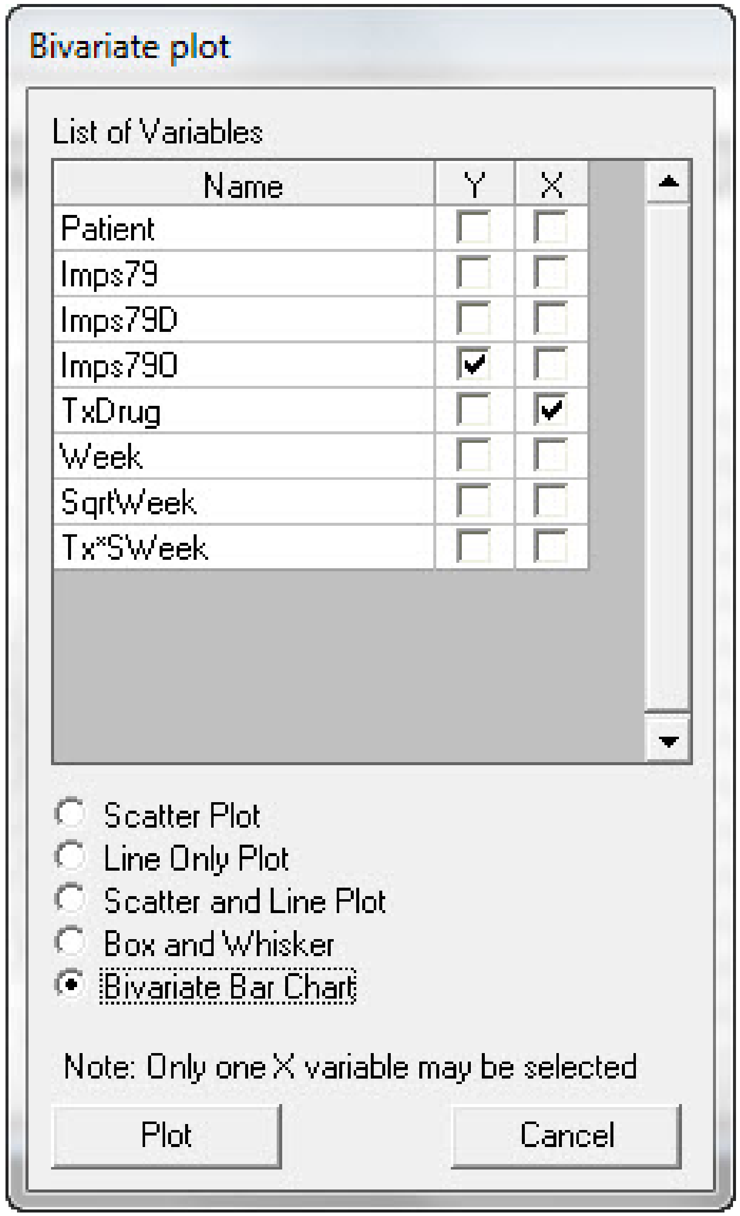
Select “File” > “Data-based Graphs” > “Bivariate”

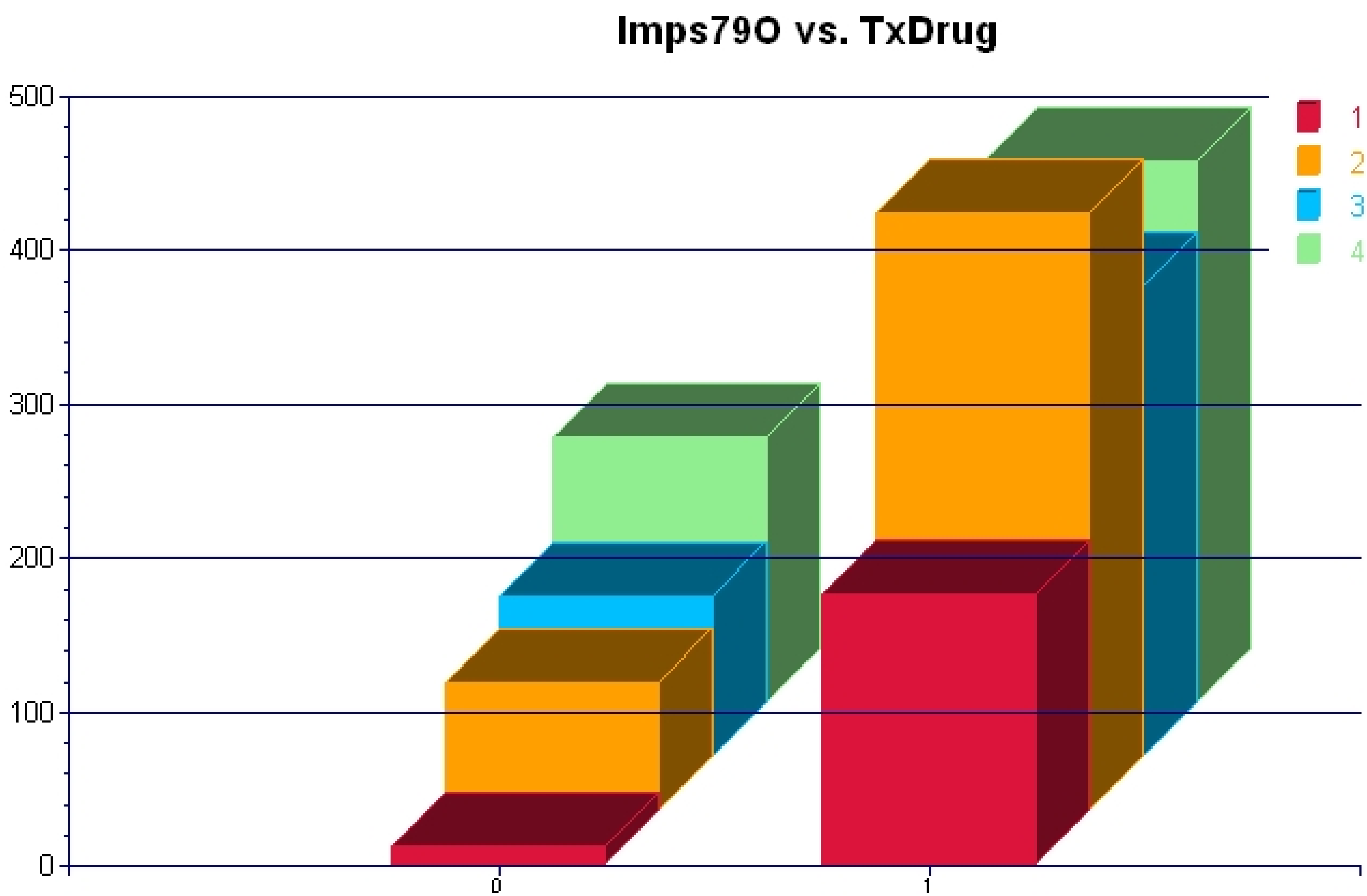




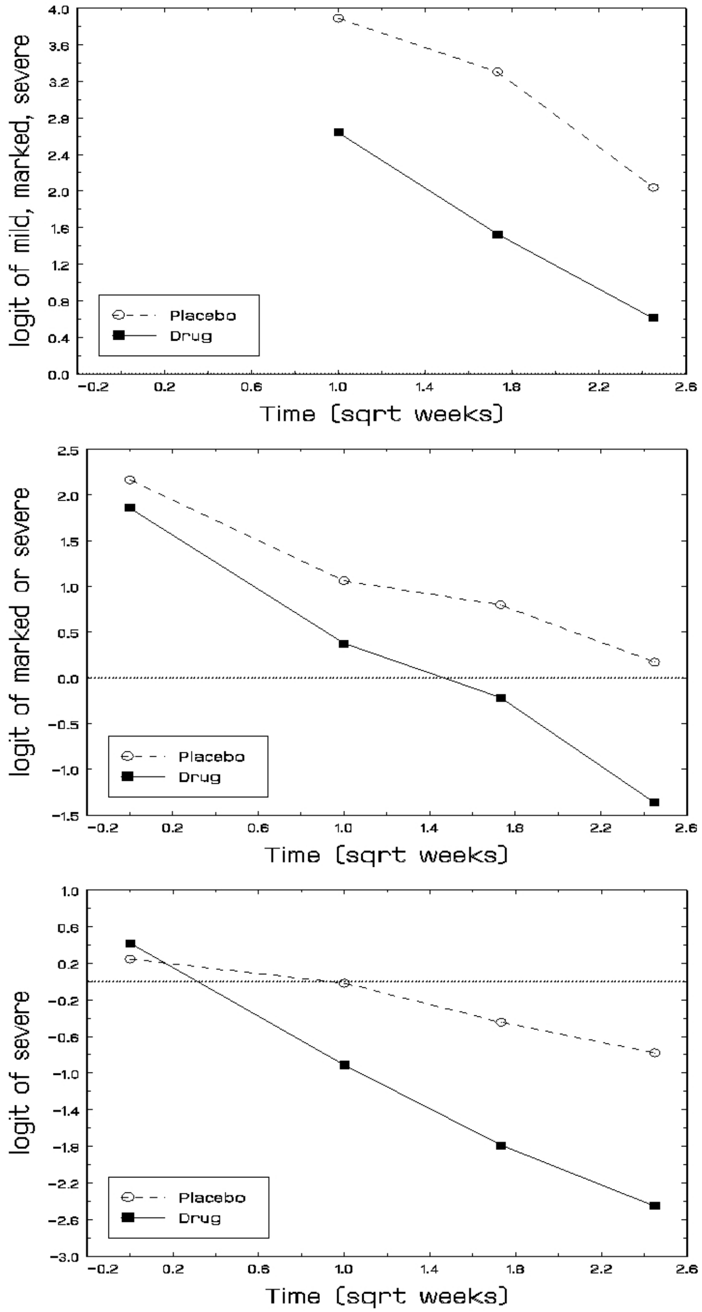
Imps79O vs. Week
300
250
200
150
100
50
0
0
1
2
3
4
5
6
1
2
3
4

Select “File” > “Data-based Graphs” > “Bivariate”




Imps79O vs. TxDrug
500
400
300
200
100
0
0
1
1
2
3
4

Observed Logits across Time by Condition



Within-Subjects / Between-Subjects components

Within-subjects model - level 1 $(j = 1, \ldots, n_i \text{ obs})$

$$\lambda_{ijc} = \gamma_c - [b_{0i} \ + \ b_{1i}\sqrt{Week}_j]$$

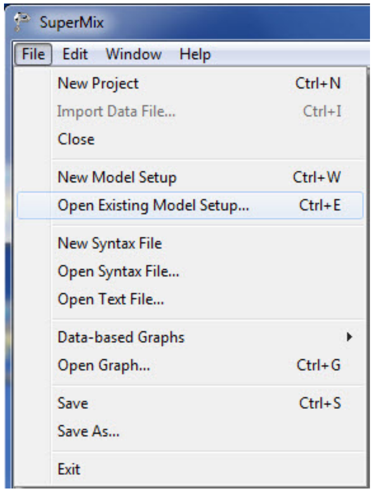
Between-subjects model - level 2 $(i = 1, \ldots, N \text{ subjects})$

$$b_{0i} \ = \ \beta_0 \ + \ \beta_2 Grp_i \ + \ \upsilon_{0i}$$

$$b_{1i} \ = \ \beta_1 \ + \ \beta_3 Grp_i \ + \ \upsilon_{1i}$$

$$\boldsymbol{\upsilon}_i \sim \mathcal{NID}(\mathbf{0}, \boldsymbol{\Sigma}_\upsilon)$$

Under “File” click on “Open Existing Model Setup”



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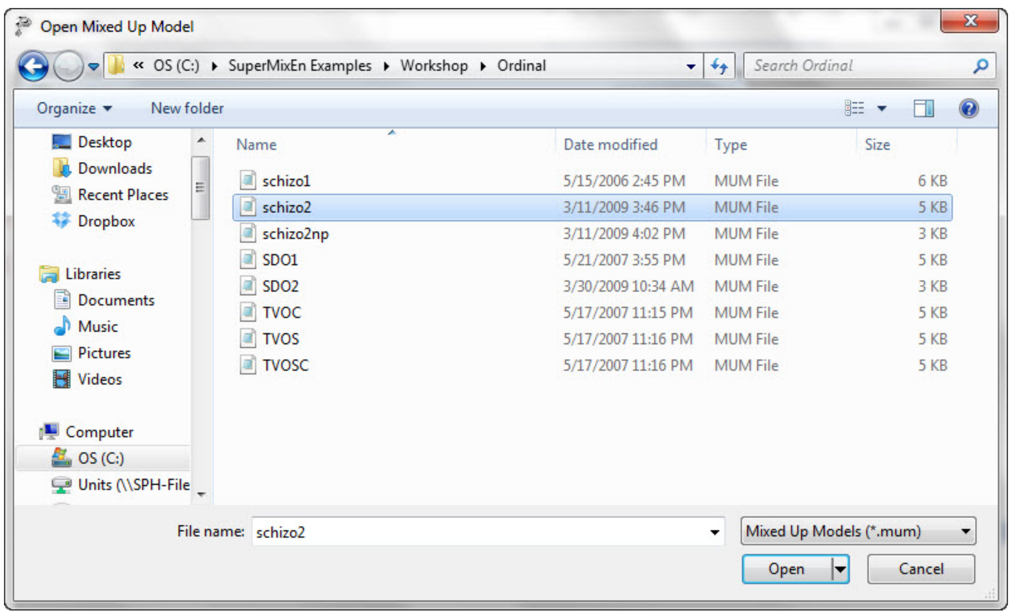
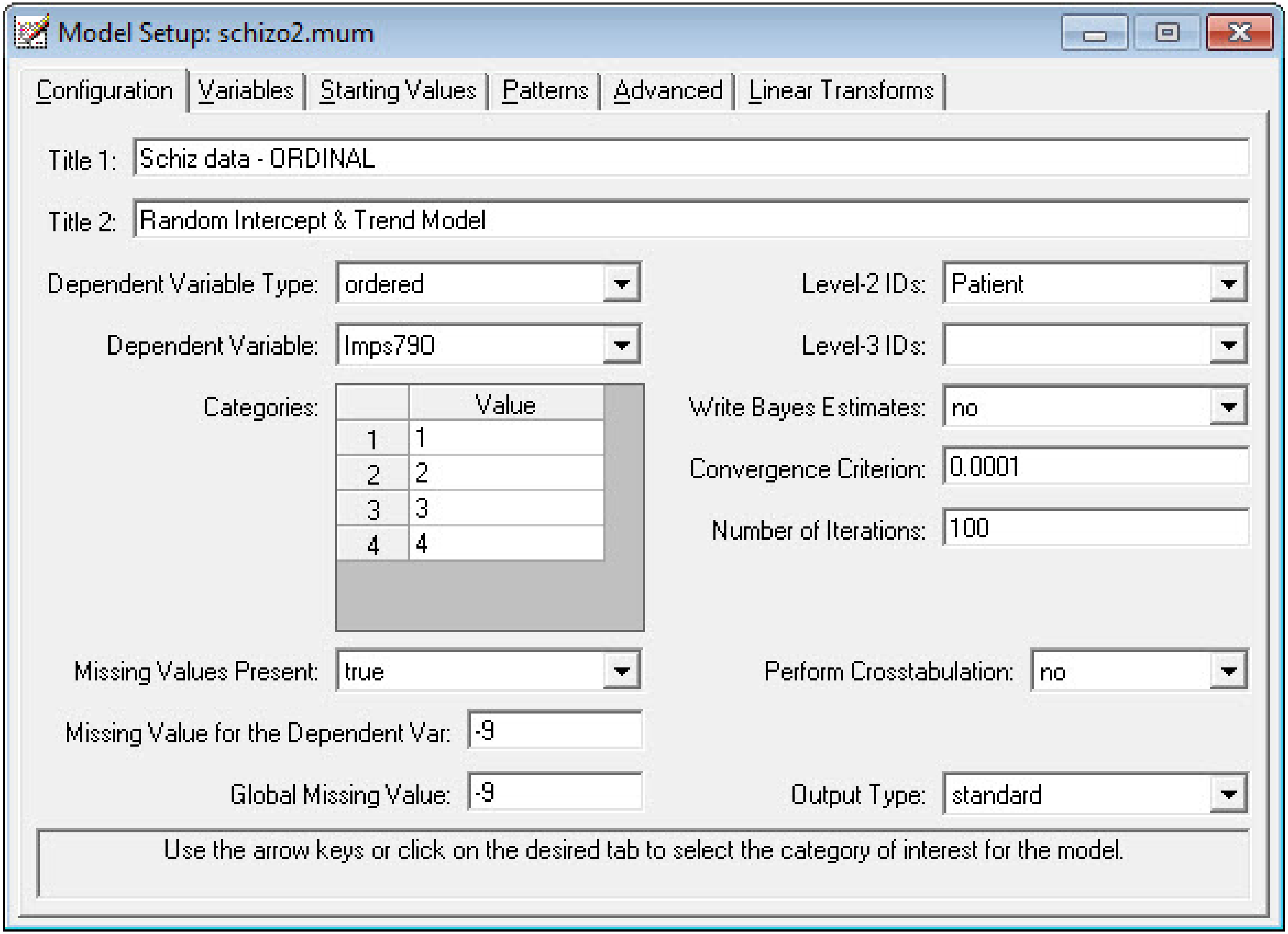
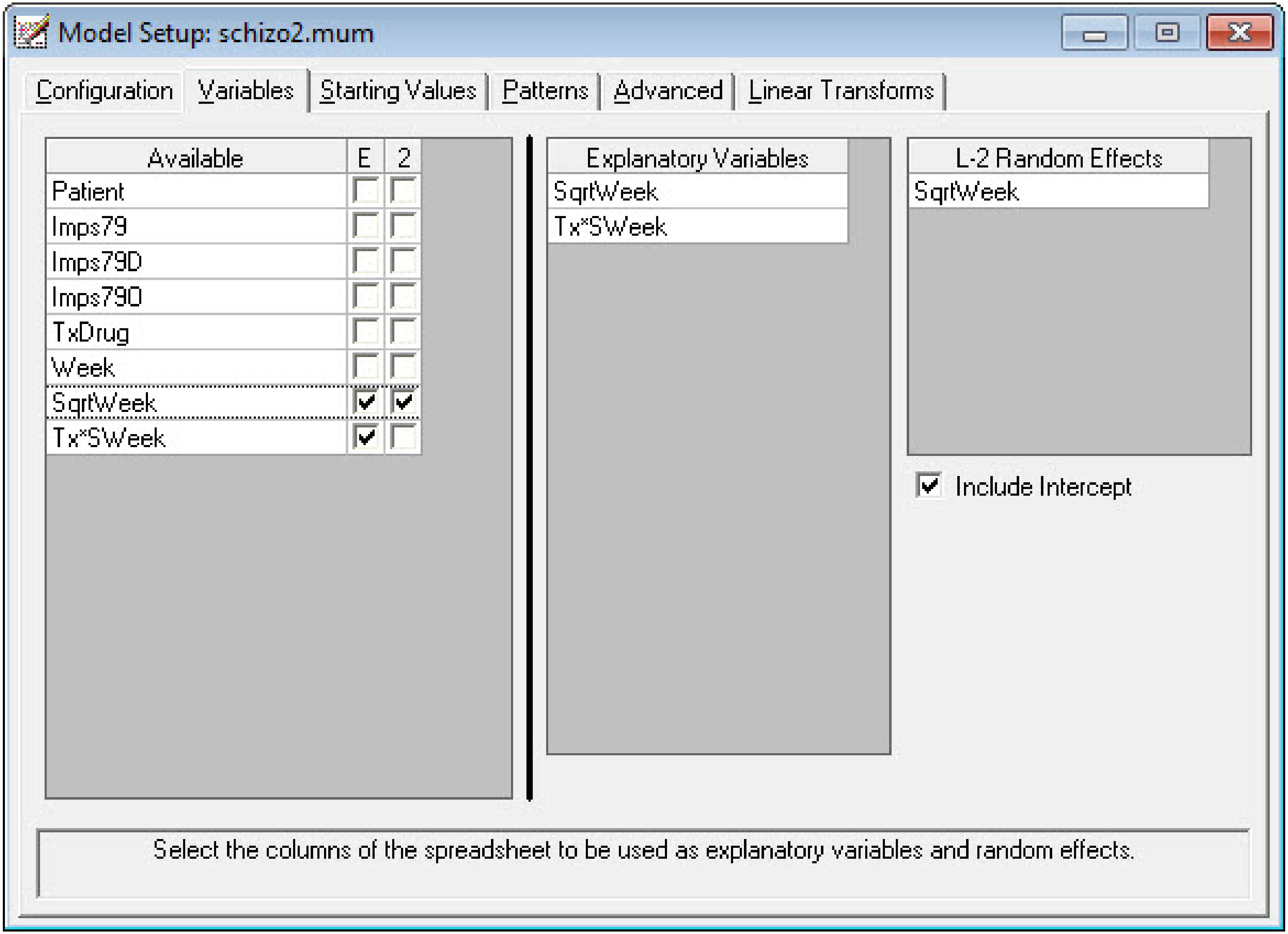
(or C:\SuperMixEn Student Examples\Workshop\Ordinal\schizo2.mum)



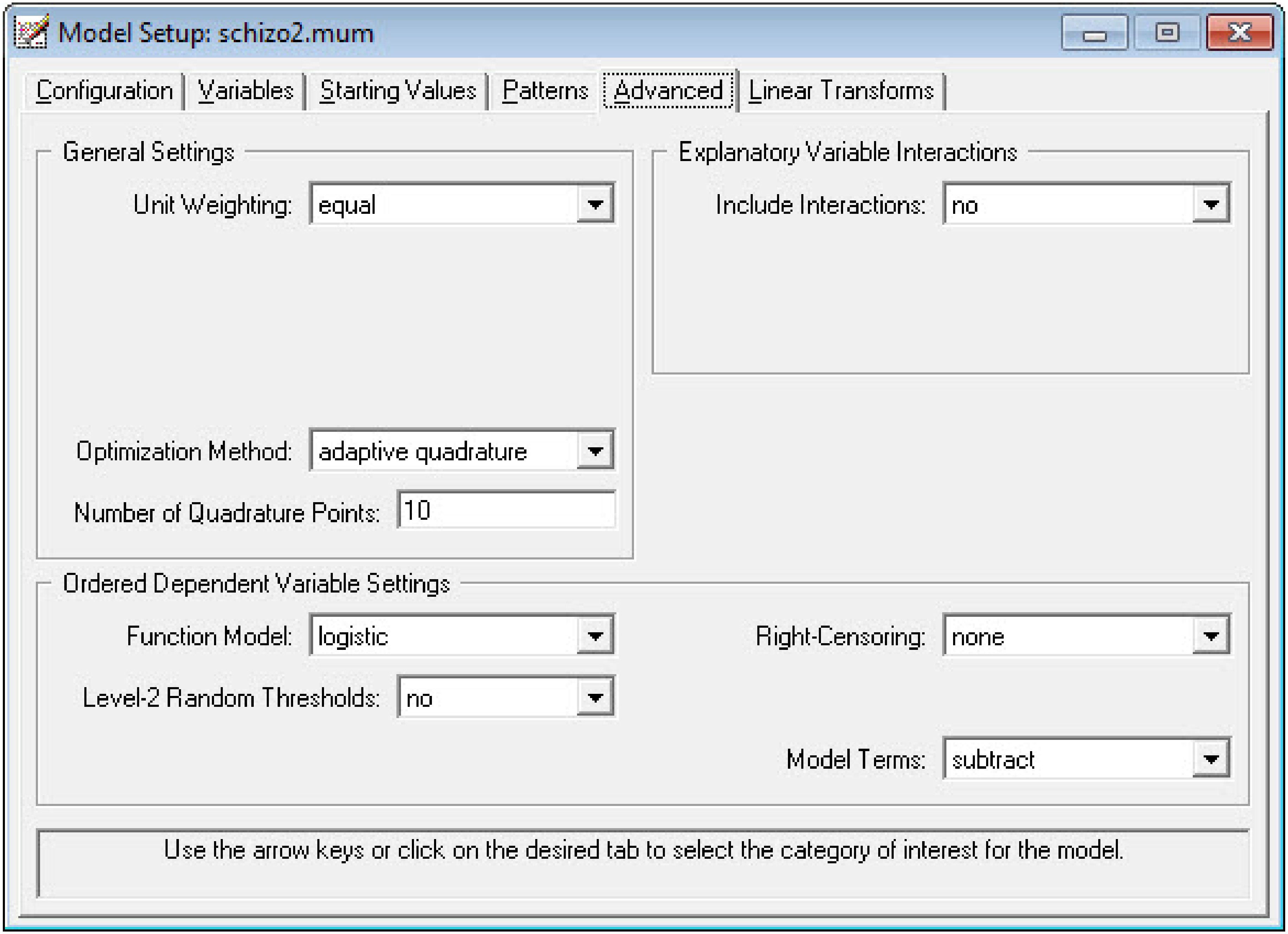
Note that "Dependent Variable Type" is "ordered"



Note the lack of **TxDrug** as an explanatory variable



Make sure "Optimization Method" is set to "adaptive quadrature"



Note: Cumulative Logit link function

schizo2.out

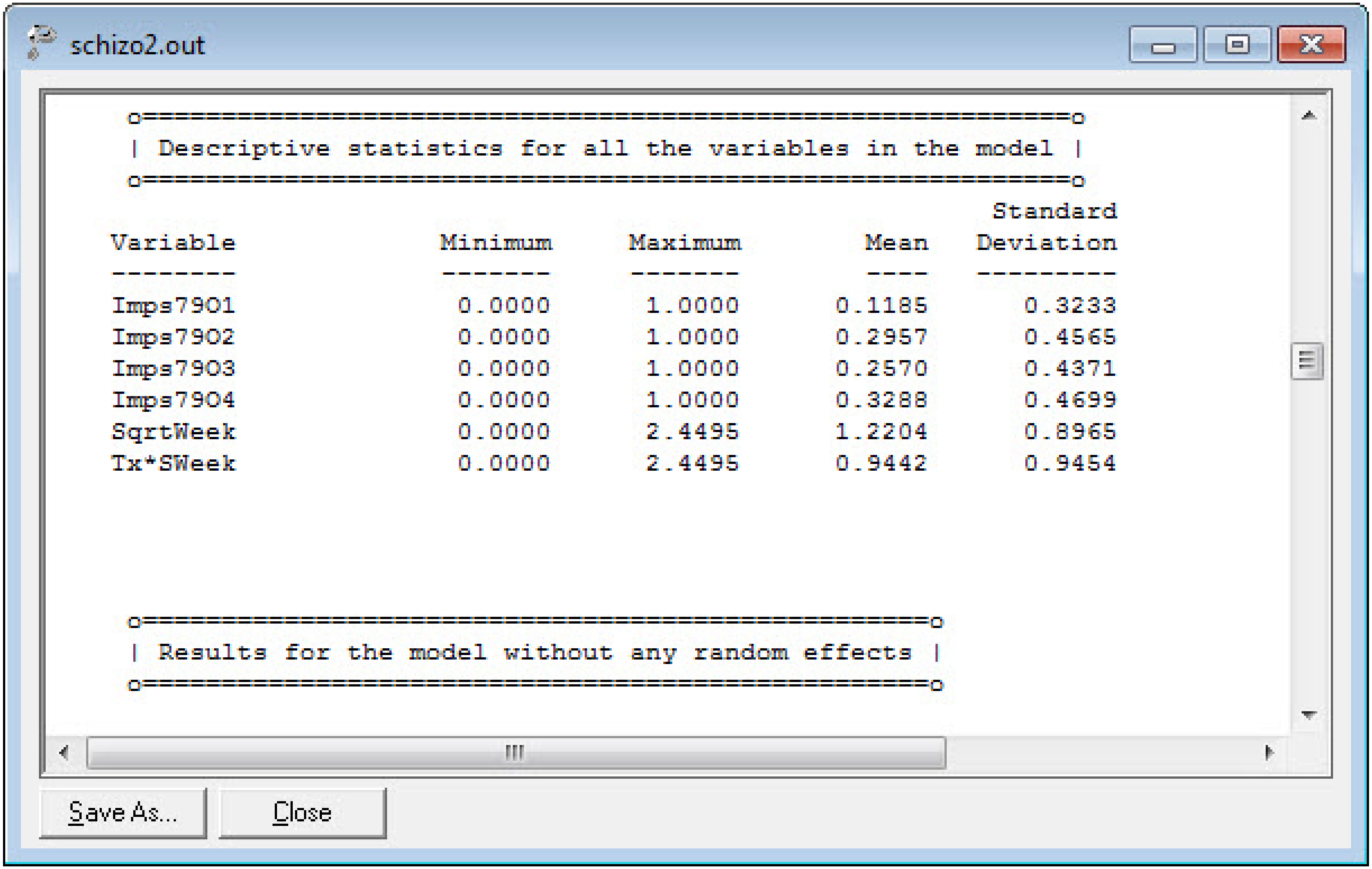
```
o=================================o
| Schiz data - ORDINAL            |
| Random Intercept & Trend Model |
o=================================o


            Model and Data Descriptions

   Sampling Distribution                     = Multinomial
   Link Function                             = Cumulative Logit
   Number of Level-2 Units                     437
   Number of Level-1 Units                     1603
   Number of Level-1 Units per Level-2 Unit =
     4     4     3     4     4     4     4     4     4     3     4     4
     4     2     3     4     3     4     3     4     4     4     3     3
     2     4     4     4     4     4     3     4     4     4     4     4
     4     4     4     4     2     3     4     3     4     4     4     3
     4     4     2     2     4     5     4     2     4     4     3     4
     4     3     2     3     4     4     4     4     4     4     2     4
     4     4     5     4     4     2     2     4     2     4     4     3
     3     4     4     4     4     4     4     4     4     3     3     4
     2     3     4     4     4     2     5     3     4     4     2     4
     4     4     2     4     4     4     4     4     4     4     4     4
     5     2     4     3     4     4     2     2     4     4     4     4
     4     2     4     4     4     4     4     4     4     4     4     4
     4     4     4     2     4     4     2     4     4     4     3     4
     2     4     4     3     2     3     4     4     3     3     4     3
     4     4     4     4     4     4     4     4     4     4     4     4
     4     4     2     3     3     5     4     3     4     4     3     2
     4     4     4     4     4     3     3     4     4     4     4     4
     4     4     4     4     4     4     4     4     4     4     3     4
     4     4     4     4     4     2     3     4     4     4     2     4
```

Save As...   Close

Category response indicators (IMPS79O1-IMPS79O4); results of fixed-effects model (to be ignored, or for comparison purposes)




```
o==================================================================o
| Descriptive statistics for all the variables in the model |
o==================================================================o

                                                                Standard
Variable                 Minimum      Maximum         Mean     Deviation
--------                 -------      -------         ----     ---------
Imps79O1                  0.0000       1.0000       0.1185        0.3233
Imps79O2                  0.0000       1.0000       0.2957        0.4565
Imps79O3                  0.0000       1.0000       0.2570        0.4371
Imps79O4                  0.0000       1.0000       0.3288        0.4699
SqrtWeek                  0.0000       2.4495       1.2204        0.8965
Tx*SWeek                  0.0000       2.4495       0.9442        0.9454


o=========================================================o
| Results for the model without any random effects |
o=========================================================o
```

schizo2.out

```
 o==========================================o
 | Optimization Method: Adaptive Quadrature |
 o==========================================o

Number of quadrature points =            10
Number of free parameters =               8
Number of iterations used =               5

-2lnL (deviance statistic) =       3325.51347
Akaike Information Criterion       3341.51347
Schwarz Criterion                  3384.55053
```

Estimated regression weights

Parameter	Estimate	Standard Error	z Value	P Value
Threshold1	-7.3662	0.3711	-19.8494	0.0000
Threshold2	-3.4647	0.2438	-14.2121	0.0000
Threshold3	-0.8577	0.1850	-4.6353	0.0000
SqrtWeek	-0.8996	0.1897	-4.7430	0.0000
Tx*SWeek	-1.6740	0.2081	-8.0456	0.0000

Odds Ratio and 95% Odds Ratio Confidence Intervals

Parameter	Estimate	Odds Ratio	Bounds Lower	Bounds Upper
Threshold1	-7.3662	0.0006	0.0003	0.0013
Threshold2	-3.4647	0.0313	0.0194	0.0504
Threshold3	-0.8577	0.4242	0.2951	0.6096
SqrtWeek	-0.8996	0.4067	0.2805	0.5899
Tx*SWeek	-1.6740	0.1875	0.1247	0.2819

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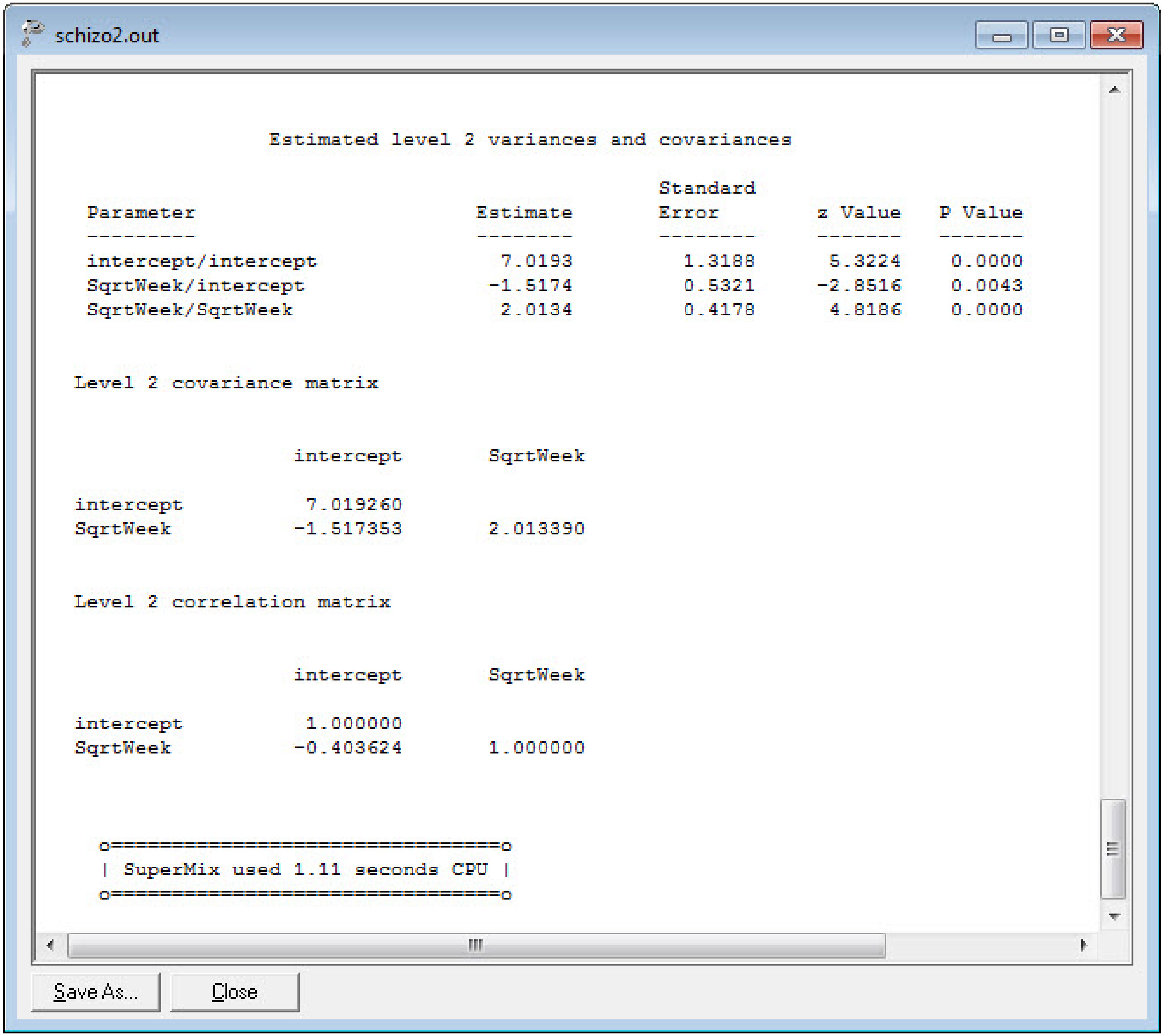


schizo2.out

Estimated level 2 variances and covariances

Parameter	Estimate	Standard Error	z Value	P Value
intercept/intercept	7.0193	1.3188	5.3224	0.0000
SqrtWeek/intercept	-1.5174	0.5321	-2.8516	0.0043
SqrtWeek/SqrtWeek	2.0134	0.4178	4.8186	0.0000

Level 2 covariance matrix

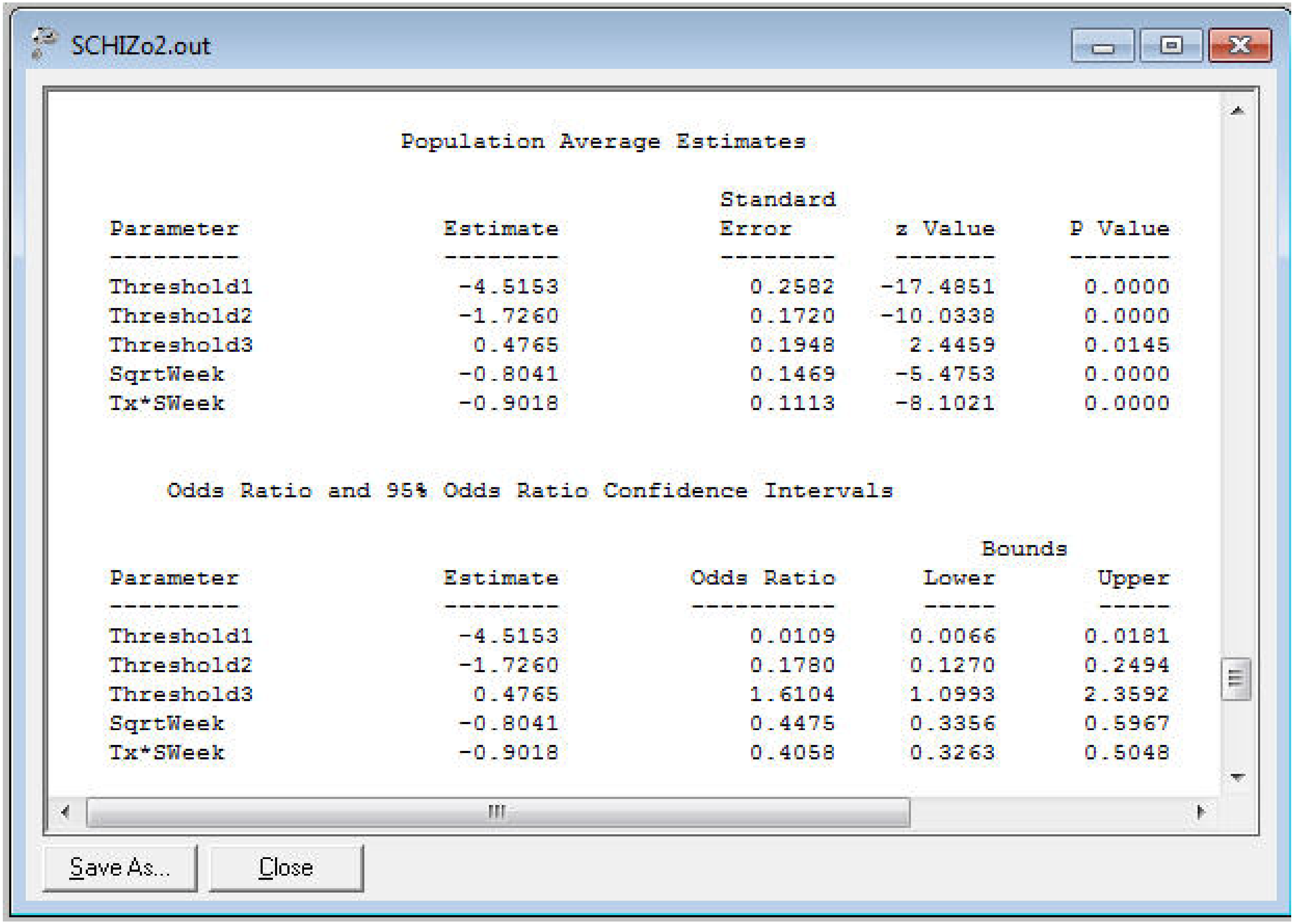
	intercept	SqrtWeek
intercept	7.019260	
SqrtWeek	-1.517353	2.013390

Level 2 correlation matrix

	intercept	SqrtWeek
intercept	1.000000	
SqrtWeek	-0.403624	1.000000

o================================o
| SuperMix used 1.11 seconds CPU |
o================================o

Save As... Close


SCHIZo2.out

Population Average Estimates

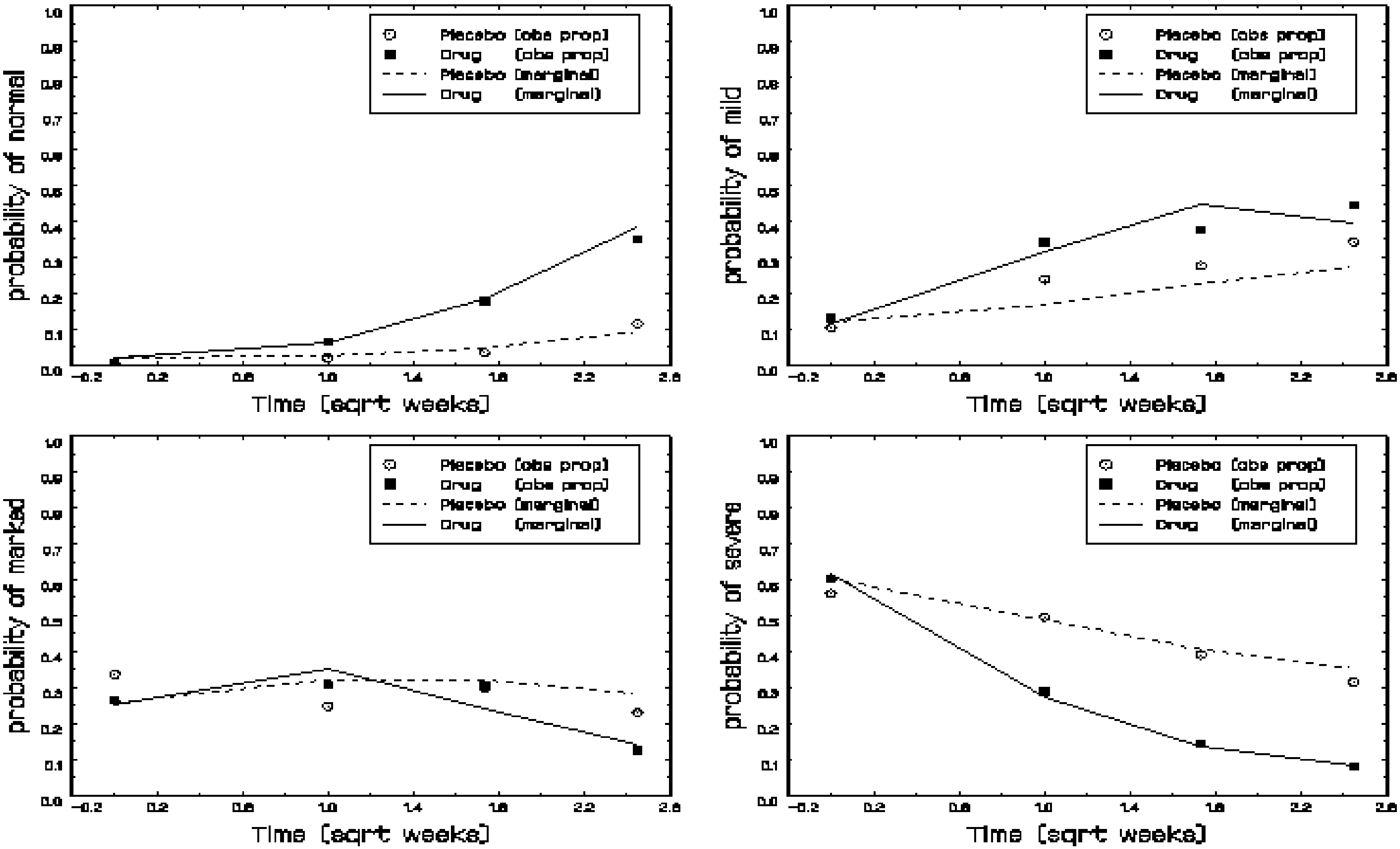
Parameter	Estimate	Standard Error	z Value	P Value
Threshold1	-4.5153	0.2582	-17.4851	0.0000
Threshold2	-1.7260	0.1720	-10.0338	0.0000
Threshold3	0.4765	0.1948	2.4459	0.0145
SqrtWeek	-0.8041	0.1469	-5.4753	0.0000
Tx*SWeek	-0.9018	0.1113	-8.1021	0.0000

Odds Ratio and 95% Odds Ratio Confidence Intervals

Parameter	Estimate	Odds Ratio	Bounds Lower	Bounds Upper
Threshold1	-4.5153	0.0109	0.0066	0.0181
Threshold2	-1.7260	0.1780	0.1270	0.2494
Threshold3	0.4765	1.6104	1.0993	2.3592
SqrtWeek	-0.8041	0.4475	0.3356	0.5967
Tx*SWeek	-0.9018	0.4058	0.3263	0.5048

Save As... Close

Model Fit of Observed Proportions



SAS IML code: SCHZOFIT.SAS - computing marginal probabilities - ordinal model adapted from syntax at http://www.uic.edu/classes/bstt/bstt513/ (Week 12)

```
TITLE1 'NIMH Schizophrenia Data - Estimated Marginal Probabilities';
PROC IML;
/* Results from random intercept and trend model */;
/* using Population Average Estimates */;
 x0  = { 0.00000 0,
         1.00000 0,
         1.73205 0,
         2.44949 0};
 x1  = { 0.00000 0.00000,
         1.00000 1.00000,
         1.73205 1.73205,
         2.44949 2.44949};

 beta   = { -.8041, -.9018};
 thresh = {-4.5153, -1.726, .4765};
```

```
za0 = (thresh[1] - x0*beta) ;
zb0 = (thresh[2] - x0*beta) ;
zc0 = (thresh[3] - x0*beta) ;
za1 = (thresh[1] - x1*beta) ;
zb1 = (thresh[2] - x1*beta) ;
zc1 = (thresh[3] - x1*beta) ;

grp0a = 1 / ( 1 + EXP(- za0));
grp0b = 1 / ( 1 + EXP(- zb0));
grp0c = 1 / ( 1 + EXP(- zc0));
grp1a = 1 / ( 1 + EXP(- za1));
grp1b = 1 / ( 1 + EXP(- zb1));
grp1c = 1 / ( 1 + EXP(- zc1));

print 'Random intercept and trend model';
print using Population Average Estimates';
print 'marginal prob for group 0 - catg 1' grp0a [FORMAT=8.4];
print 'marginal prob for group 0 - catg 2' (grp0b-grp0a) [FORMAT=8.4];
print 'marginal prob for group 0 - catg 3' (grp0c-grp0b) [FORMAT=8.4];
print 'marginal prob for group 0 - catg 4' (1-grp0c) [FORMAT=8.4];
print 'marginal prob for group 1 - catg 1' grp1a [FORMAT=8.4];
print 'marginal prob for group 1 - catg 2' (grp1b-grp1a) [FORMAT=8.4];
print 'marginal prob for group 1 - catg 3' (grp1c-grp1b) [FORMAT=8.4];
print 'marginal prob for group 1 - catg 4' (1-grp1c) [FORMAT=8.4];
```

Proportional and Non-proportional Odds

Proportional Odds model

$$\log\left[\frac{P(Y_{ij} \leq c)}{1 - P(Y_{ij} \leq c)}\right] = \gamma_c - \left[\boldsymbol{x}'_{ij}\boldsymbol{\beta} + \boldsymbol{z}'_{ij}\boldsymbol{v}_i\right]$$

$$\text{with } \boldsymbol{v}_i \sim N(\mathbf{0}, \boldsymbol{\Sigma}_{\upsilon})$$

- relationship between the explanatory variables and the cumulative logits does not depend on c
- effects of $\boldsymbol{x}$ variables DO NOT vary across the $C - 1$ cumulative logits

Non-Proportional/Partial Proportional Odds model

$$\log\left[\frac{P(Y_{ij} \leq c)}{1 - P(Y_{ij} \leq c)}\right] = \gamma_{0c} - \left[\boldsymbol{u}'_{ij}\boldsymbol{\gamma}_c + \boldsymbol{x}'_{ij}\boldsymbol{\beta} + \boldsymbol{z}'_{ij}\boldsymbol{\upsilon}_i\right]$$

$\boldsymbol{u}_{ij} = h \times 1$ vector for the set of h covariates for which proportional odds is not assumed

- effects of $\boldsymbol{u}$ variables DO vary across the $C - 1$ cumulative logits
- more flexible model for ordinal response relations
- can be used to empirically test proportional odds assumption

Proportional Odds Assumption: covariate effects are the same across all cumulative logits

group	*Response* Absent	Mild	Severe	total
control	27	46	27	100
cumulative odds	$\frac{27}{73} = .37$	$\frac{73}{27} = 2.7$		
logit	*-1*	*1*		
treatment	38	44	18	100
cumulative odds	$\frac{38}{62} = .61$	$\frac{82}{18} = 4.6$		
logit	*-.5*	*1.5*		

$\Rightarrow$ *group difference = .5 for both cumulative logits*

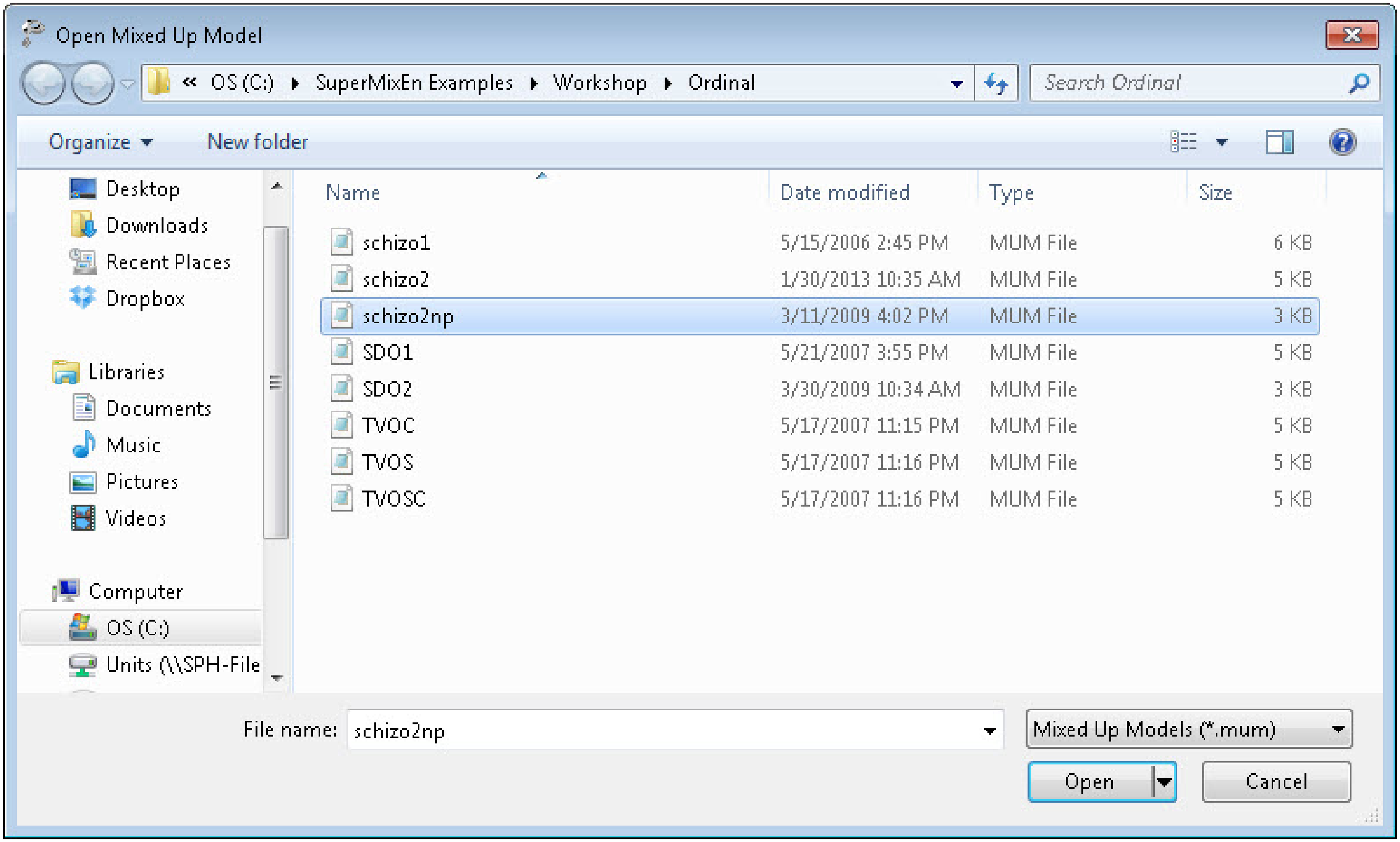
Non-Proportional Odds: covariate effects vary across the cumulative logits

group	*Response* Absent	Mild	Severe	total
control	27	46	27	100
cumulative odds	$\frac{27}{73} = .37$	$\frac{73}{27} = 2.7$		
logit	*-1*	*1*		
treatment	28	60	12	100
cumulative odds	$\frac{28}{72} = .39$	$\frac{88}{12} = 7.3$		
logit	*-.95*	*2*		

$\Rightarrow$ *UNEQUAL group difference across cumulative logits*

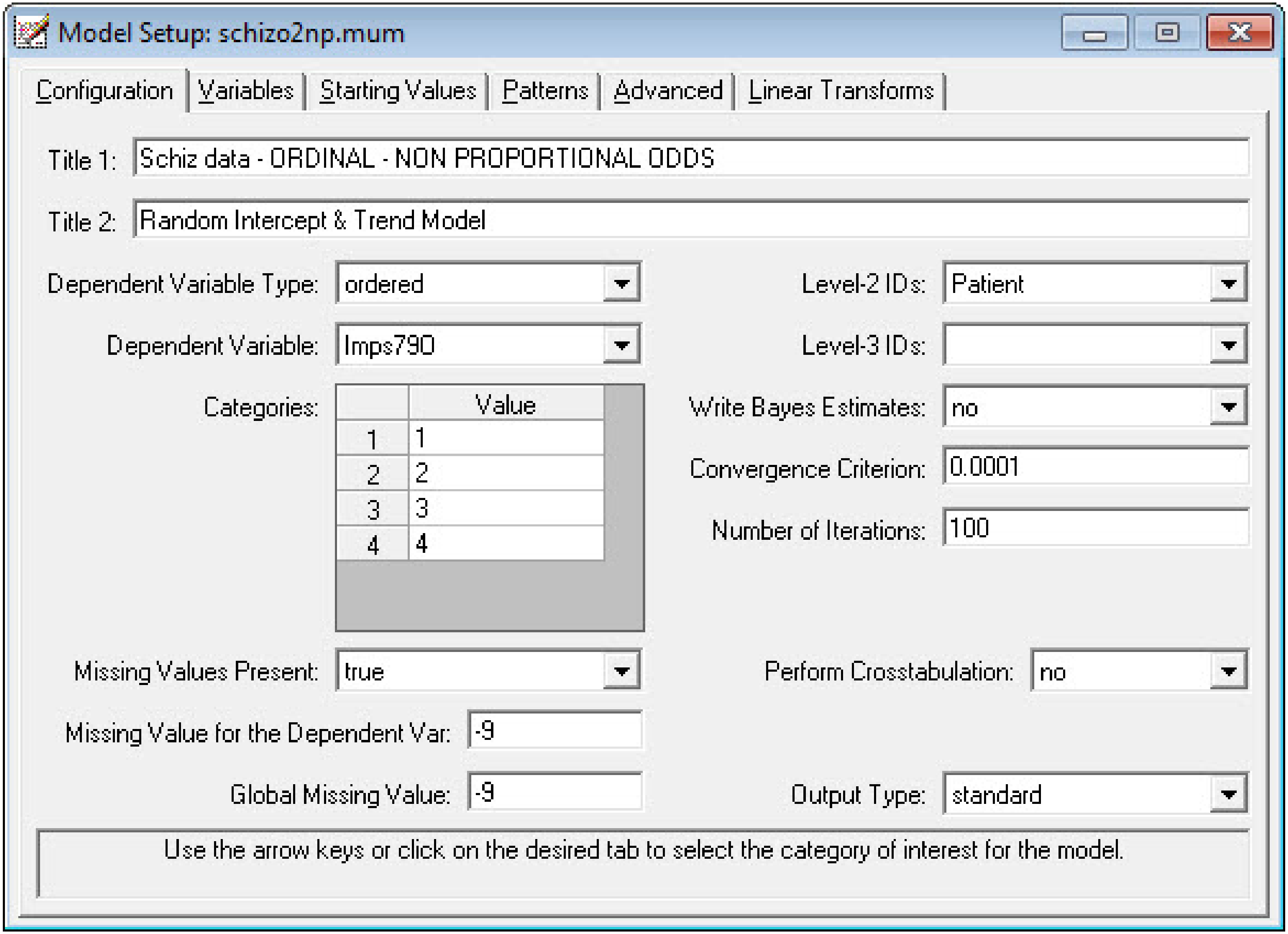
Open C:\SuperMixEn Examples\Workshop\Ordinal\schizo2np.mum

(or C:\SuperMixEn Student Examples\Workshop\Ordinal\schizo2np.mum)

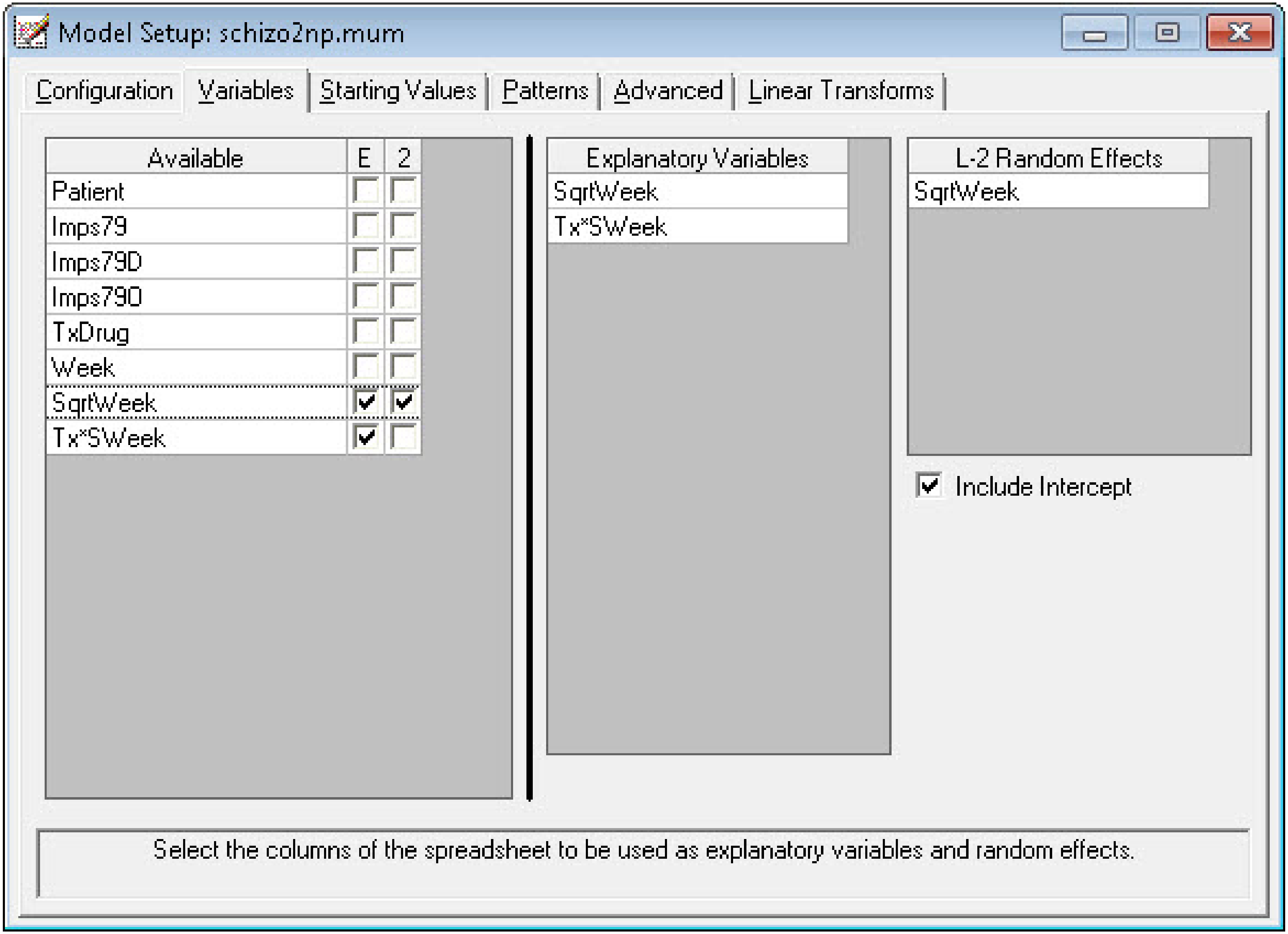


,

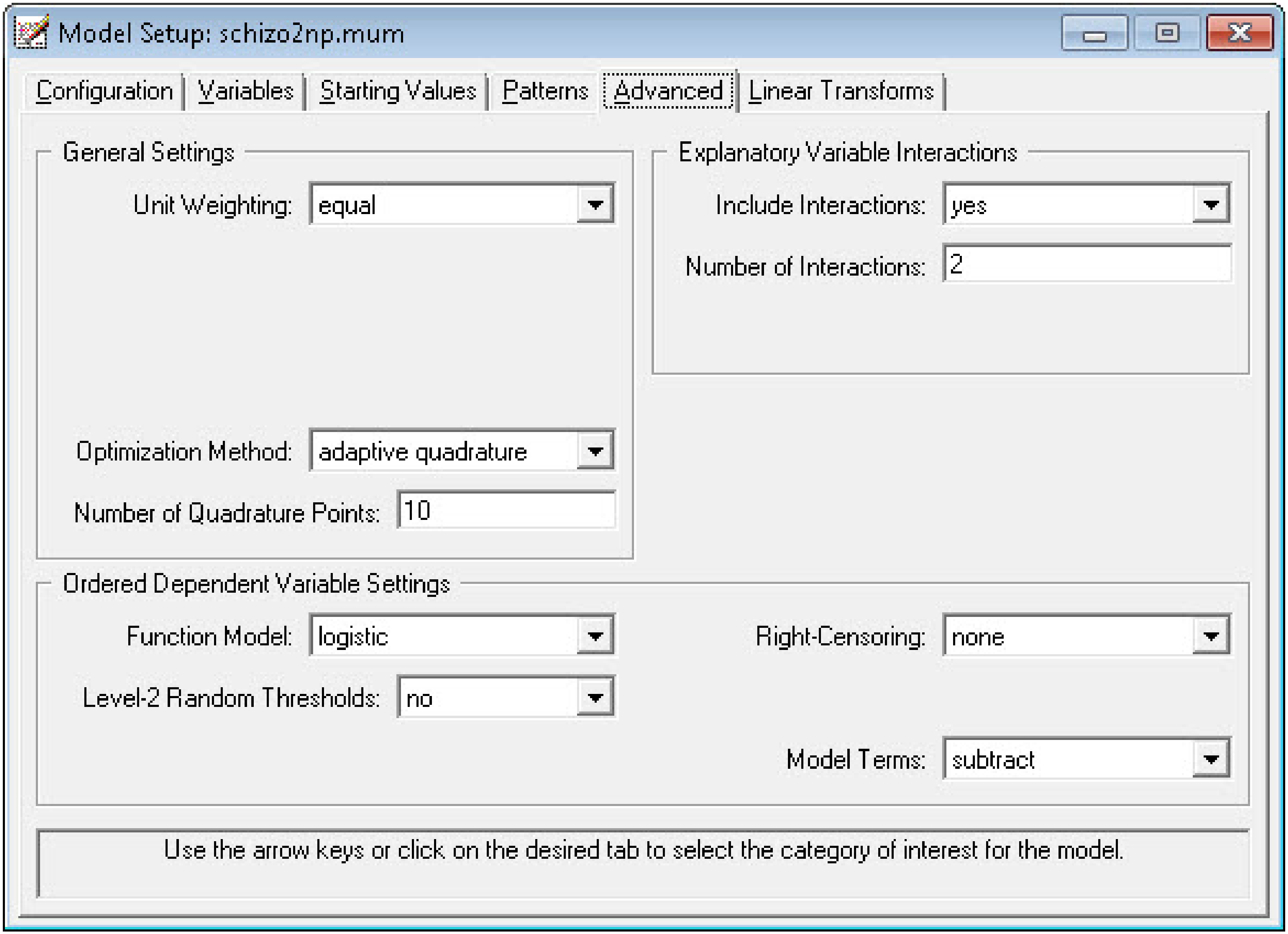
Note that "Dependent Variable Type" is "ordered"



Two explanatory variables: `SqrtWeek` and `Tx*SWeek`



“Explanatory Variable Interactions” - both are selected



schizo2np.out

```
 o========================================o
 | Optimization Method: Adaptive Quadrature |
 o========================================o

Number of quadrature points =              10
Number of free parameters =                12
Number of iterations used =                 6

-2lnL (deviance statistic) =       3324.16153
Akaike Information Criterion       3348.16153
Schwarz Criterion                  3412.71711


                    Estimated regression weights

                                          Standard
Parameter               Estimate           Error       z Value      P Value
---------               --------          --------     -------      -------
Threshold1               -7.4687           0.4860     -15.3681       0.0000
Threshold2               -3.5799           0.2779     -12.8808       0.0000
Threshold3               -0.8100           0.1935      -4.1848       0.0000
SqrtWeek                 -0.9506           0.3307      -2.8741       0.0041
Tx*SWeek                 -1.6827           0.2879      -5.8456       0.0000

Interactions of predictors with: Threshold2
SqrtWeek                 -0.0826           0.2991      -0.2761       0.7825
Tx*SWeek                  0.0799           0.2496       0.3199       0.7490

Interactions of predictors with: Threshold3
SqrtWeek                  0.1171           0.3332       0.3515       0.7252
Tx*SWeek                 -0.0004           0.2870      -0.0013       0.9990
```

Save As... Close

Proportional Odds Assumption Accepted: $\chi^2_4 = 3325.51 - 3324.16 = 1.35$

Linear Transforms

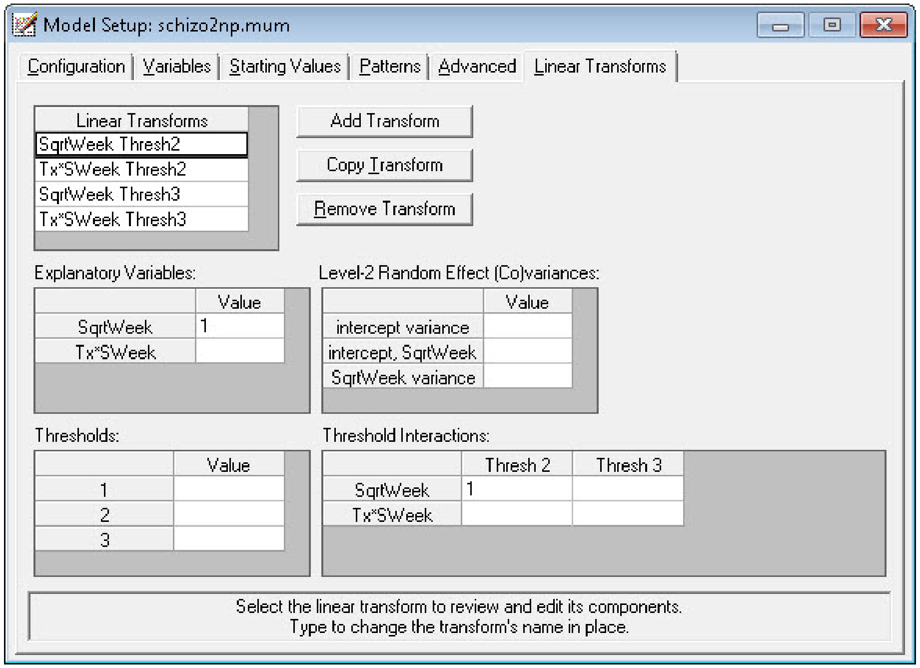
Fixed part of model:

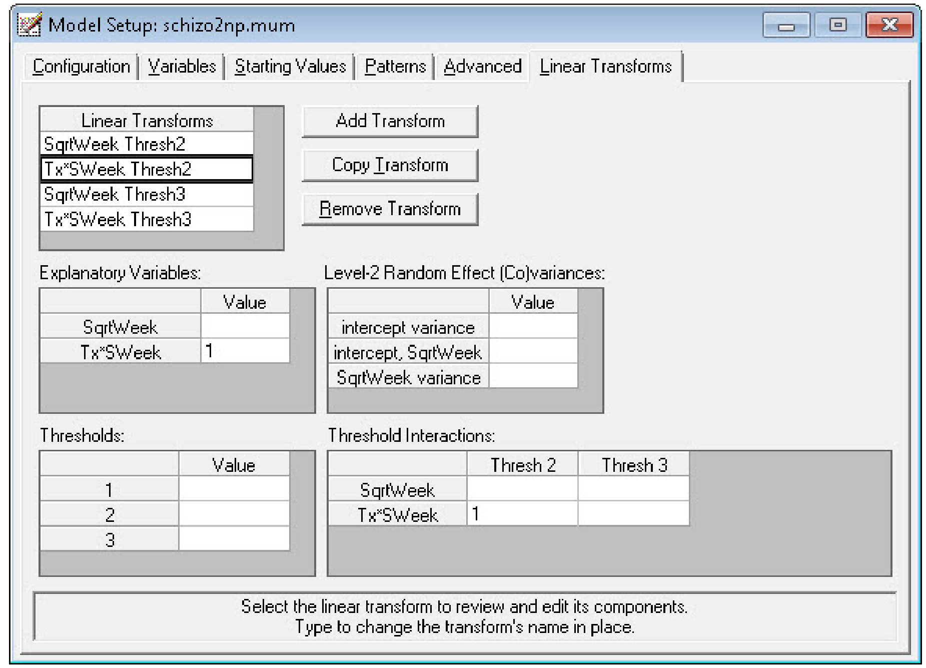
$$\lambda_c = \hat{\gamma}_{0c} - \Big[\hat{\beta}_1 \texttt{SqrtWeek} + \hat{\beta}_2 \texttt{Tx*SWeek} \\ + \; \hat{\gamma}_{1c} \texttt{SqrtWeek} + \hat{\gamma}_{2c} \texttt{Tx*SWeek}\Big]$$

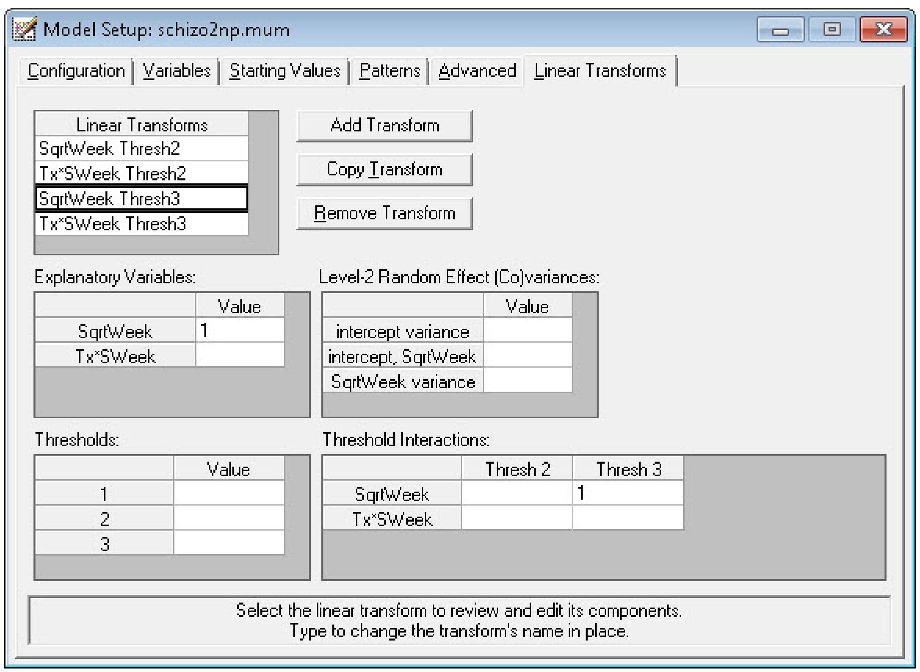
	cumulative logit		
variable	1 vs 2,3,4	1,2 vs 3,4	1,2,3, vs 4
`SqrtWeek`	$\hat{\beta}_1$	$\hat{\beta}_1 + \hat{\gamma}_{12}$	$\hat{\beta}_1 + \hat{\gamma}_{13}$
`Tx*SWeek`	$\hat{\beta}_2$	$\hat{\beta}_2 + \hat{\gamma}_{22}$	$\hat{\beta}_2 + \hat{\gamma}_{23}$

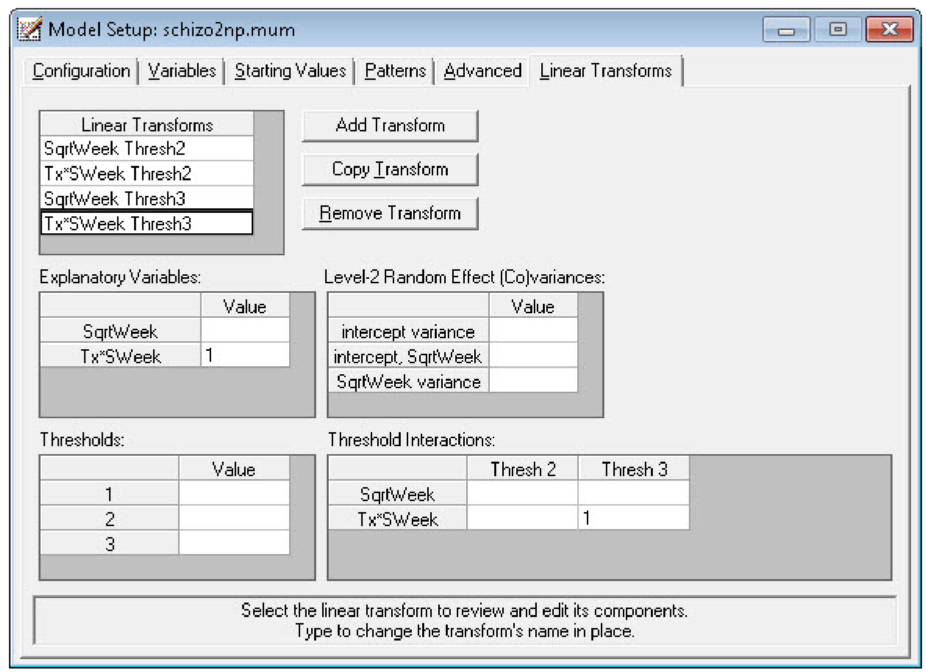
$H_0 : \beta_1 + \gamma_{12} = 0$; `SqrtWeek` effect is 0 on the 2nd cumulative logit

$$z = \frac{\hat{\beta}_1 + \hat{\gamma}_{12}}{SE(\hat{\beta}_1 + \hat{\gamma}_{12})}$$


Model Setup: schizo2np.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Linear Transforms
SqrtWeek Thresh2
Tx*SWeek Thresh2
SqrtWeek Thresh3
Tx*SWeek Thresh3
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
SqrtWeek 1
Tx*SWeek
Level-2 Random Effect (Co)variances:
Value
intercept variance
intercept, SqrtWeek
SqrtWeek variance
Thresholds:
Value
1
2
3
Threshold Interactions:
Thresh 2
Thresh 3
SqrtWeek 1
Tx*SWeek
Select the linear transform to review and edit its components.
Type to change the transform's name in place.


Model Setup: schizo2np.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Linear Transforms
SqrtWeek Thresh2
Tx*SWeek Thresh2
SqrtWeek Thresh3
Tx*SWeek Thresh3
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
SqrtWeek
Tx*SWeek 1
Level-2 Random Effect (Co)variances:
Value
intercept variance
intercept, SqrtWeek
SqrtWeek variance
Thresholds:
Value
1
2
3
Threshold Interactions:
Thresh 2
Thresh 3
SqrtWeek
Tx*SWeek 1
Select the linear transform to review and edit its components.
Type to change the transform's name in place.


Model Setup: schizo2np.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Linear Transforms
SqrtWeek Thresh2
Tx*SWeek Thresh2
SqrtWeek Thresh3
Tx*SWeek Thresh3
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
SqrtWeek 1
Tx*SWeek
Level-2 Random Effect (Co)variances:
Value
intercept variance
intercept, SqrtWeek
SqrtWeek variance
Thresholds:
Value
1
2
3
Threshold Interactions:
Thresh 2
Thresh 3
SqrtWeek 1
Tx*SWeek
Select the linear transform to review and edit its components.
Type to change the transform's name in place.


Model Setup: schizo2np.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Linear Transforms
SqrtWeek Thresh2
Tx*SWeek Thresh2
SqrtWeek Thresh3
Tx*SWeek Thresh3
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
SqrtWeek
Tx*SWeek 1
Level-2 Random Effect (Co)variances:
Value
intercept variance
intercept, SqrtWeek
SqrtWeek variance
Thresholds:
Value
1
2
3
Threshold Interactions:
Thresh 2
Thresh 3
SqrtWeek
Tx*SWeek 1
Select the linear transform to review and edit its components.
Type to change the transform's name in place.

schizo2np.out

```
          |-------------------------------------|
          |         TESTING OF TRANSFORMS       |
          |  (General Linear Hypothesis Testing) |
          |-------------------------------------|


 ------------------------------------------------------------------------------------------
  Coefficients                                       Estimate    Transform No.
                                                                 1          2          3
 ------------------------------------------------------------------------------------------
    1 Threshold1                                    -7.46875    0.0000     0.0000     0.0000
    2 Threshold2                                    -3.57991    0.0000     0.0000     0.0000
    3 Threshold3                                    -0.80996    0.0000     0.0000     0.0000
    4 SqrtWeek                                      -0.95058    1.0000     0.0000     1.0000
    5 Tx*SWeek                                      -1.68268    0.0000     1.0000     0.0000
    6 SqrtWeek          *Threshold2                 -0.08259    1.0000     0.0000     0.0000
    7 Tx*SWeek          *Threshold2                  0.07985    0.0000     1.0000     0.0000
    8 SqrtWeek          *Threshold3                  0.11712    0.0000     0.0000     1.0000
    9 Tx*SWeek          *Threshold3                 -0.00037    0.0000     0.0000     0.0000
   10 Var(intercept)                                 7.37046    0.0000     0.0000     0.0000
   11 Cov(SqrtWeek,intercept)                       -1.67047    0.0000     0.0000     0.0000
   12 Var(SqrtWeek)                                  2.03449    0.0000     0.0000     0.0000

  Transform Estimate                                           -1.0332    -1.6028    -0.8335
  Standard Error                                                0.2240     0.2287     0.2063
  Z-Statistic                                                  -4.6133    -7.0090    -4.0392
  Exceedence Pobability                                         0.0000     0.0000     0.0001
```

Save As...   Close

schizo2np.out

```
LINEAR TRANSFORMS (continued)

----------------------------------------------------------------------------
  Coefficients                                        Estimate    Transform No.
                                                                       4
----------------------------------------------------------------------------
   1 Threshold1                                     -7.46875     0.0000
   2 Threshold2                                     -3.57991     0.0000
   3 Threshold3                                     -0.80996     0.0000
   4 SqrtWeek                                       -0.95058     0.0000
   5 Tx*SWeek                                       -1.68268     1.0000
   6 SqrtWeek        *Threshold2                    -0.08259     0.0000
   7 Tx*SWeek        *Threshold2                     0.07985     0.0000
   8 SqrtWeek        *Threshold3                     0.11712     0.0000
   9 Tx*SWeek        *Threshold3                    -0.00037     1.0000
  10 Var(intercept)                                  7.37046     0.0000
  11 Cov(SqrtWeek,intercept)                        -1.67047     0.0000
  12 Var(SqrtWeek)                                   2.03449     0.0000

  Transform Estimate                                            -1.6831
  Standard Error                                                 0.2370
  Z-Statistic                                                   -7.1012
  Exceedence Pobability                                          0.0000
```

Save As... Close

NIMH Schiz Study: Severity of Illness ($N = 437$)
Ordinal LR Estimates (se) - *random intercept and trend model*

	Proportional Odds Model	Non-Proportional Odds Model		
		1 vs 2,3,4	1,2 vs 3,4	1,2,3 vs 4
Time (sqrt week)	-0.900	-0.951	-1.033	-0.834
	(0.190)	(0.331)	(0.224)	(0.206)
Drug by Time	-1.674	-1.683	-1.603	-1.683
	(0.208)	(0.288)	(0.229)	(0.237)
$-2\log L$	3325.51		3324.16	

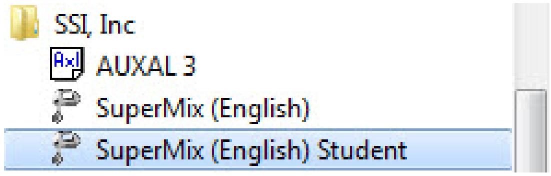
- Proportional Odds accepted ($\chi^2_4 = 3325.51 - 3324.16 = 1.35$)

San Diego Homeless Research Project (Hough)

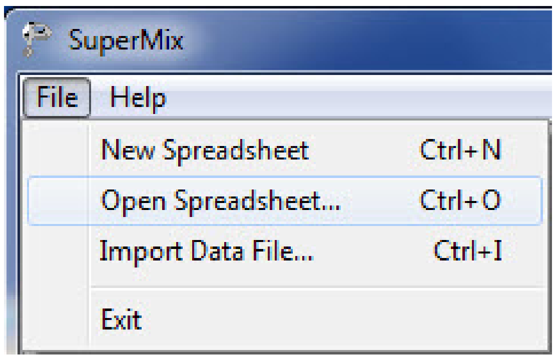
- 361 mentally ill subjects who were homeless or at very high risk of becoming homeless
- 2 conditions: HUD Section 8 rental certificates (yes/no)
- baseline and 6, 12, and 24 month follow-ups
- Categorical outcome: housing status
  - streets / shelters ($Y = 0$)
  - community / institutions ($Y = 1$)
  - independent ($Y = 2$)

Question: Do Section 8 certificates influence housing status across time?

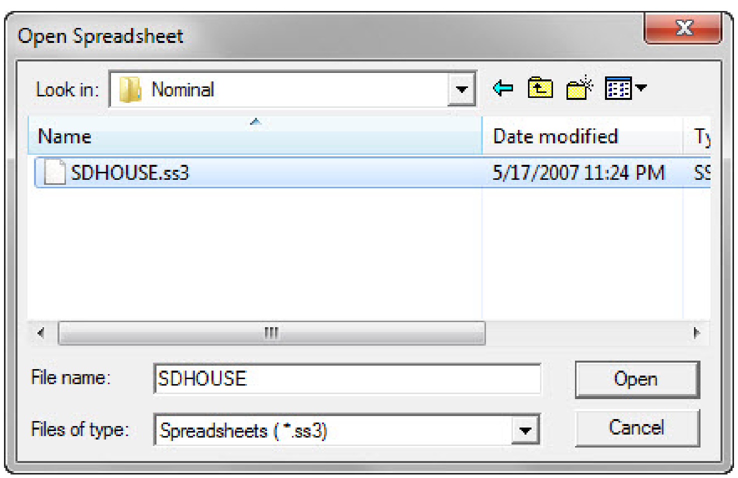
- Under SSI, Inc > “SuperMix (English)” or “SuperMix (English) Student”



- Under “File” click on “Open Spreadsheet”



- Open C:\SuperMixEn Examples\Workshop\Nominal\SDHOUSE.ss3 (or C:\SuperMixEn Student Examples\Workshop\Nominal\SDHOUSE.ss3)

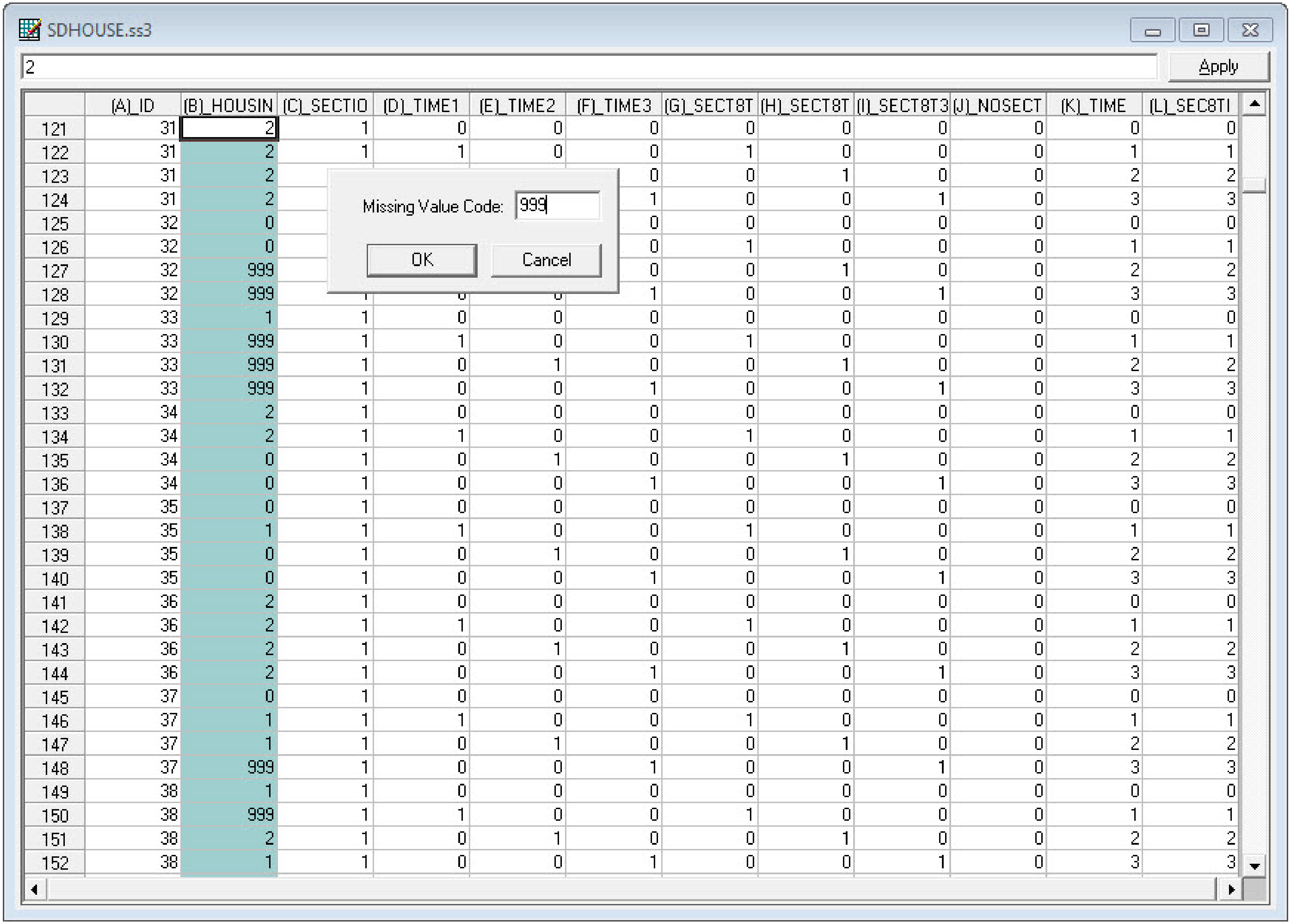


C:\SuperMixEn Examples\Workshop\Nominal\SDHOUSE.ss3

SDHOUSE.ss3

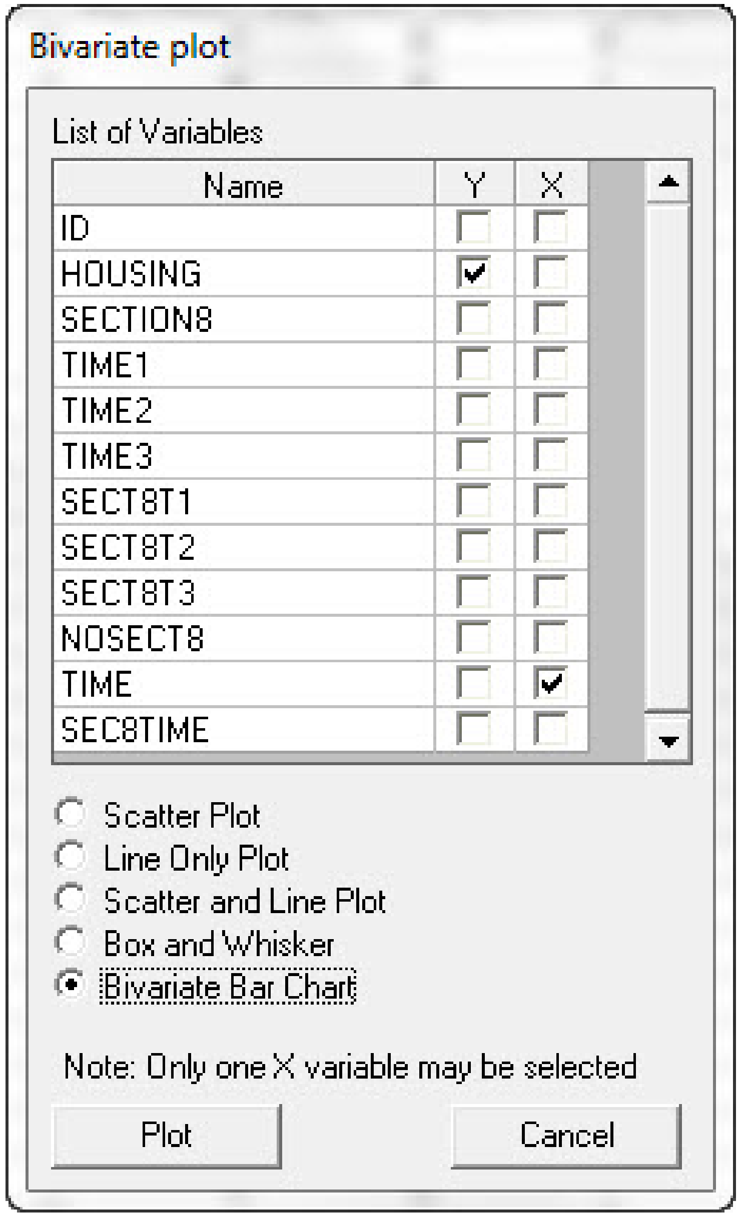
	(A)_ID	(B)_HOUSIN	(C)_SECTIO	(D)_TIME1	(E)_TIME2	(F)_TIME3	(G)_SECT8T	(H)_SECT8T	(I)_SECT8T3	(J)_NOSECT	(K)_TIME	(L)_SEC8TI
1	1	1	1	0	0	0	0	0	0	0	0	0
2	1	2	1	1	0	0	1	0	0	0	1	1
3	1	2	1	0	1	0	0	1	0	0	2	2
4	1	2	1	0	0	1	0	0	1	0	3	3
5	2	1	1	0	0	0	0	0	0	0	0	0
6	2	2	1	1	0	0	1	0	0	0	1	1
7	2	2	1	0	1	0	0	1	0	0	2	2
8	2	1	1	0	0	1	0	0	1	0	3	3
9	3	0	1	0	0	0	0	0	0	0	0	0
10	3	2	1	1	0	0	1	0	0	0	1	1
11	3	2	1	0	1	0	0	1	0	0	2	2
12	3	2	1	0	0	1	0	0	1	0	3	3
13	4	1	1	0	0	0	0	0	0	0	0	0
14	4	1	1	1	0	0	1	0	0	0	1	1
15	4	1	1	0	1	0	0	1	0	0	2	2
16	4	1	1	0	0	1	0	0	1	0	3	3
17	5	0	1	0	0	0	0	0	0	0	0	0
18	5	1	1	1	0	0	1	0	0	0	1	1
19	5	2	1	0	1	0	0	1	0	0	2	2
20	5	2	1	0	0	1	0	0	1	0	3	3
21	6	2	1	0	0	0	0	0	0	0	0	0
22	6	2	1	1	0	0	1	0	0	0	1	1
23	6	2	1	0	1	0	0	1	0	0	2	2
24	6	2	1	0	0	1	0	0	1	0	3	3
25	7	2	1	0	0	0	0	0	0	0	0	0
26	7	2	1	1	0	0	1	0	0	0	1	1
27	7	2	1	0	1	0	0	1	0	0	2	2
28	7	2	1	0	0	1	0	0	1	0	3	3
29	8	2	1	0	0	0	0	0	0	0	0	0
30	8	0	1	1	0	0	1	0	0	0	1	1
31	8	0	1	0	1	0	0	1	0	0	2	2
32	8	2	1	0	0	1	0	0	1	0	3	3

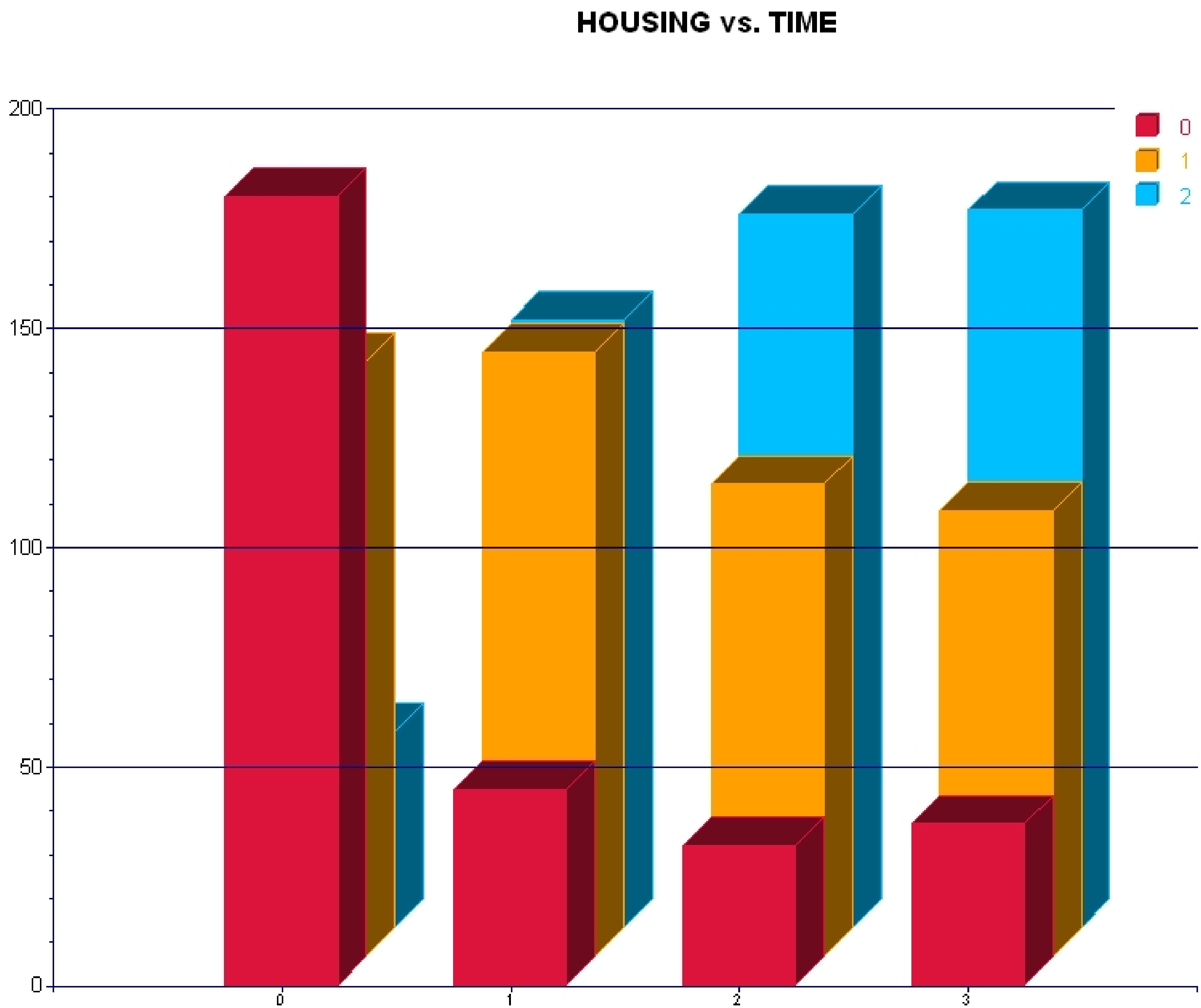
Select **`Housing`** column, then "Edit" > "Set Missing Value"



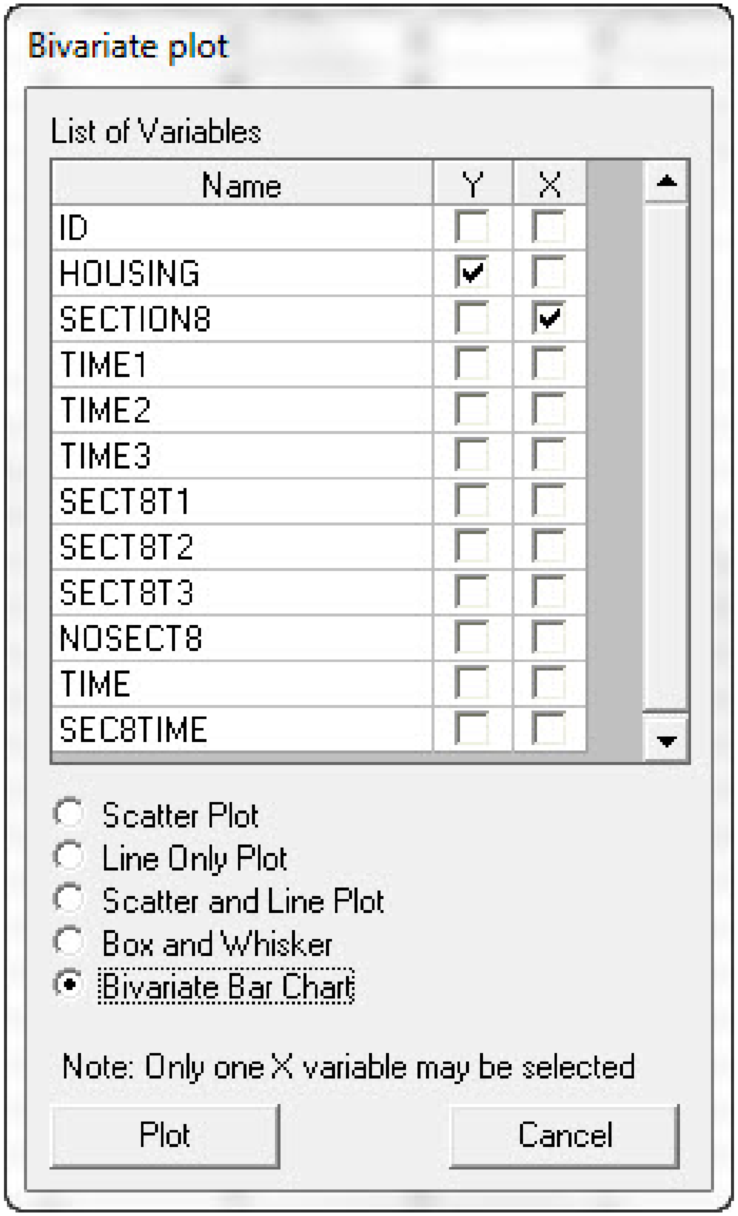
	(A)_ID	(B)_HOUSIN	(C)_SECTIO	(D)_TIME1	(E)_TIME2	(F)_TIME3	(G)_SECT8T	(H)_SECT8T	(I)_SECT8T3	(J)_NOSECT	(K)_TIME	(L)_SEC8TI
121	31	2	1	0	0	0	0	0	0	0	0	0
122	31	2	1	1	0	0	1	0	0	0	1	1
123	31	2				0	0	1	0	0	2	2
124	31	2				1	0	0	1	0	3	3
125	32	0				0	0	0	0	0	0	0
126	32	0				0	1	0	0	0	1	1
127	32	999				0	0	1	0	0	2	2
128	32	999				1	0	0	1	0	3	3
129	33	1	1	0	0	0	0	0	0	0	0	0
130	33	999	1	1	0	0	1	0	0	0	1	1
131	33	999	1	0	1	0	0	1	0	0	2	2
132	33	999	1	0	0	1	0	0	1	0	3	3
133	34	2	1	0	0	0	0	0	0	0	0	0
134	34	2	1	1	0	0	1	0	0	0	1	1
135	34	0	1	0	1	0	0	1	0	0	2	2
136	34	0	1	0	0	1	0	0	1	0	3	3
137	35	0	1	0	0	0	0	0	0	0	0	0
138	35	1	1	1	0	0	1	0	0	0	1	1
139	35	0	1	0	1	0	0	1	0	0	2	2
140	35	0	1	0	0	1	0	0	1	0	3	3
141	36	2	1	0	0	0	0	0	0	0	0	0
142	36	2	1	1	0	0	1	0	0	0	1	1
143	36	2	1	0	1	0	0	1	0	0	2	2
144	36	2	1	0	0	1	0	0	1	0	3	3
145	37	0	1	0	0	0	0	0	0	0	0	0
146	37	1	1	1	0	0	1	0	0	0	1	1
147	37	1	1	0	1	0	0	1	0	0	2	2
148	37	999	1	0	0	1	0	0	1	0	3	3
149	38	1	1	0	0	0	0	0	0	0	0	0
150	38	999	1	1	0	0	1	0	0	0	1	1
151	38	2	1	0	1	0	0	1	0	0	2	2
152	38	1	1	0	0	1	0	0	1	0	3	3

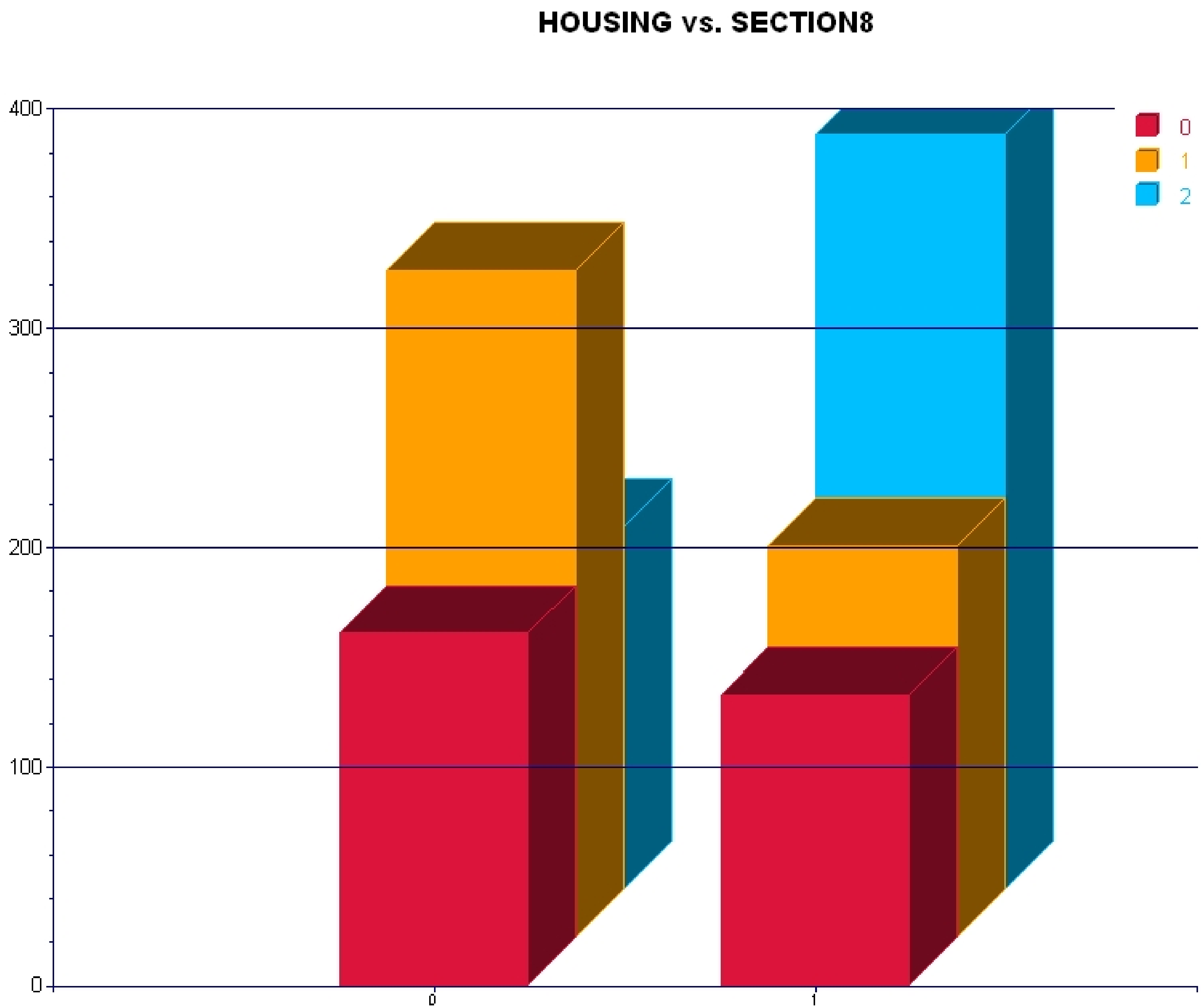
Select "File" > "Data-based Graphs" > "Bivariate"

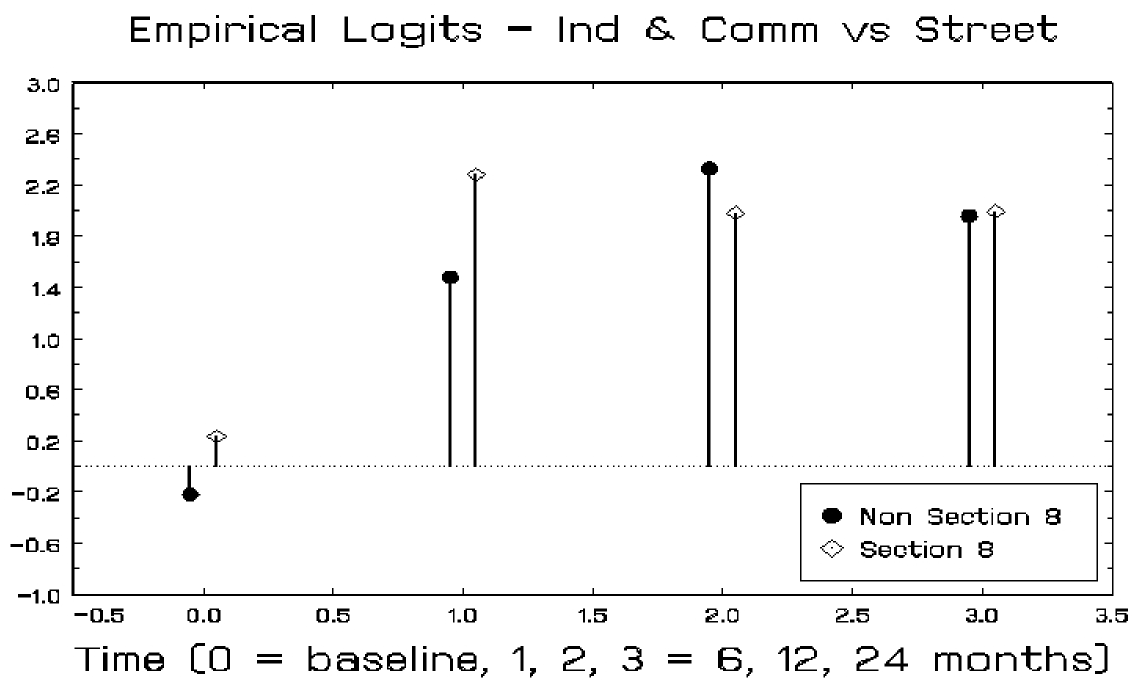


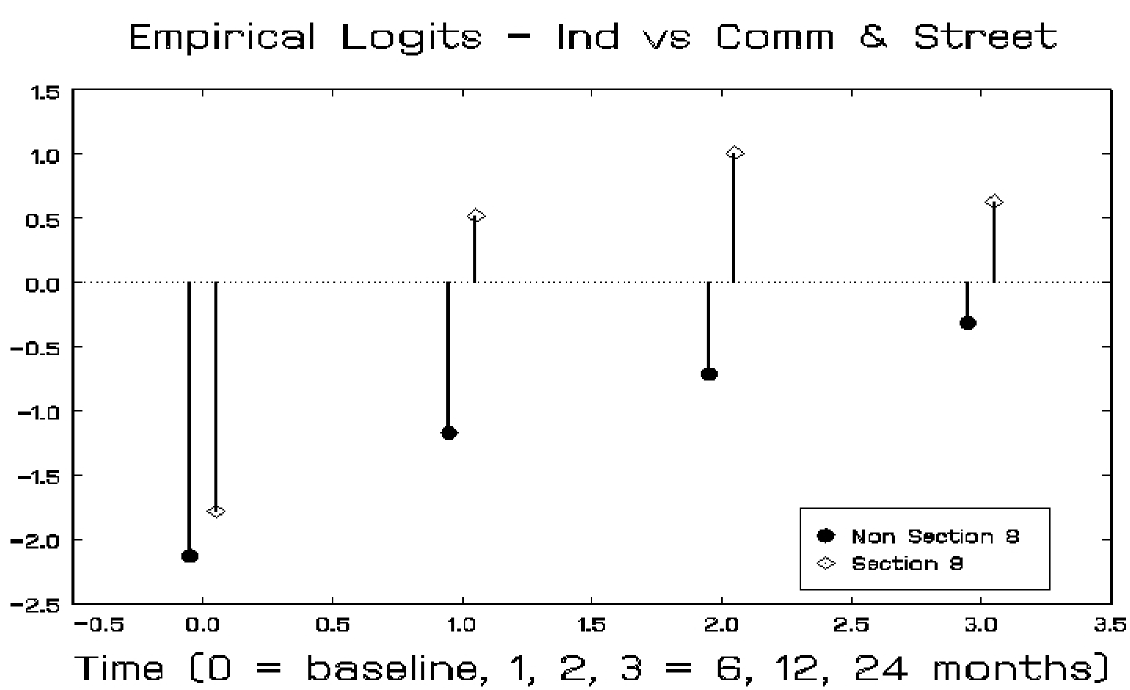

HOUSING vs. TIME
200
150
100
50
0
0
1
2
3
0
1
2

Select "File" > "Data-based Graphs" > "Bivariate"

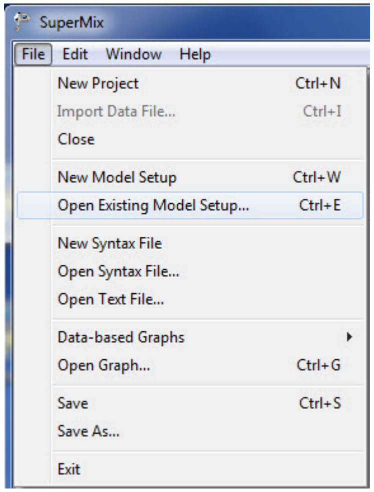



HOUSING vs. SECTION8
400
300
200
100
0
0
1
0
1
2

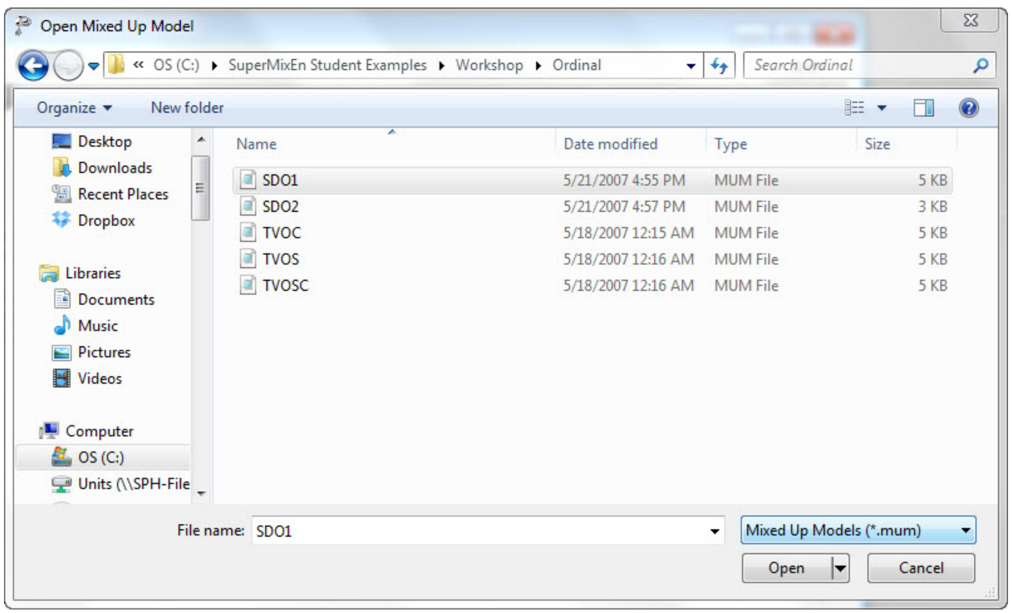

Empirical Logits - Ind & Comm vs Street
3.0
2.6
2.2
1.8
1.4
1.0
0.6
0.2
-0.2
-0.6
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Non Section 8
Section 8
Time (0 = baseline, 1, 2, 3 = 6, 12, 24 months)


Empirical Logits - Ind vs Comm & Street
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Non Section 8
Section 8
Time (0 = baseline, 1, 2, 3 = 6, 12, 24 months)

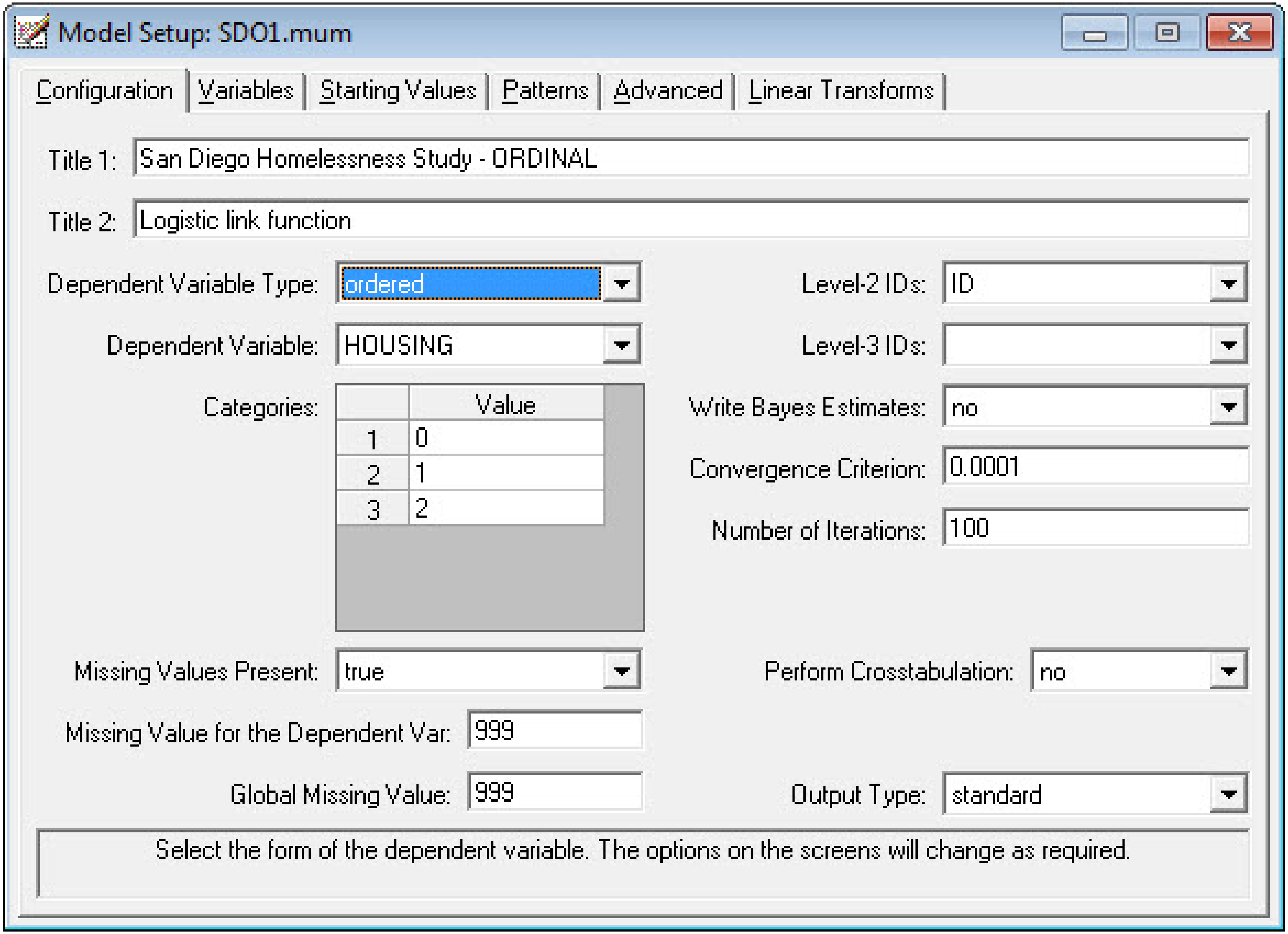
Under "File" click on "Open Existing Model Setup"



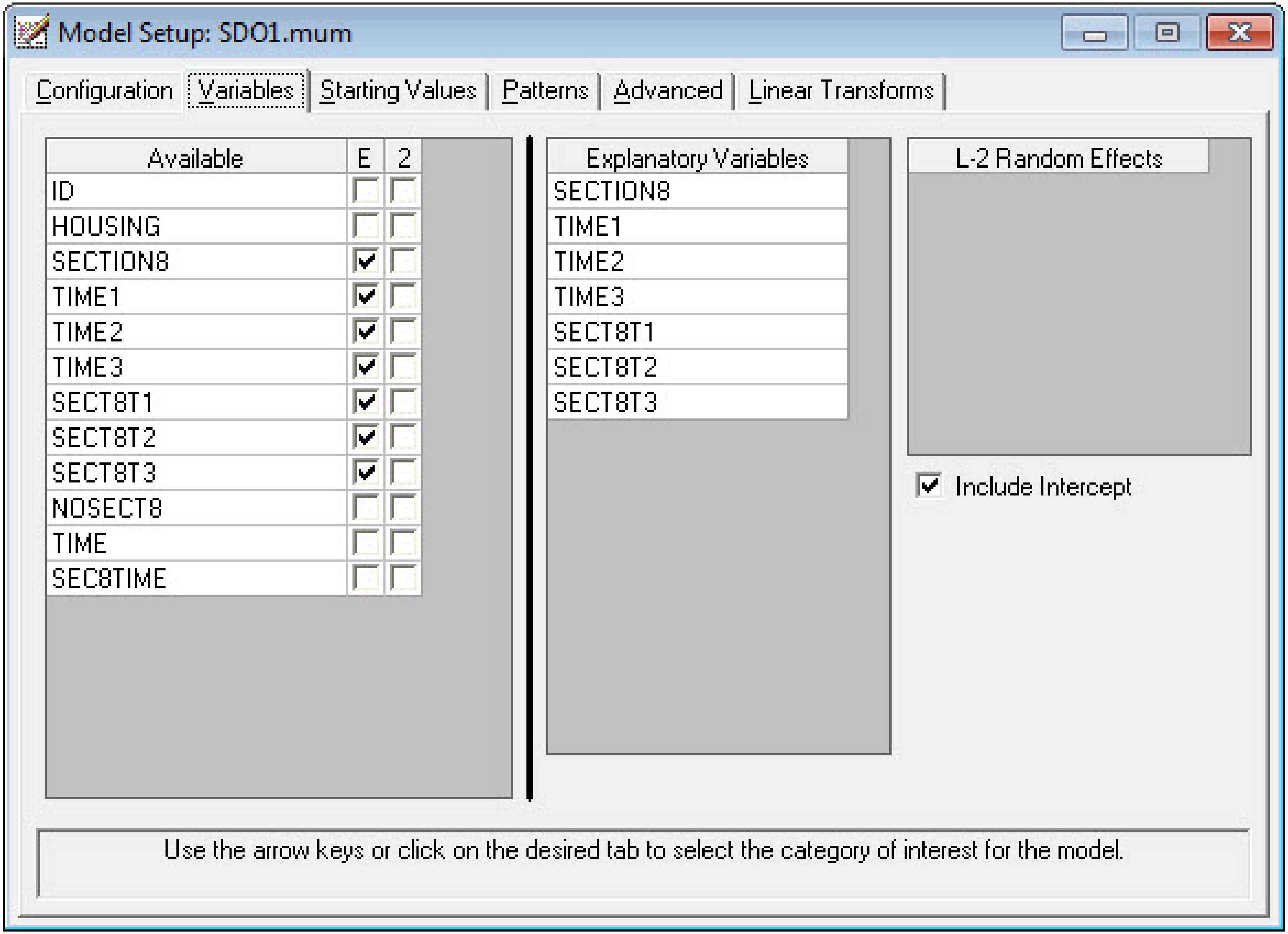
Open C:\SuperMixEn Examples\Workshop\Ordinal\SDO1.mum
(or C:\SuperMixEn Student Examples\Workshop\Ordinal\SDO1.mum)



Note that “Dependent Variable Type” is “ordered”



All explanatory variables are indicator (dummy) variables



Housing status across time: 1289 observations within 361 subjects
Ordinal Mixed Regression Model estimates and standard errors (se)

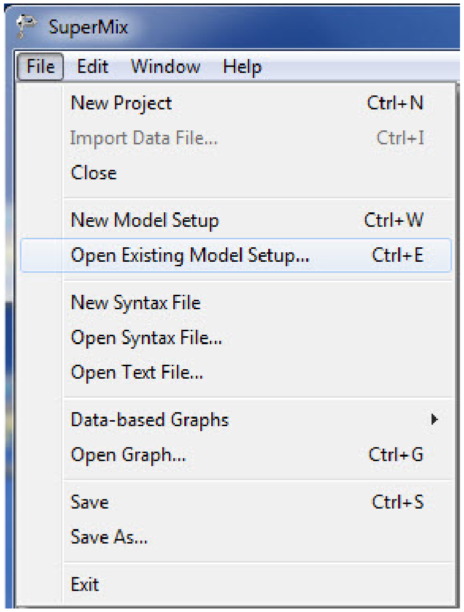
	Proportional Odds		Non-Proportional Odds					
			Non-street[1]		Independent[2]		difference	
term	estimate	se	estimate	se	estimate	se	estimate	se
threshold_1	.220	.198	.322	.207				
threshold_2	**2.966**	.230			**2.700**	.298		
t1 (6 month)	**1.736**	.235	**2.298**	.303	**1.079**	.343	**-1.219**	.408
t2 (12 month)	**2.316**	.247	**3.346**	.387	**1.645**	.340	**-1.701**	.467
t3 (24 month)	**2.500**	.253	**2.822**	.348	**2.145**	.337	-.676	.422
section 8 (yes=1)	*.497*	.277	**.592**	.294	.323	.394	-.269	.384
section 8 by t1	**1.409**	.341	.566	.467	**2.024**	.471	**1.457**	.581
section 8 by t2	**1.173**	.354	*-.958*	.506	**2.017**	.476	**2.975**	.600
section 8 by t3	*.638*	.349	-.366	.480	**1.073**	.464	**1.440**	.573
subject var	**2.134**	.354	**2.128**	.353	($ICC \approx .4$)			
$-2 \log L$	2274.39		2222.25		($\chi^2_7 = 52.14$)			

bold indicates $p < .05$ *italic* indicates $.05 < p < .10$

[1] = independent + community vs street

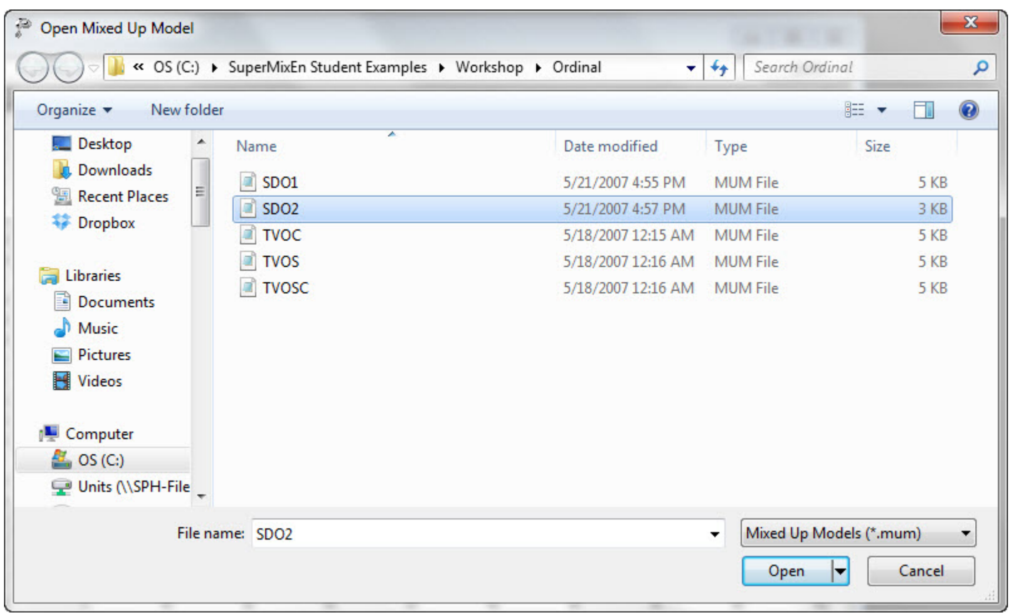
[2] = independent vs community + street

For Non-Proportional Odds model, under "File" click on "Open Existing Model Setup"

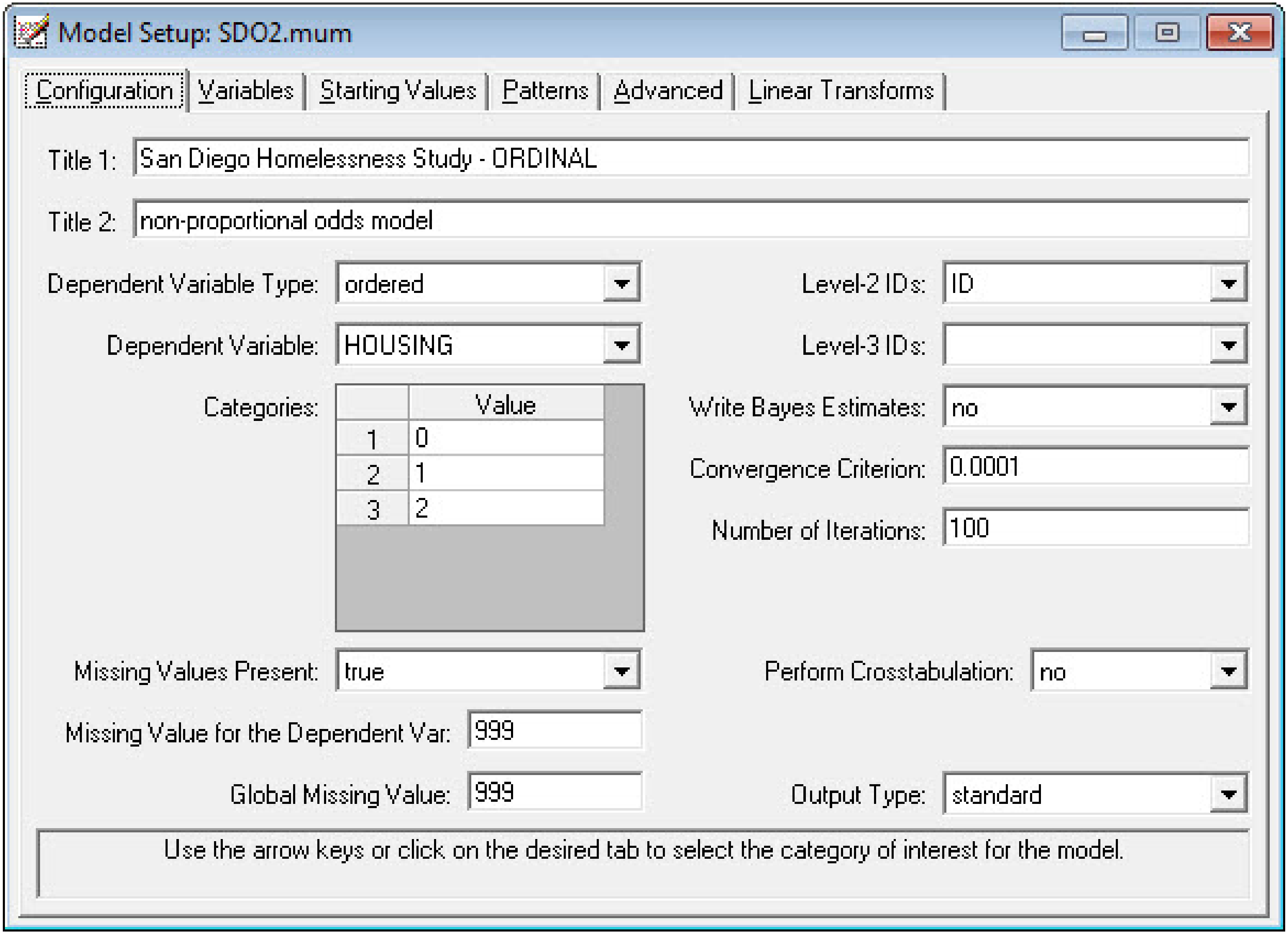


Open C:\SuperMixEn Examples\Workshop\Ordinal\SDO2.mum

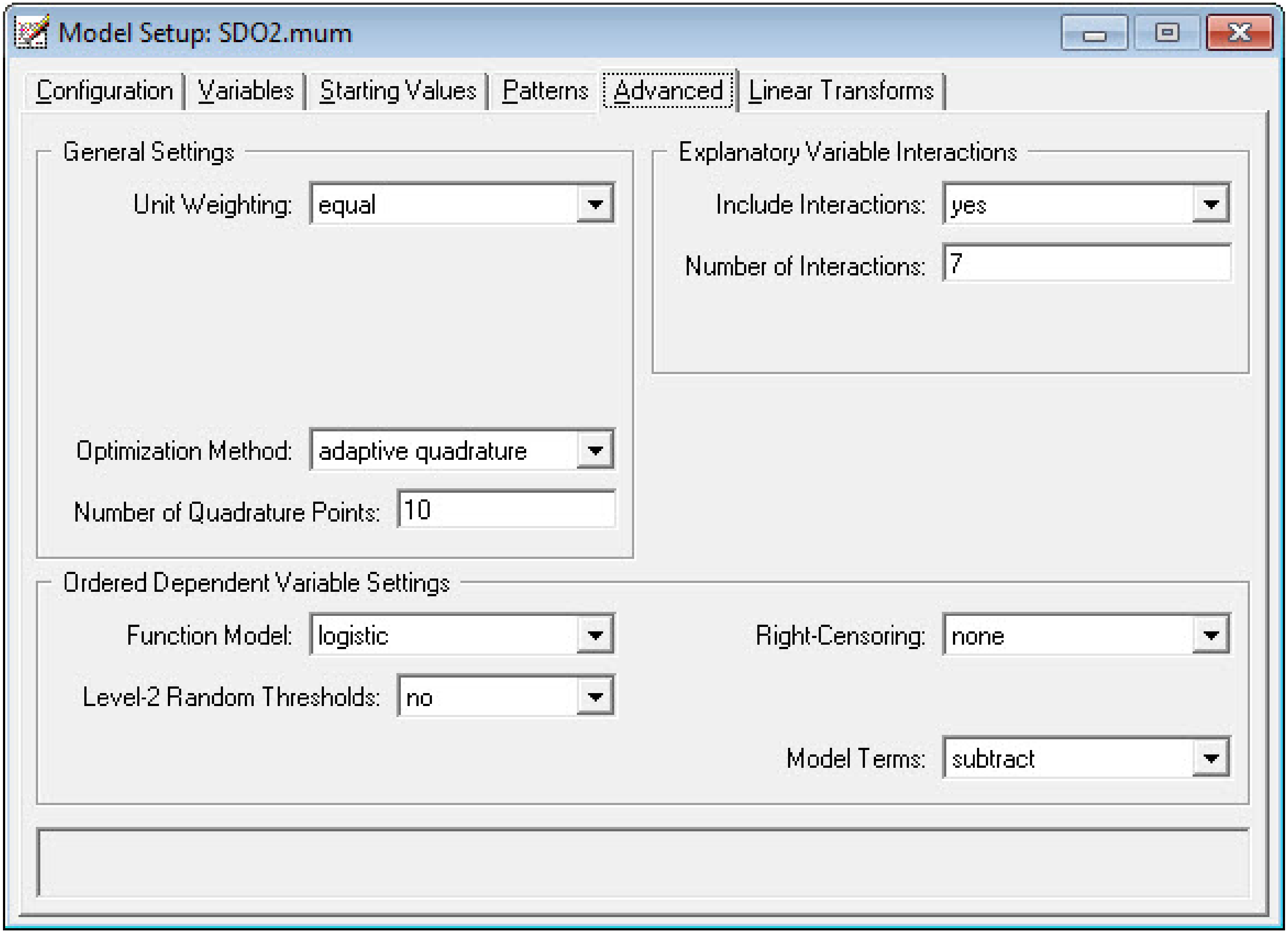
(or C:\SuperMixEn Student Examples\Workshop\Ordinal\SDO2.mum)

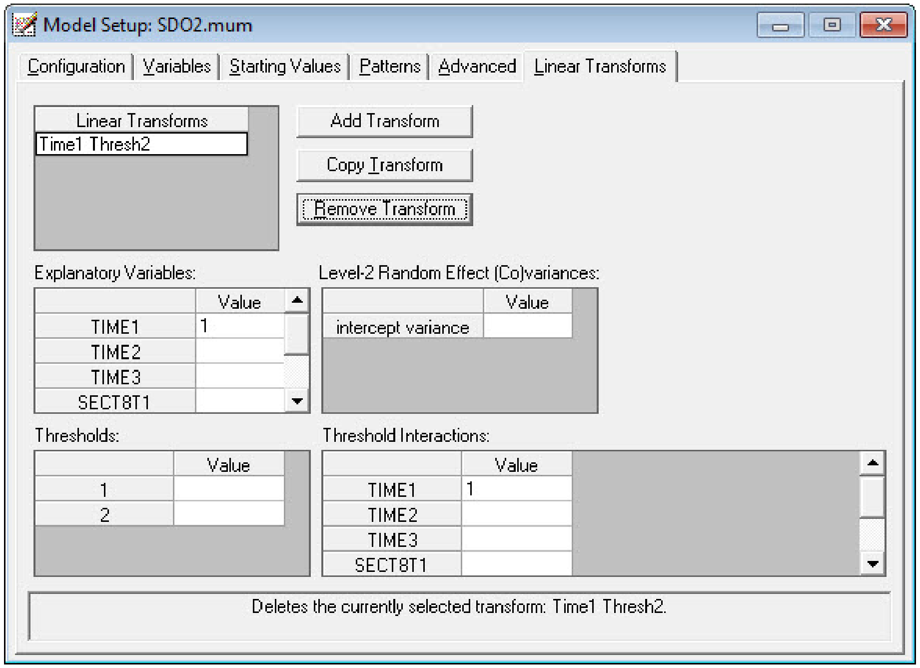


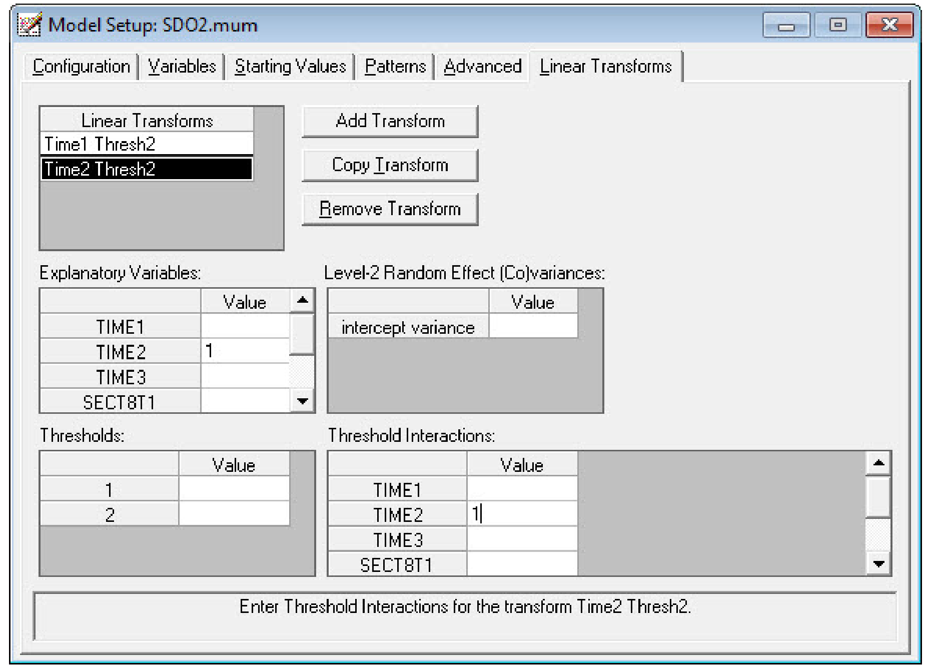
Note that “Dependent Variable Type” is “ordered”

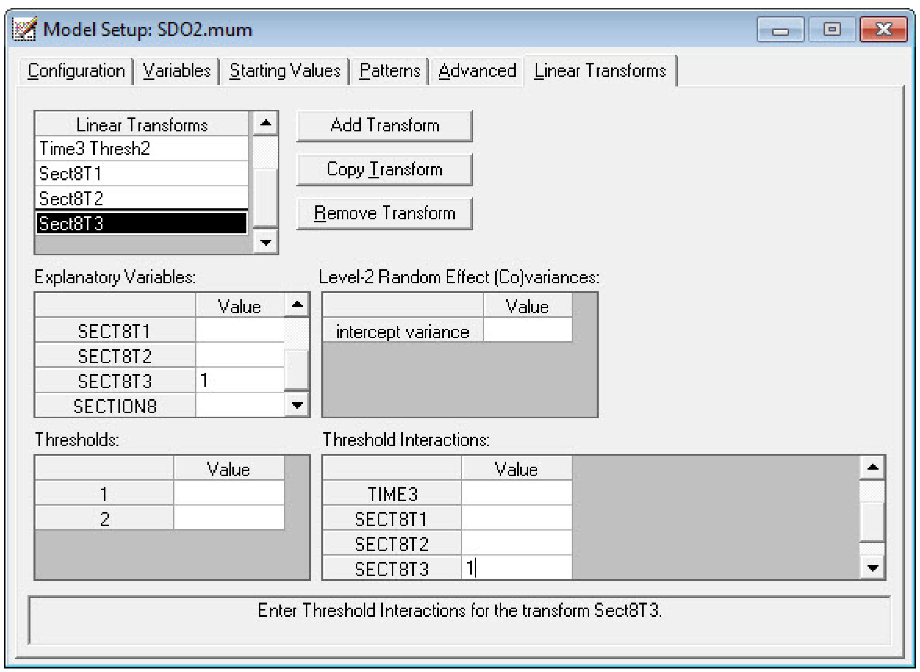


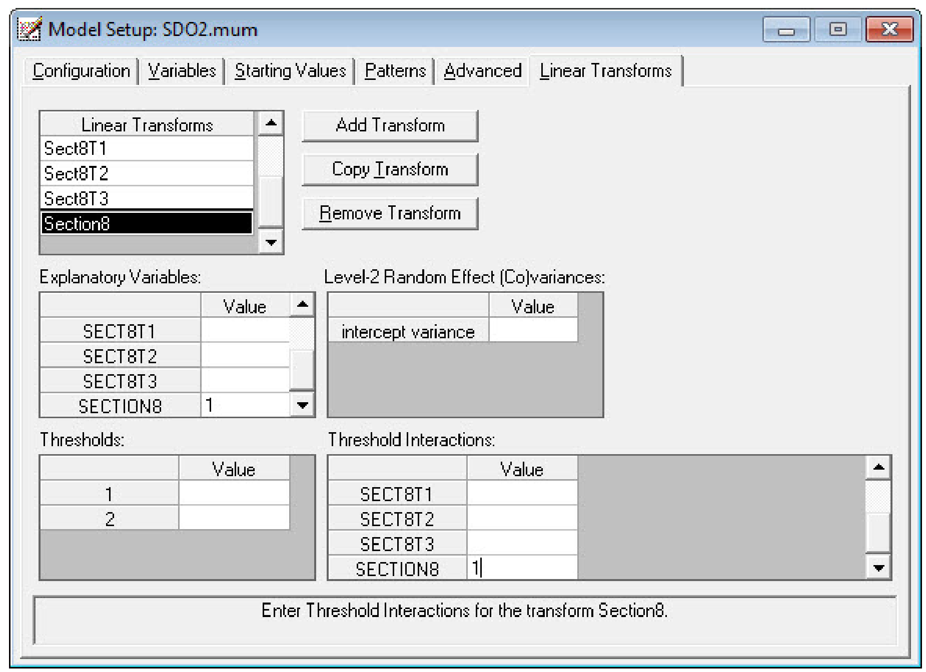
Note “Explanatory Variable Interactions” is set to 7




Model Setup: SDO2.mum
Configuration | Variables | Starting Values | Patterns | Advanced | Linear Transforms
Linear Transforms
Time1 Thresh2
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
TIME1 1
TIME2
TIME3
SECT8T1
Level-2 Random Effect (Co)variances:
Value
intercept variance
Thresholds:
Value
1
2
Threshold Interactions:
Value
TIME1 1
TIME2
TIME3
SECT8T1
Deletes the currently selected transform: Time1 Thresh2.


Model Setup: SDO2.mum
Configuration | Variables | Starting Values | Patterns | Advanced | Linear Transforms
Linear Transforms
Time1 Thresh2
Time2 Thresh2
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
TIME1
TIME2 1
TIME3
SECT8T1
Level-2 Random Effect (Co)variances:
Value
intercept variance
Thresholds:
Value
1
2
Threshold Interactions:
Value
TIME1
TIME2 1
TIME3
SECT8T1
Enter Threshold Interactions for the transform Time2 Thresh2.


Model Setup: SDO2.mum
Configuration | Variables | Starting Values | Patterns | Advanced | Linear Transforms
Linear Transforms
Time3 Thresh2
Sect8T1
Sect8T2
Sect8T3
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
SECT8T1
SECT8T2
SECT8T3 1
SECTION8
Level-2 Random Effect (Co)variances:
Value
intercept variance
Thresholds:
Value
1
2
Threshold Interactions:
Value
TIME3
SECT8T1
SECT8T2
SECT8T3 1
Enter Threshold Interactions for the transform Sect8T3.


Model Setup: SDO2.mum
Configuration | Variables | Starting Values | Patterns | Advanced | Linear Transforms
Linear Transforms
Sect8T1
Sect8T2
Sect8T3
Section8
Add Transform
Copy Transform
Remove Transform
Explanatory Variables:
Value
SECT8T1
SECT8T2
SECT8T3
SECTION8 1
Level-2 Random Effect (Co)variances:
Value
intercept variance
Thresholds:
Value
1
2
Threshold Interactions:
Value
SECT8T1
SECT8T2
SECT8T3
SECTION8 1
Enter Threshold Interactions for the transform Section8.

Mixed Multinomial Logistic Regression Model

Y_{ij} = nominal response of level-2 unit i and level-1 unit j

Which member of The Polkaholics is your favorite?
(asked before, during, and after a show)

Mixed-effects Multinomial Logistic Regression Model

$$\log \frac{p_{ijc}}{p_{ij1}} = \boldsymbol{u}'_{ij}\boldsymbol{\gamma}_c + \boldsymbol{z}'_{ij}\boldsymbol{v}_{ic} \qquad c = 2, 3, \ldots C$$

- $C - 1$ contrasts to reference cell ($c = 1$)
- regression effects $\boldsymbol{\gamma}_c$ vary across contrasts
- random-effects $\boldsymbol{v}_{ic}$ vary across contrasts
  - independent
  - correlated

For example, with C = 3

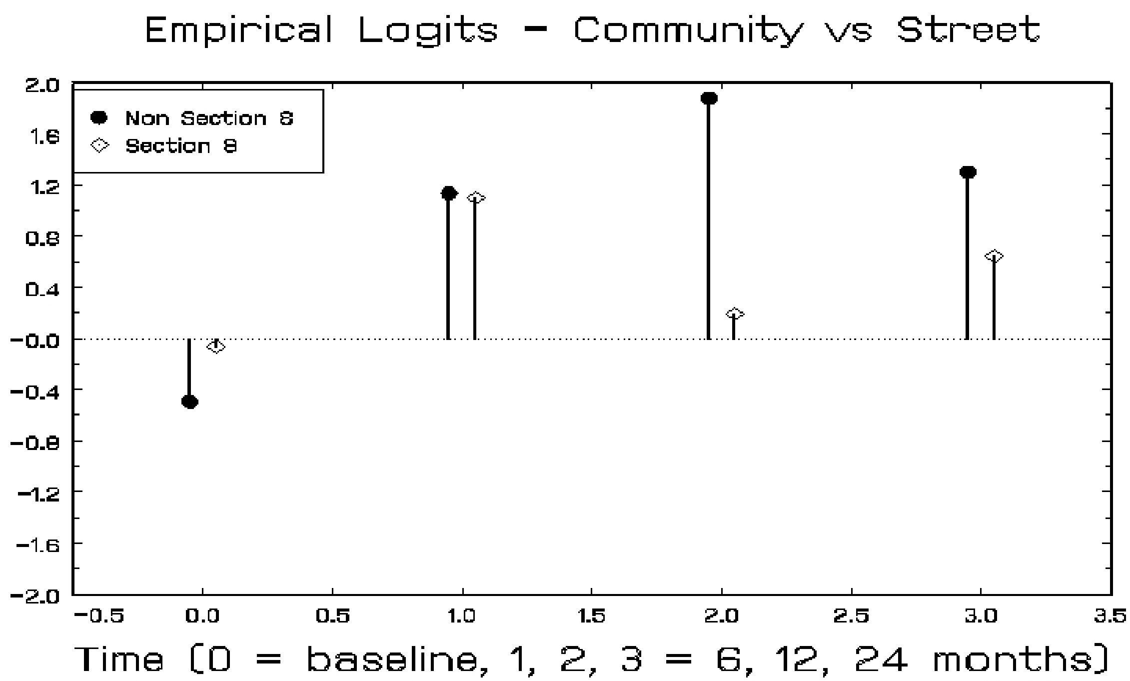
contrast	ordinal	nominal
c1	2 & 3 vs 1	2 vs 1
c2	3 vs 1 & 2	3 vs 1

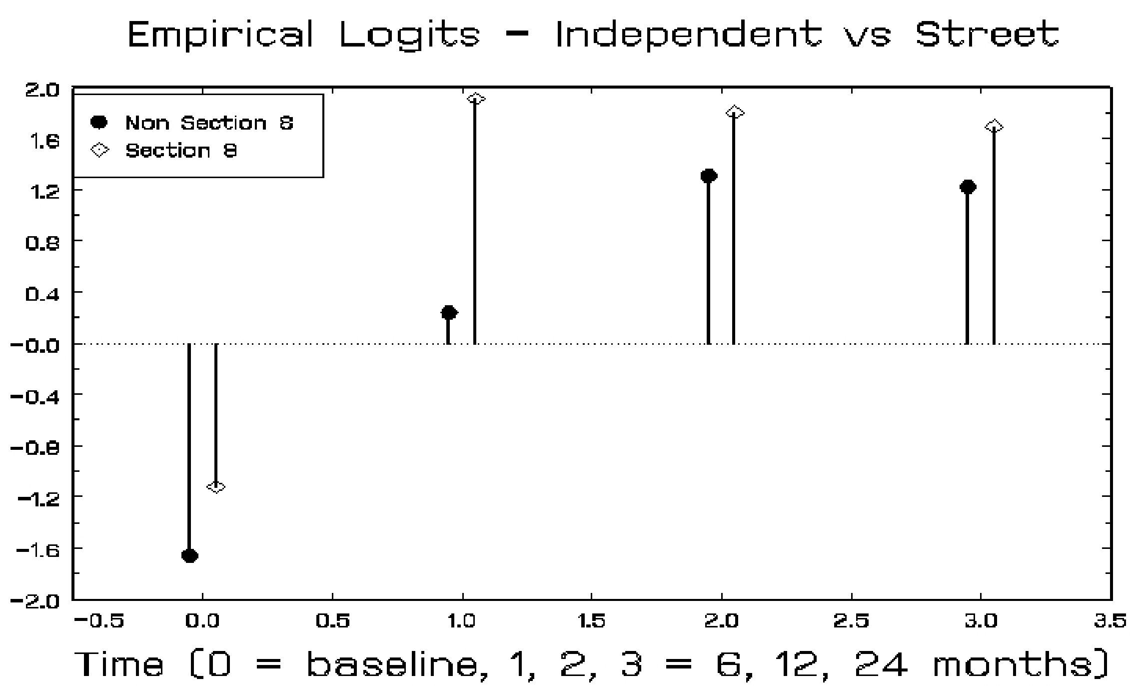
Model in terms of the category probabilities

$$p_{ijc} = \Pr(Y_{ij} = c \mid \boldsymbol{\upsilon}_{ic}) = \frac{\exp(\mathrm{z}_{ijc})}{1 + \Sigma_{h=2}^{C} \exp(\mathrm{z}_{ijh})} \quad \text{for } c = 2, 3, \ldots, C$$

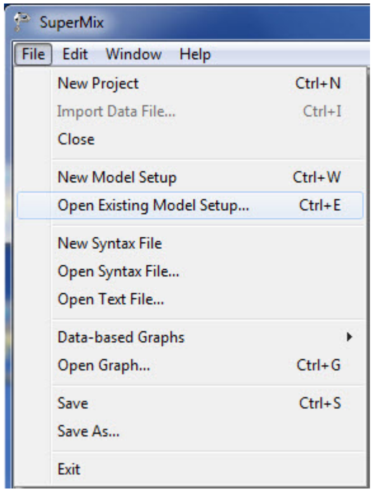
$$p_{ij1} = \Pr(Y_{ij} = 1 \mid \boldsymbol{\upsilon}_{ic}) = \frac{1}{1 + \Sigma_{h=2}^{C} \exp(\mathrm{z}_{ijh})}$$

where the multinomial logit $\mathrm{z}_{ijc} = \boldsymbol{u}'_{ij}\boldsymbol{\gamma}_c + \boldsymbol{z}'_{ij}\boldsymbol{\upsilon}_{ic}$

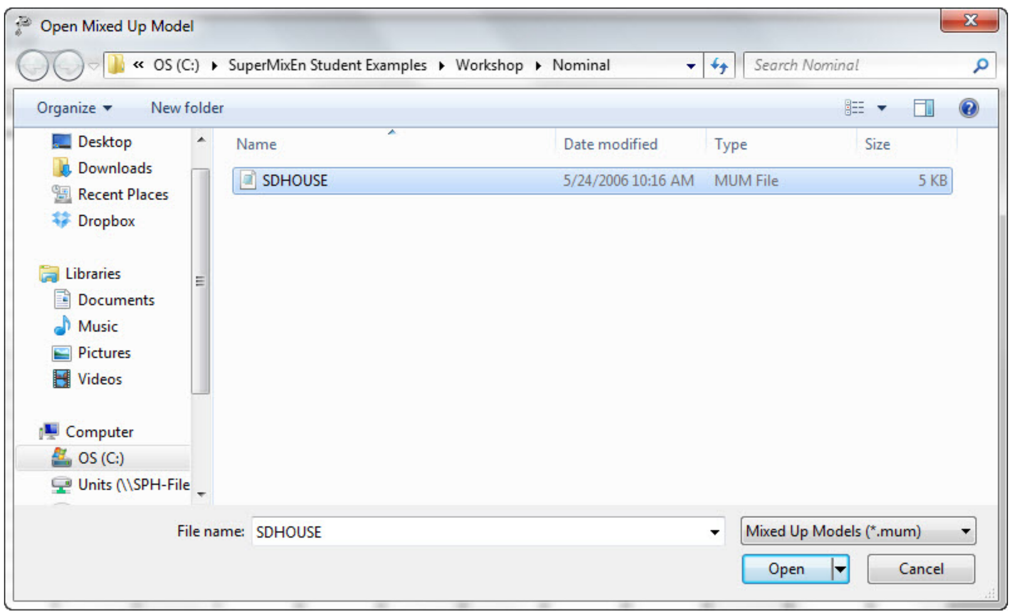

Empirical Logits - Community vs Street
Non Section 8
Section 8
2.0
1.6
1.2
0.8
0.4
-0.0
-0.4
-0.8
-1.2
-1.6
-2.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Time (0 = baseline, 1, 2, 3 = 6, 12, 24 months)


Empirical Logits - Independent vs Street
Non Section 8
Section 8
2.0
1.6
1.2
0.8
0.4
-0.0
-0.4
-0.8
-1.2
-1.6
-2.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Time (0 = baseline, 1, 2, 3 = 6, 12, 24 months)

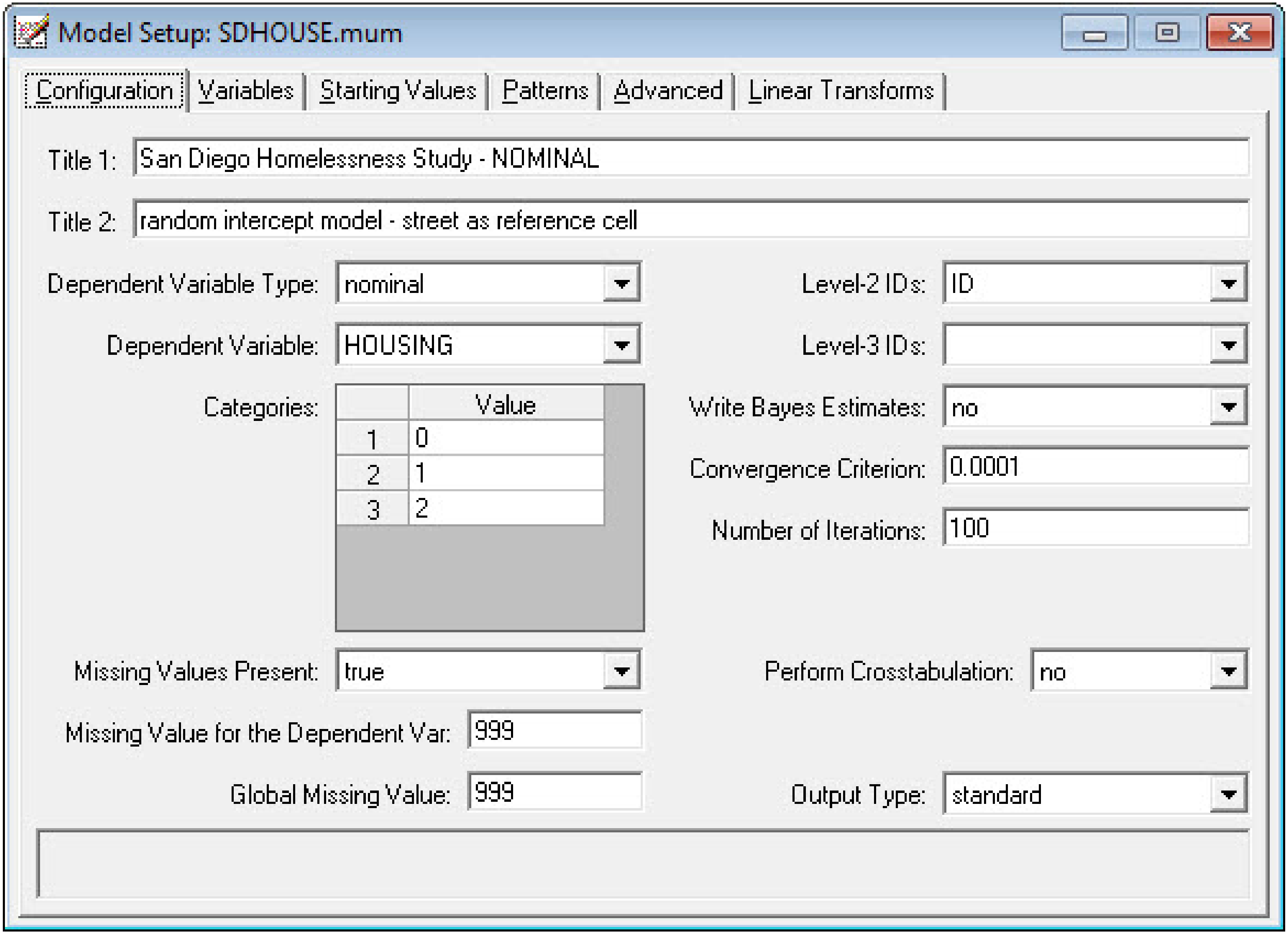
Under "File" click on "Open Existing Model Setup"

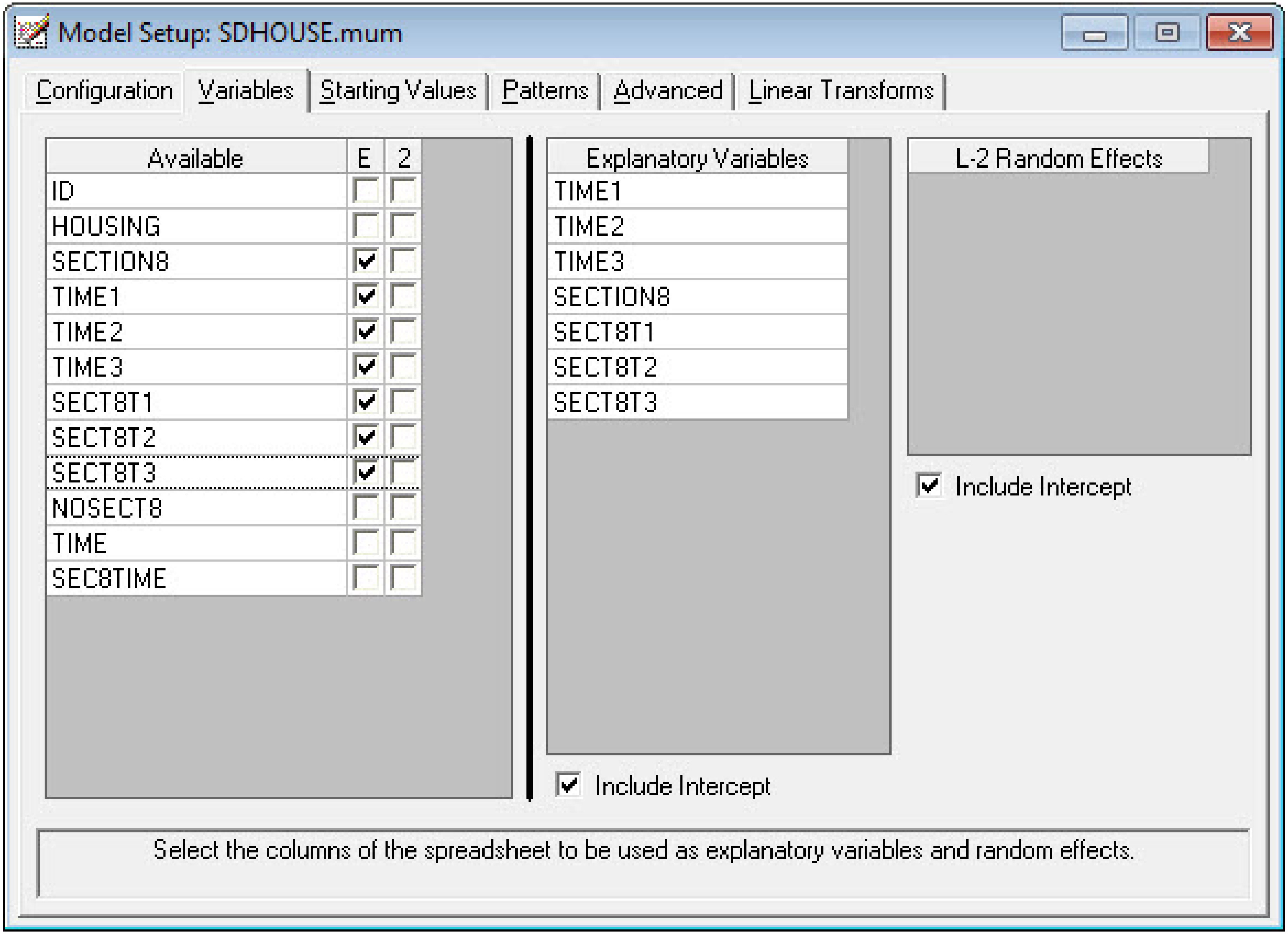


Open C:\SuperMixEn Examples\Workshop\Nominal\sdhouse.mum
(or C:\SuperMixEn Student Examples\Workshop\Nominal\sdhouse.mum)



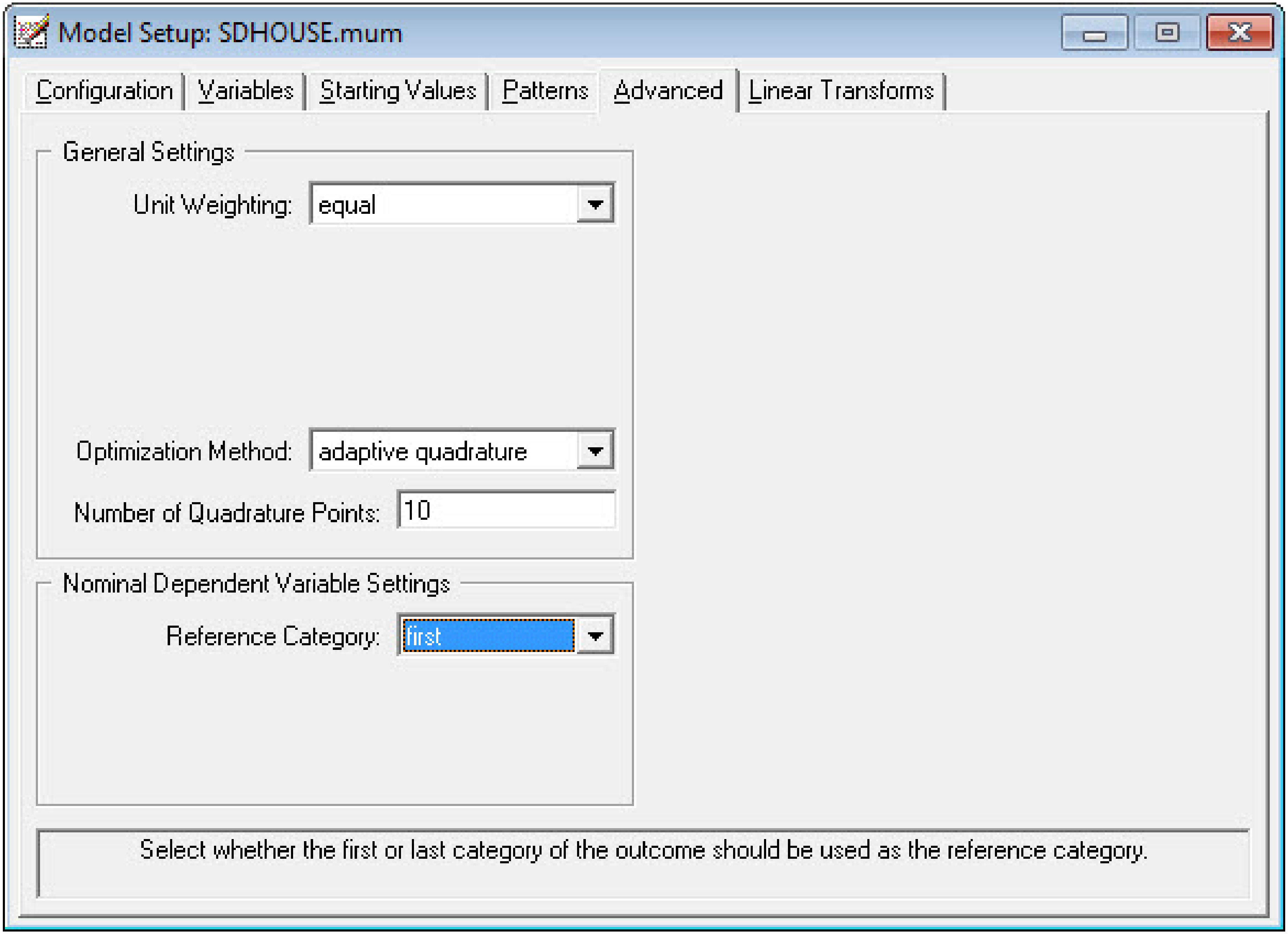
Note that "Dependent Variable Type" is "nominal"



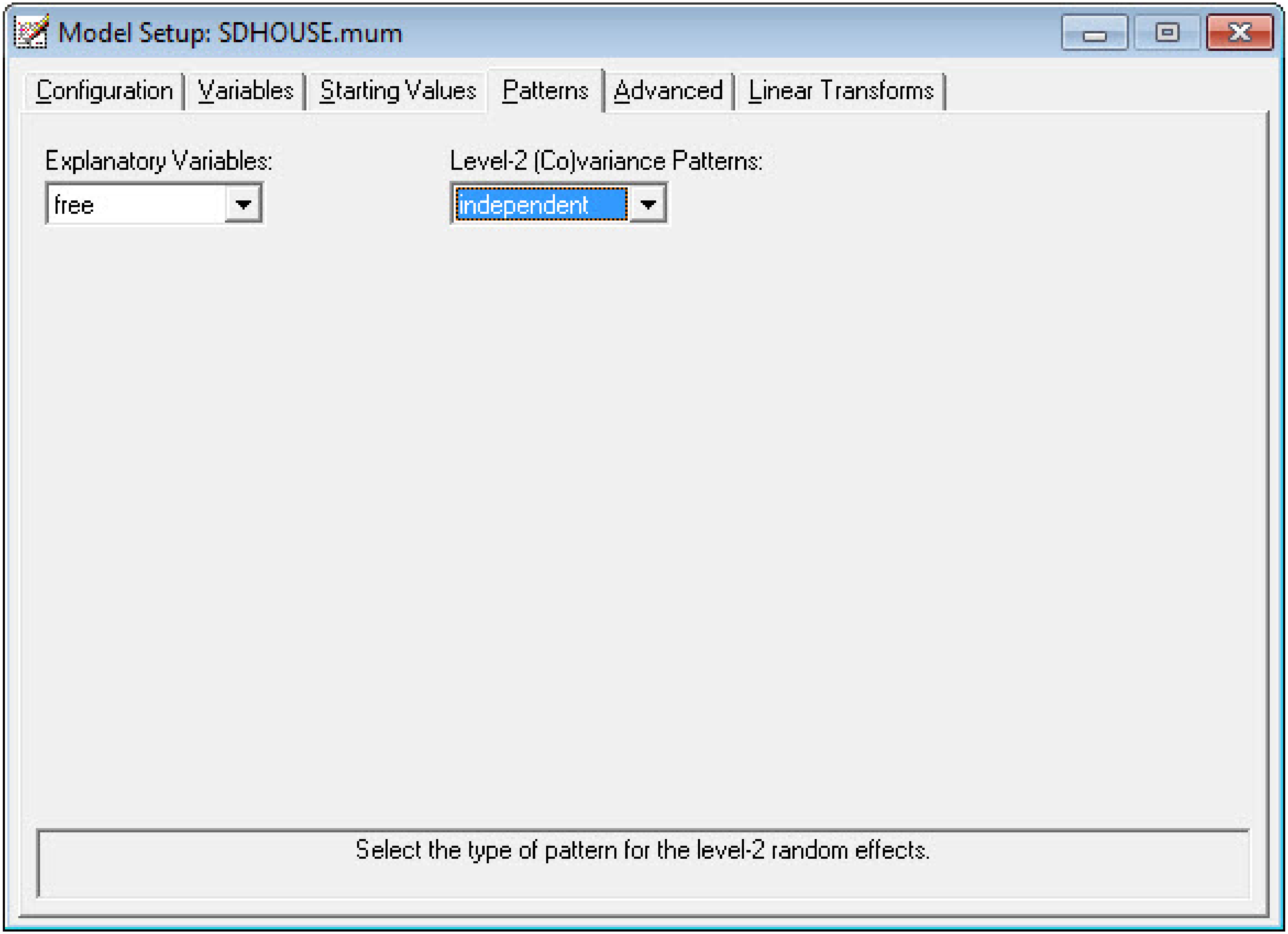


Model Setup: SDHOUSE.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Available
E
2
ID
HOUSING
SECTION8
TIME1
TIME2
TIME3
SECT8T1
SECT8T2
SECT8T3
NOSECT8
TIME
SEC8TIME
Explanatory Variables
TIME1
TIME2
TIME3
SECTION8
SECT8T1
SECT8T2
SECT8T3
L-2 Random Effects
Include Intercept
Include Intercept
Select the columns of the spreadsheet to be used as explanatory variables and random effects.

Can select first or last category as the reference cell



Try independent random effects first



SDHOUSE.out

```
 o============================================o
 | Optimization Method: Numerical Quadrature |
 o============================================o

Number of quadrature points =             10
Number of free parameters =               18
Number of iterations used =                5

-2lnL (deviance statistic) =       2218.71755
Akaike Information Criterion       2254.71755
Schwarz Criterion                  2347.62674


                    Estimated regression weights

                                          Standard
Parameter              Estimate           Error       z Value      P Value
---------              --------           --------    -------      -------

Response Code  1 vs Code   0
----------------------------
intercept               -0.4511            0.1847     -2.4425       0.0146
TIME1                    1.9421            0.3002      6.4685       0.0000
TIME2                    2.8207            0.3838      7.3502       0.0000
TIME3                    2.2604            0.3548      6.3709       0.0000
SECTION8                 0.5207            0.2618      1.9892       0.0467
SECT8T1                 -0.1350            0.4617     -0.2925       0.7699
SECT8T2                 -1.9180            0.5167     -3.7122       0.0002
SECT8T3                 -0.9525            0.4808     -1.9811       0.0476

Response Code  2 vs Code   0
----------------------------
intercept               -2.6746            0.3791     -7.0560       0.0000
TIME1                    2.6847            0.4362      6.1550       0.0000
TIME2                    4.0907            0.4976      8.2208       0.0000
TIME3                    4.1009            0.4701      8.7231       0.0000
SECTION8                 0.7816            0.4817      1.6225       0.1047
SECT8T1                  2.0009            0.6193      3.2311       0.0012
SECT8T2                  0.5460            0.6509      0.8389       0.4015
SECT8T3                  0.3035            0.6198      0.4896       0.6244
```

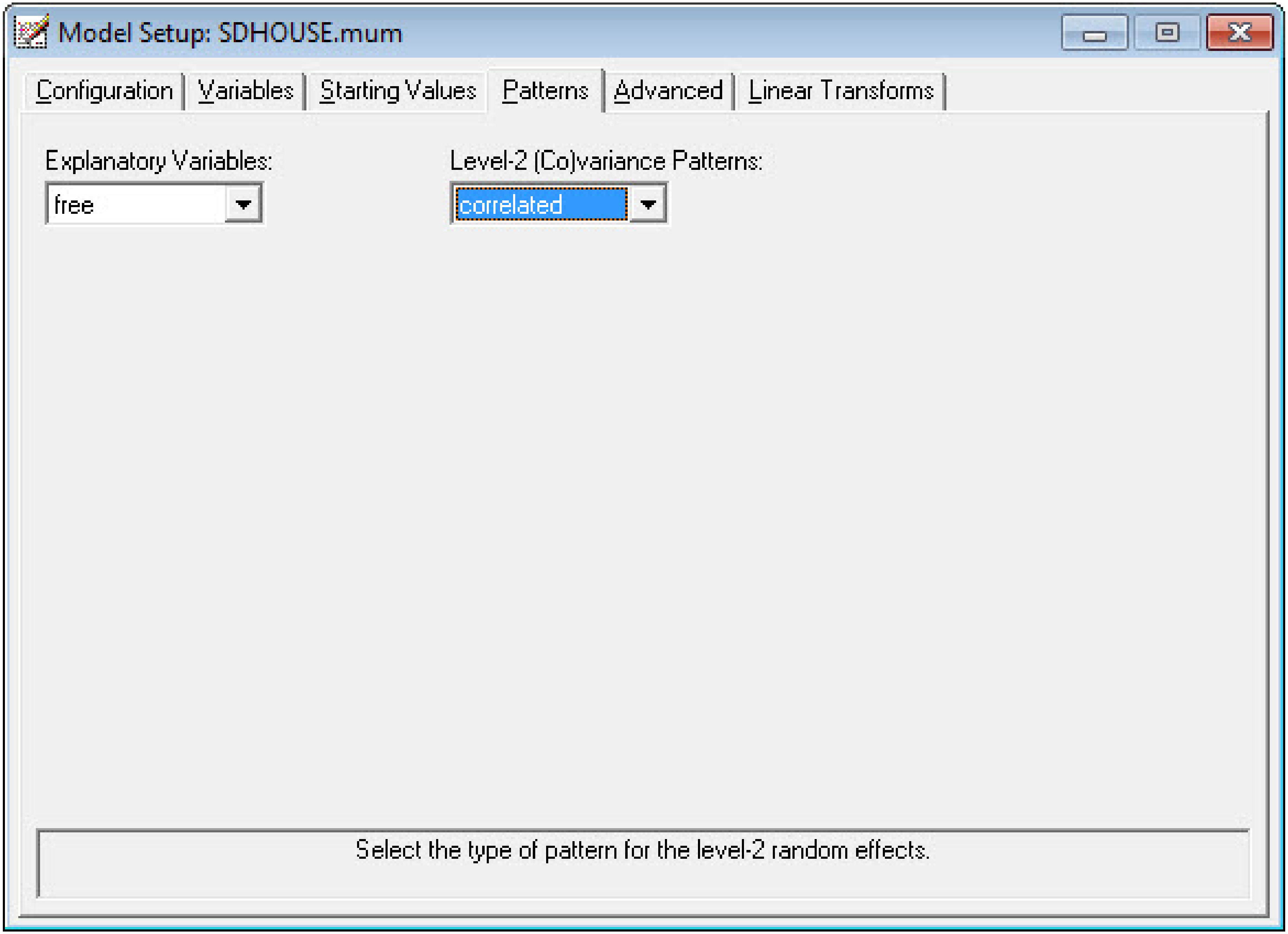
Save As... Close

SDHOUSE.out

```
                   Estimated level 2 variances and covariances

                                                        Standard
    Parameter                         Estimate          Error          z Value    P Value
    ---------                         ---------         ---------      -------    -------
    intercept1/intercept1               0.7617            0.3280        2.3219     0.0202
    intercept2/intercept2               5.4514            1.0237        5.3255     0.0000


   Level 2 covariance matrix


                     intercept1     intercept2

   intercept1          0.761654
   intercept2          0.000000       5.451441


   Level 2 correlation matrix


                     intercept1     intercept2

   intercept1          1.000000
   intercept2          0.000000       1.000000



 Calculation of intracluster correlation (01)
 --------------------------------------------
 residualvariance = pi*pi / 3 (assumed)
 cluster  variance =      0.7617

 intracluster correlation =     0.7617 / (     0.7617 + (pi*pi/3)) = 0.188



 Calculation of intracluster correlation (02)
 --------------------------------------------
 residualvariance = pi*pi / 3 (assumed)
 cluster  variance =      5.4514

 intracluster correlation =     5.4514 / (     5.4514 + (pi*pi/3)) = 0.624
```

Save As...   Close

Now allow the random effects to be correlated



SDHOUSE.out

```
o=========================================o
| Optimization Method: Adaptive Quadrature |
o=========================================o

Number of quadrature points =            10
Number of free parameters =              19
Number of iterations used =               7

-2lnL (deviance statistic) =     2180.93648
Akaike Information Criterion     2218.93648
Schwarz Criterion                2317.00729
```

Estimated regression weights

Response Code 1 vs Code 0

Parameter	Estimate	Standard Error	z Value	P Value
intercept	-0.6222	0.2330	-2.6701	0.0076
TIME1	2.3744	0.3477	6.8292	0.0000
TIME2	3.3452	0.4416	7.5759	0.0000
TIME3	2.5894	0.4022	6.4378	0.0000
SECTION8	0.6516	0.3281	1.9858	0.0471
SECT8T1	-0.3311	0.5228	-0.6334	0.5265
SECT8T2	-2.4746	0.5897	-4.1967	0.0000
SECT8T3	-1.1596	0.5438	-2.1322	0.0330

Response Code 2 vs Code 0

Parameter	Estimate	Standard Error	z Value	P Value
intercept	-2.5987	0.3837	-6.7729	0.0000
TIME1	2.8878	0.4541	6.3591	0.0000
TIME2	4.3939	0.5301	8.2887	0.0000
TIME3	4.3104	0.4958	8.6944	0.0000
SECTION8	0.8314	0.4938	1.6836	0.0923
SECT8T1	1.9688	0.6436	3.0592	0.0022
SECT8T2	0.2872	0.6769	0.4243	0.6713
SECT8T3	0.2017	0.6442	0.3130	0.7543

Save As... Close

LR test comparing models: $\chi^2_1 = 2218.72 - 2180.94 = 37.78$

SDHOUSE.out

```
              Estimated level 2 variances and covariances

                                                         Standard
    Parameter                           Estimate         Error         z Value    P Value
    ---------                           --------         --------      -------    -------
    intercept1/intercept1                 2.7025           0.6968        3.8786     0.0001
    intercept2/intercept1                 2.8846           0.7649        3.7710     0.0002
    intercept2/intercept2                 5.8229           1.1358        5.1269     0.0000


   Level 2 covariance matrix


                   intercept1     intercept2

   intercept1        2.702462
   intercept2        2.884597       5.822889


   Level 2 correlation matrix


                   intercept1     intercept2

   intercept1        1.000000
   intercept2        0.727170       1.000000



 Calculation of intracluster correlation (01)
 --------------------------------------------
 residualvariance = pi*pi / 3 (assumed)
 cluster  variance =     2.7025

 intracluster correlation =     2.7025 / (    2.7025 + (pi*pi/3)) = 0.451



 Calculation of intracluster correlation (02)
 --------------------------------------------
 residualvariance = pi*pi / 3 (assumed)
 cluster  variance =     5.8229

 intracluster correlation =     5.8229 / (    5.8229 + (pi*pi/3)) = 0.639
```

Save As... Close

Summary

Models for longitudinal ordinal and nominal data as developed as models for continuous and dichotomous data

- Proportional odds models
- Non and partial proportional odds models
- Nominal models (with reference-cell contrasts)
- Grouped-time survival analysis models

$\Rightarrow$ SuperMix can do it all, including 3-level models, also for counts

- full likelihood solution using adaptive quadrature