Mixed Models for Multilevel Data Analysis: An Applied Introduction

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This work was supported by National Institute of Mental Health Contract N44MH32056.

What are Multilevel Data?

- Data that are hierarchically structured, nested, clustered
- Data collected from units organized or observed within units at a higher level (from which data are also obtained)

data collected on	*who are clustered within*
students	classrooms
siblings	families
repeated observations	individuals

==> these are examples of two-level data

level 1 - (students) - measurement of primary outcome and important mediating variables

level 2 - (classrooms) - provides context or organization of level-1 units which may influence outcome; other mediating variables

What is Multilevel Data Analysis?

"any set of analytical procedures that involve data gathered from individuals and from the social structure in which they are embedded and are analyzed in a manner that models the multilevel structure"

L. Burstein, *Units of Analysis*, 1985, Int Ency of Educ

- analysis that *models the multilevel structure*
- recognizes influence of structure on individual outcome

structure	*may influence response from*
classroom	students
family	siblings
individual	repeated observations

Why do Multilevel Data Analysis?

- assess amount of variability due to each level (*e.g.*, family variance and individual variance)
- model level 1 outcome in terms of effects at both levels

$$individual\ var. = fn(individual\ var. + family\ var.)$$

- assess interaction between level effects (*e.g.*, individual outcome influenced by family SES for males, not females)
- Responses are not independent - individuals within clusters share influencing factors

$\Rightarrow$ Multilevel analysis - another example of *Golden Rule of Statistics*: "one person's error term is another person's (or many persons') career"

		cluster variables		*subject variables*		
cluster	subject	tx group	size	outcome	sex	age
1	1	.	.	.	.	.
	⋮	.	.	.	.	.
	n_1	.	.	.	.	.
2	1	.	.	.	.	.
	⋮	.	.	.	.	.
	n_2	.	.	.	.	.
.	1	.	.	.	.	.
	⋮	.	.	.	.	.
	$n_.$	.	.	.	.	.
N	1	.	.	.	.	.
	⋮	.	.	.	.	.
	n_N	.	.	.	.	.

$i = 1 \ldots N$ clusters

$j = 1 \ldots n_i$ subjects in cluster i

		time-invariant variables			*time-varying variables*	
subject	time	tx group	sex	age	outcome	dose
1	1	.	.	.	.	.
	⋮	.	.	.	.	.
	n_1	.	.	.	.	.
2	1	.	.	.	.	.
	⋮	.	.	.	.	.
	n_2	.	.	.	.	.
.	1	.	.	.	.	.
	⋮	.	.	.	.	.
	$n_.$	.	.	.	.	.
N	1	.	.	.	.	.
	⋮	.	.	.	.	.
	n_N	.	.	.	.	.

$i = 1 \ldots N$ subjects

$j = 1 \ldots n_i$ timepoints for subject i

Multilevel models aka

- random-effects models
- random-coefficient models
- mixed-effects models
- hierarchical linear models

Useful for analyzing

- Clustered data
  - subjects (level-1) within clusters (level-2)
    - e.g., clinics, hospitals, families, worksites, schools, classrooms, city wards
- Longitudinal data
  - repeated obs. (level-1) within subjects (level-2)

General (2-level) Model for Clustered Data

Consider the model with p covariates for the $n_i \times 1$ response vector $\boldsymbol{y}$ for cluster i $(i = 1, 2, \ldots, N)$:

$$\boldsymbol{y}_i = \boldsymbol{X}_i\boldsymbol{\beta} + \upsilon_i + \boldsymbol{\varepsilon}_i$$

$$\begin{aligned}
\boldsymbol{y}_i &= n_i \times 1 \text{ vector of responses for cluster } i \\
\boldsymbol{X}_i &= n_i \times (p+1) \text{ covariate matrix} \\
\boldsymbol{\beta} &= (p+1) \times 1 \text{ vector of regression coefficients} \\
\upsilon_i &= \text{cluster effects} \sim \mathcal{NID}(0, \sigma_\upsilon^2) \\
\boldsymbol{\varepsilon}_i &= n_i \times 1 \text{ vector of residuals} \sim \mathcal{NID}(0, \sigma^2\boldsymbol{I}_{n_i})
\end{aligned}$$

- as cluster subscript i is present for $\boldsymbol{y}$ and $\boldsymbol{X}$, cluster sample size can vary
- the covariate matrix $\boldsymbol{X}$ can include
  - covariates measured at subject-level
  - covariates measured at cluster-level
  - cross-level interactions
- the total number of covariates $= p$
- the number of columns in $\boldsymbol{X}$ is $p + 1$ to include intercept (first column of $\boldsymbol{X}$ consists only of ones)

υ_i - random parameter distributed $\mathcal{NID}(0, \sigma_\upsilon^2)$

- distinguishes model from ususal (fixed-effects) multiple regression model
- represent effect of subject clustering (one for every cluster)
- if subject clustering has little effect
  - estimates of $\upsilon_i \approx 0$
  - σ_υ^2 will approach 0
- if subject clustering has strong effect
  - estimates of $\upsilon_i \neq 0$
  - σ_υ^2 will increase from 0

$$\boldsymbol{y}_i \sim \mathcal{NID}(\boldsymbol{X}_i\boldsymbol{\beta}, \sigma_v^2 \mathbf{1}_i \mathbf{1}_i' + \sigma^2 \boldsymbol{I}_{n_i})$$

- usual mean from multiple regression model
- var-covar structure accounts for clustering
  - within a cluster, variance $= \sigma^2 + \sigma_v^2$ and covariance $= \sigma_v^2$
  - "compound symmetry" structure
  - ratio of the cluster variance σ_v^2 to the total variance $\sigma^2 + \sigma_v^2$ is the *intraclass correlation*

Intra-"class" correlation $r = \sigma_v^2/(\sigma_v^2 + \sigma^2)$

- "class" is bad term, since in education "class" has meaning
- Goldstein suggests "intra-unit" correlation, replacing "unit" with appropriate term (clinic, school, family, firm *etc.*,)
- takes on values between 0 (when $\sigma_v^2 = 0$) and 1 (when $\sigma^2 = 0$)
- degree of similarity of measurements within a cluster
- ratio of variability attributable to cluster over total variability
- proportion of total (unexplained) variability of y_{ij} which is accounted for the clusters
- tends larger for smaller clusters (Kish, 1965; Donner, 1982)
  - 0.05 to 0.12 for spouse pairs, 0.0016 to 0.0126 for physician practices, 0.0005 to 0.0085 for counties
- can change depending on the dependent variable

Anorexic Women Study (Casper) - 63 sisters in 26 families
Maximum Likelihood (ML) estimates

	Height	Psych Factor	BMI
intercept	64.166	0.568	0.352
family variance	2.743	0.031	0.000
residual variance	2.895	0.055	0.005
intra-family correlation	0.487	0.362	0.000
descriptive statistics			
mean	64.16	0.57	0.35
variance	5.66	0.084	0.005

Random-effects Regression Models for Clustered Data: With an Example from Smoking Prevention Research

Hedeker, Gibbons, and Flay

Journal of Consulting and Clinical Psychology, 1994, 62:757-765

The Television School and Family Smoking Prevention and Cessation Project (Flay, *et al.*, 1988); a subsample of this project was chosen with the characteristics:

- *sample* - 1600 7th-graders - 135 classrooms - 28 LA schools
  - between 1 to 13 classrooms per school
  - between 2 to 28 students per classroom
- *outcome* - knowledge of the effects of tobacco use
- *timing* - students tested at pre and post-intervention
- *design* - schools randomized to
  - a social-resistance classroom curriculum (CC)
  - a media (television) intervention (TV)
  - CC combined with TV
  - a no-treatment control group

Tobacco and Health Knowledge Scale

Subgroup Descriptive Statistics at Pretest and Post-Intervention

	CC = no		CC = yes	
	TV = no	TV = yes	TV = no	TV = yes
n	421	416	380	383
Pretest mean	2.152	2.087	2.050	1.979
sd	1.182	1.288	1.285	1.286
Post-Int mean	2.361	2.539	2.968	2.823
sd	1.296	1.437	1.405	1.312
Difference	0.209	0.452	0.918	0.844

Within-Cluster / Between-Cluster representation

Within-clusters model - level 1 $\quad (j = 1, \ldots, n_i)$

$$PostTHKS_{ij} = b_{0i} \; + \; \left[b_{1i} PreTHKS_{ij}\right] \; + \; \varepsilon_{ij}$$

Between-clusters model - level 2 $\quad (i = 1, \ldots, N)$

$$b_{0i} \; = \; \beta_0 \; + \; [\beta_2 CC_i] \; + \; \upsilon_{0i}$$

$$b_{1i} \; = \; \beta_1$$

$$\varepsilon_{ij} \; \sim \; NID(0, \sigma^2) \quad \text{level-1 residuals}$$

$$\upsilon_{0i} \; \sim \; NID(0, \sigma_\upsilon^2) \quad \text{level-2 residuals}$$

TVSFP Study (Flay *et al.*, 1988): Tobacco and Health Knowledge *Posttest* Scores
1600 students in 135 classrooms in 28 schools: ML estimates (and standard errors)

	students in classrooms			*students in schools*		
Intercept	2.618	2.007	1.757	2.682	2.047	1.800
	(0.052)	(0.072)	(0.080)	(0.078)	(0.089)	(0.092)
Pretest score		0.302	0.310		0.303	0.310
		(0.026)	(0.026)		(0.026)	(0.026)
Classroom curriculum			0.497			0.470
			(0.086)			(0.106)
Cluster var	0.194	0.157	0.096	0.130	0.101	0.044
	(0.043)	(0.037)	(0.029)	(0.045)	(0.036)	(0.020)
Residual var	1.725	1.601	1.601	1.788	1.653	1.653
	(0.064)	(0.060)	(0.059)	(0.064)	(0.059)	(0.059)
ICC	0.101	0.090	0.057	0.068	0.057	0.026
$\log L$	-2760.9	-2696.4	-2681.3	-2756.8	-2692.0	-2684.7
χ^2_1		129.0	30.2		129.6	14.6

Within-Cluster / Between-Cluster representation

Within-clusters model - *level 1* $\quad (j = 1, \ldots, n_i)$

$$PostTHKS_{ij} = b_{0i} \ + \ \varepsilon_{ij}$$

Between-clusters model - *level 2* $\quad (i = 1, \ldots, N)$

$$b_{0i} = \beta_0 \ + \ \beta_1 CC_i \ + \ \beta_2 TV_i \ + \ \beta_3 (CC_i \times TV_i) \ + \ \upsilon_{0i}$$

$$\begin{aligned} \varepsilon_{ij} \ &\sim \ NID(0, \sigma^2) \quad \text{level-1 residuals} \\ \upsilon_{0i} \ &\sim \ NID(0, \sigma_\upsilon^2) \quad \text{level-2 residuals} \end{aligned}$$

- If cluster effect is completely explained by condition, then
  - $\upsilon_{0i} = 0$ for all i (thus $\sigma_\upsilon^2 = 0$)
  - model is same as ordinary regression (individual-level analysis)
- If $n_i = n$ for all clusters (and no level-1 covariates), then
  - model is same as ordinary regression of cluster means (cluster-level analysis)

THKS post-intervention scores - Regression estimates (se)

	Ordinary Regression		*Multilevel Model*
	Class-level	Student-level	Students in classes
Intercept	**2.342**	**2.361**	**2.341**
	(.117)	(.066)	(.092)
classroom curriculum (CC)	**.507**	**.607**	**.589**
	(.166)	(.096)	(.133)
television (TV)	-.082	.177	.120
	(.150)	(.094)	(.131)
interaction (CC by TV)	.011	*-.323*	-.247
	(.236)	(.137)	(.189)
residual variance	.468	1.860	**1.727**
			(.064)
class variance			**.134**
			(.037)
p < .05 **p < .01**			*ICC = .072*

Within-Cluster / Between-Cluster representation

Within-clusters model - *level 1* $\quad (j = 1, \ldots, n_i)$

$$PostTHKS_{ij} = b_{0i} \; + \; b_{1i} PreTHKS_{ij} \; + \; \varepsilon_{ij}$$

Between-clusters model - *level 2* $\quad (i = 1, \ldots, N)$

$$b_{0i} \; = \; \beta_0 \; + \; \beta_2 CC_i \; + \; \beta_3 TV_i \; + \; \beta_4 (CC_i \times TV_i) \; + \; \upsilon_{0i}$$

$$b_{1i} \; = \; \beta_1$$

$$\varepsilon_{ij} \; \sim \; NID(0, \sigma^2) \quad \text{level-1 residuals}$$

$$\upsilon_{0i} \; \sim \; NID(0, \sigma_\upsilon^2) \quad \text{level-2 residuals}$$

3-level model representation

Within-schools, within-classrooms, between-subjects model - *level 1* $(k = 1, \ldots, n_{ij})$

$$PostTHKS_{ijk} = b_{0ij} + b_{1ij} PreTHKS_{ijk} + \varepsilon_{ijk}$$

Within-schools, between-classrooms model - *level 2* $\quad (j = 1, \ldots, n_i)$

$$\begin{aligned} b_{0ij} &= b_{0i} + \upsilon_{0ij} \\ b_{1ij} &= b_{1i} \end{aligned}$$

Between-schools model - *level 3* $\quad (i = 1, \ldots, N)$

$$\begin{aligned} b_{0i} &= \beta_0 + \beta_2 CC_i + \beta_3 TV_i + \beta_4 (CC_i \times TV_i) + \upsilon_{0i} \\ b_{1i} &= \beta_1 \end{aligned}$$

$$\begin{aligned} \varepsilon_{ijk} &\sim NID(0, \sigma^2) \quad \text{level-1 residuals} \\ \upsilon_{0ij} &\sim NID(0, \sigma^2_{\upsilon_{(2)}}) \quad \text{level-2 residuals} \\ \upsilon_{0i} &\sim NID(0, \sigma^2_{\upsilon_{(3)}}) \quad \text{level-3 residuals} \end{aligned}$$

THKS Post-Intervention Scores - Regression Estimates (se)

	Ordinary Regression Models		*Multilevel Models*		
	Class-level	Student-level	Stu in classes	Stu in schools	Three-level
Intercept	1.3087 ***	1.6613 ***	1.6776 ***	1.6952 ***	1.6970 ***
	(0.229)	(0.084)	(0.099)	(0.115)	(0.117)
pretest	0.4962 ***	0.3252 ***	0.3116 ***	0.3103 ***	0.3072 ***
THKS	(0.097)	(0.026)	(0.026)	(0.026)	(0.026)
classroom	0.5749 ***	0.6406 ***	0.6330 ***	0.6601 ***	0.6392 ***
curriculum	(0.153)	(0.092)	(0.119)	(0.144)	(0.147)
television	-0.0150	0.1987 **	0.1597	0.2023	0.1781
	(0.150)	(0.090)	(0.117)	(0.140)	(0.144)
interaction	-0.0485	-0.3216 **	-0.2747	-0.3696 *	-0.3204
	(0.216)	(0.130)	(0.168)	(0.201)	(0.206)
error	0.3924	1.6929	1.6030 ***	1.6522 ***	1.6020 ***
variance			(0.059)	(0.059)	(0.059)
class			0.0870 ***		0.0636 **
variance			(0.028)		(0.028)
school				0.0372 **	0.0258
variance				(0.018)	(0.020)

$^{***}p < 0.01$ $^{**}p < 0.05$ $^{*}p < 0.10$

Results

- conclusions about CC by TV interaction differ
  - non-significant by class-level analysis, significant by student-level analysis, marginally significant by multilevel
- student-level results close to multilevel, but estimates are more similar than standard errors $\rightarrow$ underestimation of standard errors by ordinary regression analysis is expected since assumption of independence of observations is violated
- students more homogeneous within classrooms than schools
  - students within classrooms model, $r = 0.052$
  - students within schools model, $r = 0.022$
- 3-level model close to students within classrooms model
  - based on 3-level model, classroom and school effects accounted for 3.8% and 1.5% of total variance, respectively

3-level ICCs

From the three-level model:
error var = 1.6020, class var = 0.0636, school var = 0.0258

Similarity of students within the same school

$$ICC = \frac{0.0258}{1.6020 + 0.0636 + 0.0258} = .0153$$

Similarity of students within the same classrooms (and schools)

$$ICC = \frac{0.0636 + 0.0258}{1.6020 + 0.0636 + 0.0258} = .0529$$

Similarity of classes within the same school

$$ICC = \frac{0.0258}{0.0636 + 0.0258} = .289$$

Explained Variance (Hox, *Multilevel Analysis*, 2002)

$$\text{level-1} \quad R_1^2 = 1 - \frac{\hat{\sigma}_p^2}{\hat{\sigma}_0^2} \qquad\qquad \text{level-2} \quad R_2^2 = 1 - \frac{\hat{\sigma}_{\upsilon_p}^2}{\hat{\sigma}_{\upsilon_0}^2}$$

subscript 0 refers to a model with no covariates (*i.e.*, null model),
subscript p refers to a model with p covariates (*i.e.*, full model)

e.g., students in classrooms models

		models		
level	variance	null	full	R^2
1 (students)	$\hat{\sigma}^2$	1.725	1.603	.071
2 (classrooms)	$\hat{\sigma}_\upsilon^2$	.194	.087	.552

Explained Variance: 3-level model

$$R_1^2 = 1 - \frac{\hat{\sigma}_p^2}{\hat{\sigma}_0^2} \qquad R_2^2 = 1 - \frac{\hat{\sigma}_{\upsilon_{(2)p}}^2}{\hat{\sigma}_{\upsilon_{(2)0}}^2} \qquad R_3^2 = 1 - \frac{\hat{\sigma}_{\upsilon_{(3)p}}^2}{\hat{\sigma}_{\upsilon_{(3)0}}^2}$$

subscript 0 refers to a model with no covariates (*i.e.*, null model),
subscript p refers to a model with p covariates (*i.e.*, full model)

e.g., students in classrooms in schools models

level	variance	null	full	R^2
1 (students)	$\hat{\sigma}^2$	1.724	1.602	.071
2 (classrooms)	$\hat{\sigma}_{\upsilon_{(2)}}^2$	.085	.064	.247
3 (schools)	$\hat{\sigma}_{\upsilon_{(3)}}^2$	.110	.026	.764

Likelihood-ratio tests:
suppose Model I is nested within Model II

$$2 \times \log(L_{\mathrm{II}} \,/\, L_{\mathrm{I}}) \;=\; 2 \times (\log L_{\mathrm{II}} - \log L_{\mathrm{I}}) \;\sim\; \chi^2_q$$

where q = number of additional parameters in Model II

$-2 \log L$ is called the *deviance* (the higher the deviance the poorer the model fit)

$$D_{\mathrm{I}} - D_{\mathrm{II}} \;\sim\; \chi^2_q$$

to evaluate the null hypothesis that the additional parameters in Model II jointly equal 0

Comparison of models using LR tests

Model	deviance	CM	χ^2	df	$p <$	halved $p <$
1. student-level	5377.90					
2a. students in classes	5359.96	1	17.94	1	.001	.001
2b. students in schools	5366.01	1	11.89	1	.001	.001
3. three-level	5357.36	1	20.54	2	.001	.001
		2a	2.60	1	.107	.053

LR tests with halved p-values (akin to one-tailed p-values) for tests of variance parameters is recommended

(Snijders & Bosker, *Multilevel Analysis, 2nd edition*, 2012, pps. 98-101)

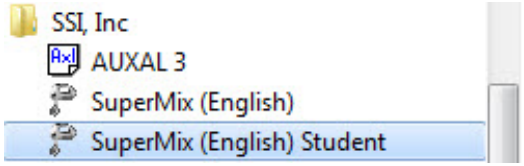
Supermix for Mixed Models

- Free student and 15-day trial editions
  http://www.ssicentral.com/supermix/downloads.html

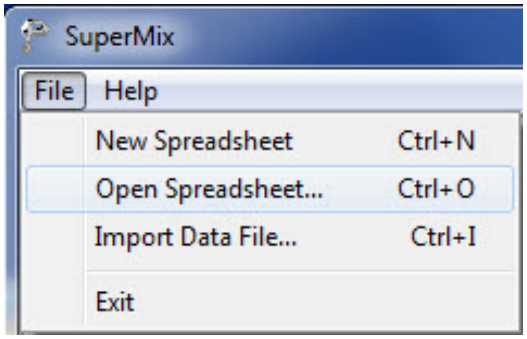
- Datasets and examples
  http://www.ssicentral.com/supermix/examples.html

- Manual and documentation in PDF form
  http://www.ssicentral.com/supermix/resources.html

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



- Under "File" click on "Open Spreadsheet"



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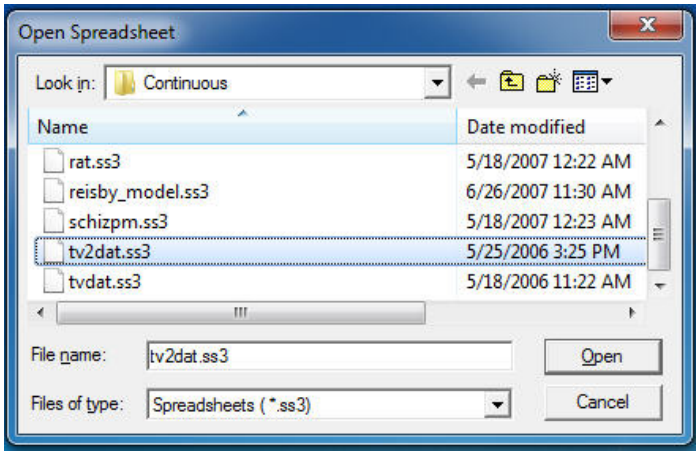
(or C:\SuperMixEn Student Examples\Workshop\Continuous\tv2dat.ss3)



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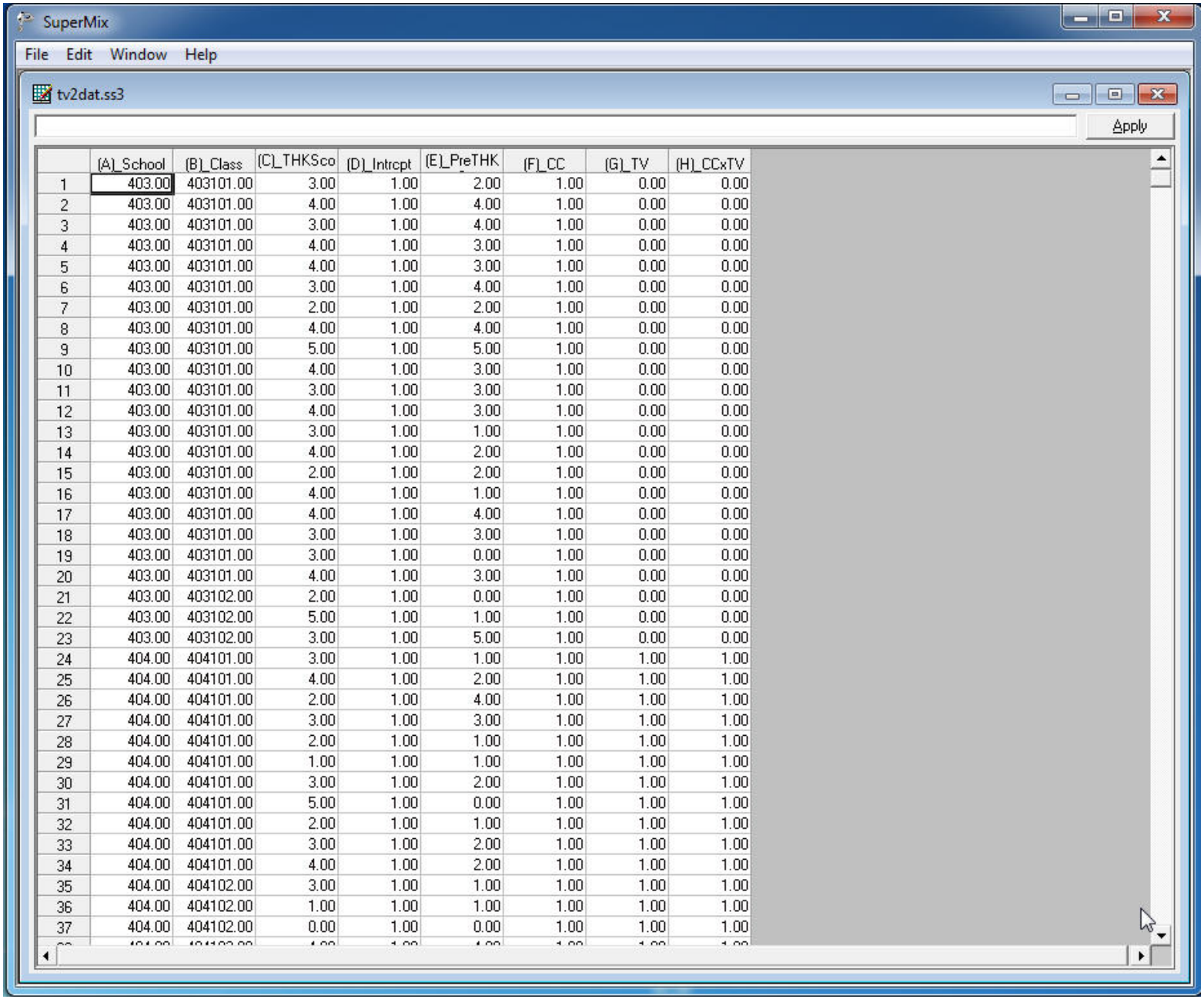
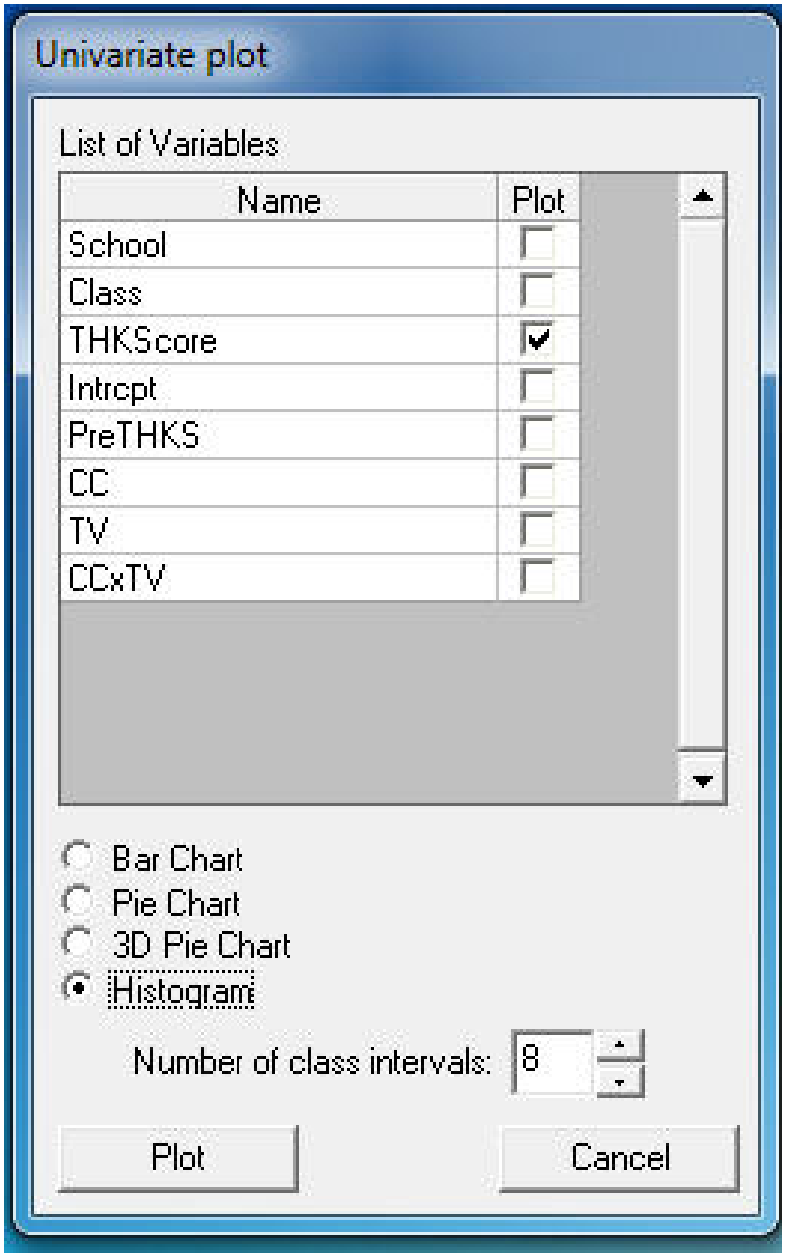
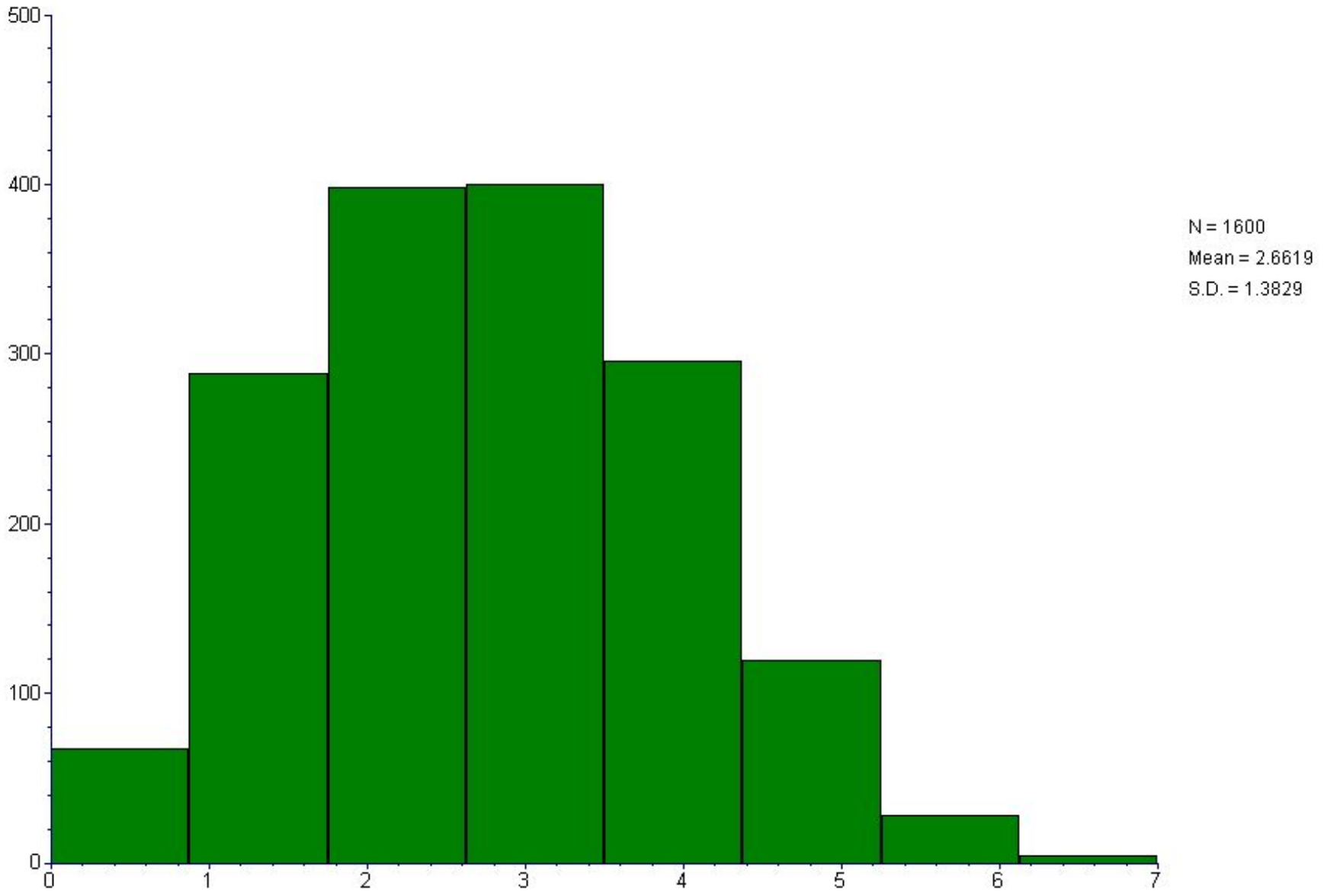


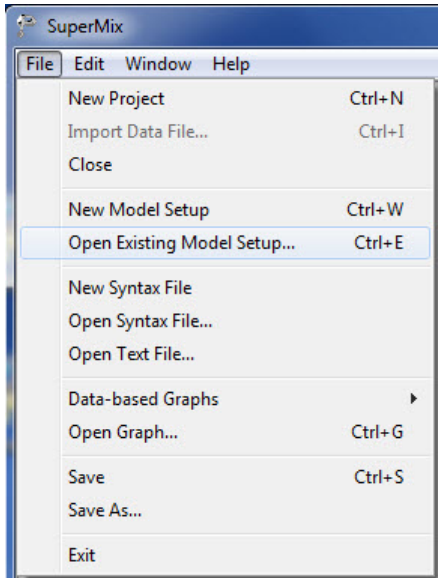
	(A)_School	(B)_Class	(C)_THKSco	(D)_Intrcpt	(E)_PreTHK	(F)_CC	(G)_TV	(H)_CCxTV
1	403.00	403101.00	3.00	1.00	2.00	1.00	0.00	0.00
2	403.00	403101.00	4.00	1.00	4.00	1.00	0.00	0.00
3	403.00	403101.00	3.00	1.00	4.00	1.00	0.00	0.00
4	403.00	403101.00	4.00	1.00	3.00	1.00	0.00	0.00
5	403.00	403101.00	4.00	1.00	3.00	1.00	0.00	0.00
6	403.00	403101.00	3.00	1.00	4.00	1.00	0.00	0.00
7	403.00	403101.00	2.00	1.00	2.00	1.00	0.00	0.00
8	403.00	403101.00	4.00	1.00	4.00	1.00	0.00	0.00
9	403.00	403101.00	5.00	1.00	5.00	1.00	0.00	0.00
10	403.00	403101.00	4.00	1.00	3.00	1.00	0.00	0.00
11	403.00	403101.00	3.00	1.00	3.00	1.00	0.00	0.00
12	403.00	403101.00	4.00	1.00	3.00	1.00	0.00	0.00
13	403.00	403101.00	3.00	1.00	1.00	1.00	0.00	0.00
14	403.00	403101.00	4.00	1.00	2.00	1.00	0.00	0.00
15	403.00	403101.00	2.00	1.00	2.00	1.00	0.00	0.00
16	403.00	403101.00	4.00	1.00	1.00	1.00	0.00	0.00
17	403.00	403101.00	4.00	1.00	4.00	1.00	0.00	0.00
18	403.00	403101.00	3.00	1.00	3.00	1.00	0.00	0.00
19	403.00	403101.00	3.00	1.00	0.00	1.00	0.00	0.00
20	403.00	403101.00	4.00	1.00	3.00	1.00	0.00	0.00
21	403.00	403102.00	2.00	1.00	0.00	1.00	0.00	0.00
22	403.00	403102.00	5.00	1.00	1.00	1.00	0.00	0.00
23	403.00	403102.00	3.00	1.00	5.00	1.00	0.00	0.00
24	404.00	404101.00	3.00	1.00	1.00	1.00	1.00	1.00
25	404.00	404101.00	4.00	1.00	2.00	1.00	1.00	1.00
26	404.00	404101.00	2.00	1.00	4.00	1.00	1.00	1.00
27	404.00	404101.00	3.00	1.00	3.00	1.00	1.00	1.00
28	404.00	404101.00	2.00	1.00	1.00	1.00	1.00	1.00
29	404.00	404101.00	1.00	1.00	1.00	1.00	1.00	1.00
30	404.00	404101.00	3.00	1.00	2.00	1.00	1.00	1.00
31	404.00	404101.00	5.00	1.00	0.00	1.00	1.00	1.00
32	404.00	404101.00	2.00	1.00	1.00	1.00	1.00	1.00
33	404.00	404101.00	3.00	1.00	2.00	1.00	1.00	1.00
34	404.00	404101.00	4.00	1.00	2.00	1.00	1.00	1.00
35	404.00	404102.00	3.00	1.00	1.00	1.00	1.00	1.00
36	404.00	404102.00	1.00	1.00	1.00	1.00	1.00	1.00
37	404.00	404102.00	0.00	1.00	0.00	1.00	1.00	1.00

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

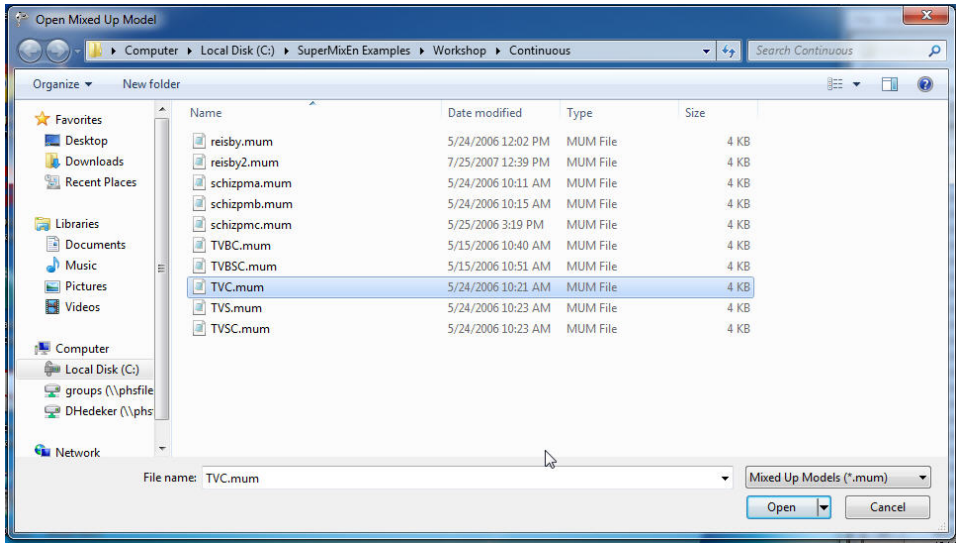


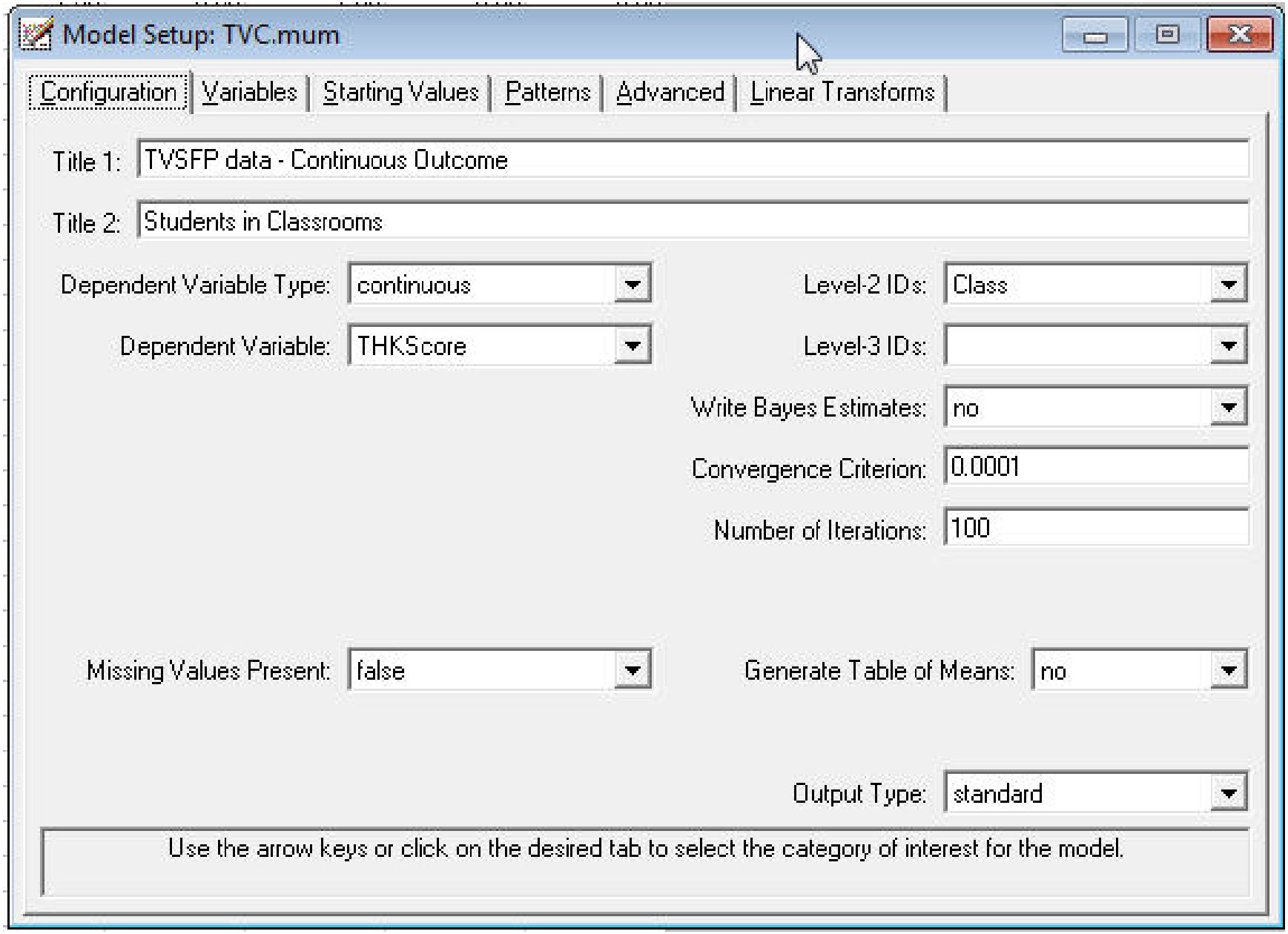

Histogram of THKScore
500
400
300
200
100
0
0
1
2
3
4
5
6
7
N = 1600
Mean = 2.6619
S.D. = 1.3829

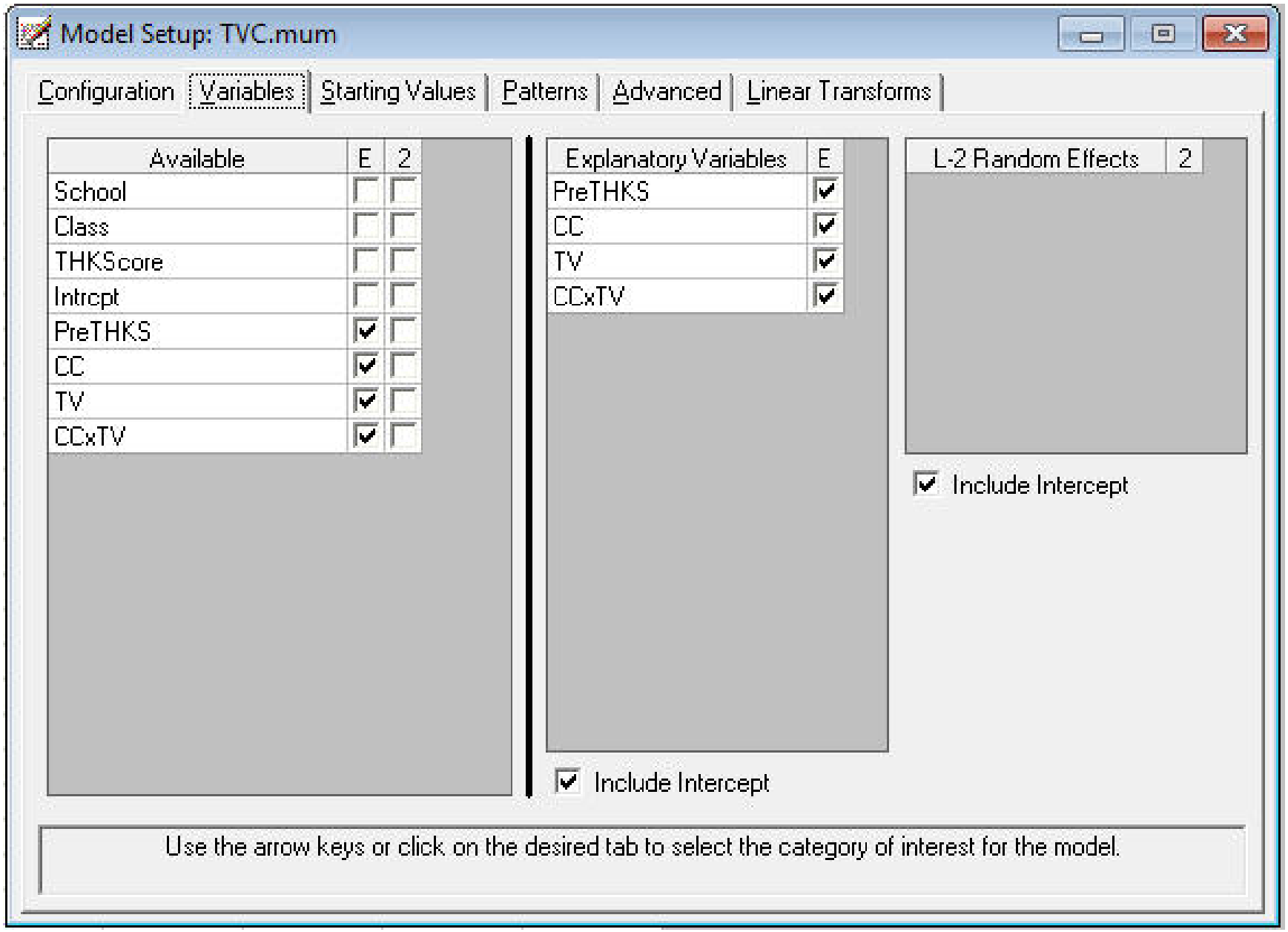
Under "File" click on "Open Existing Model Setup"

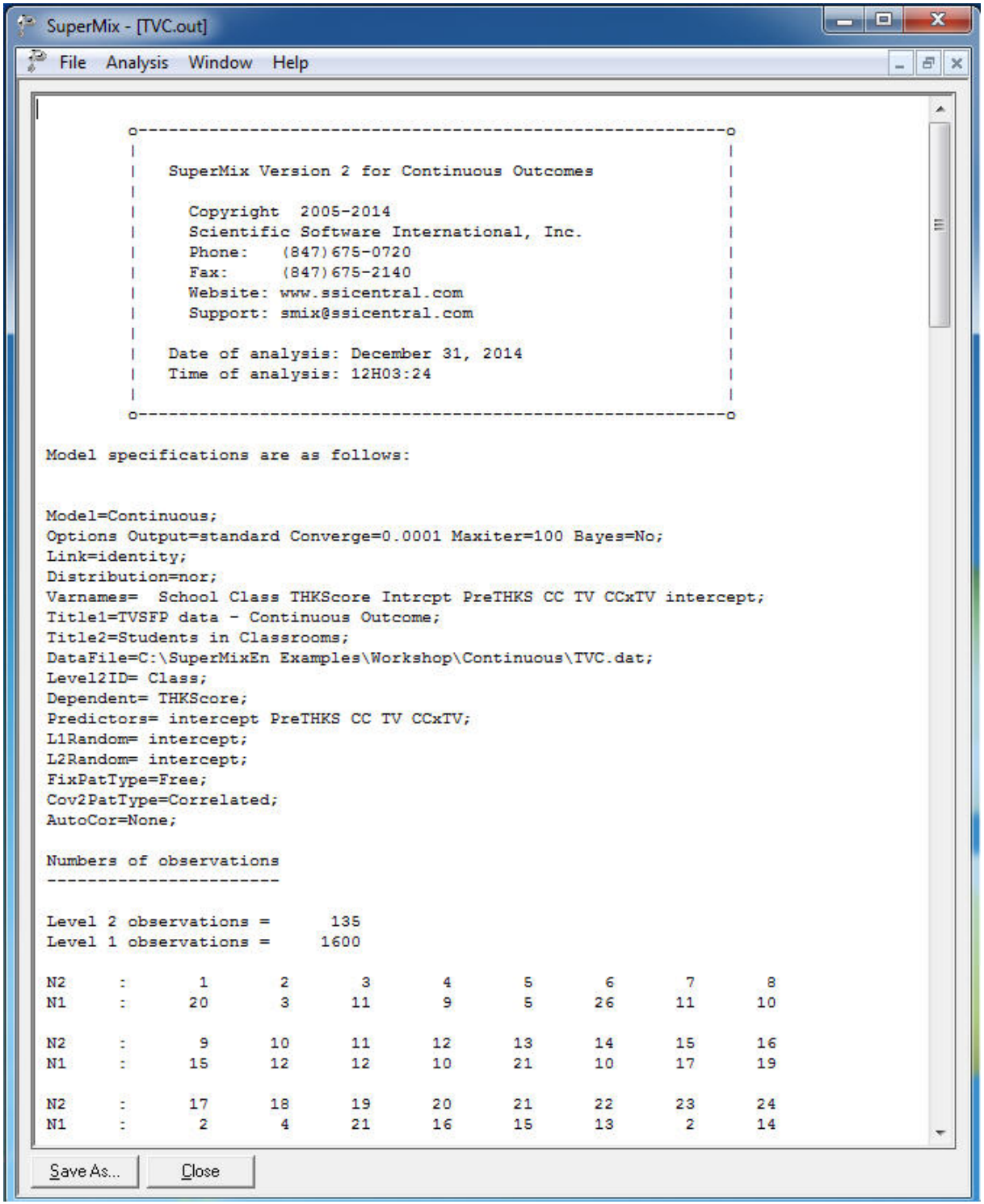


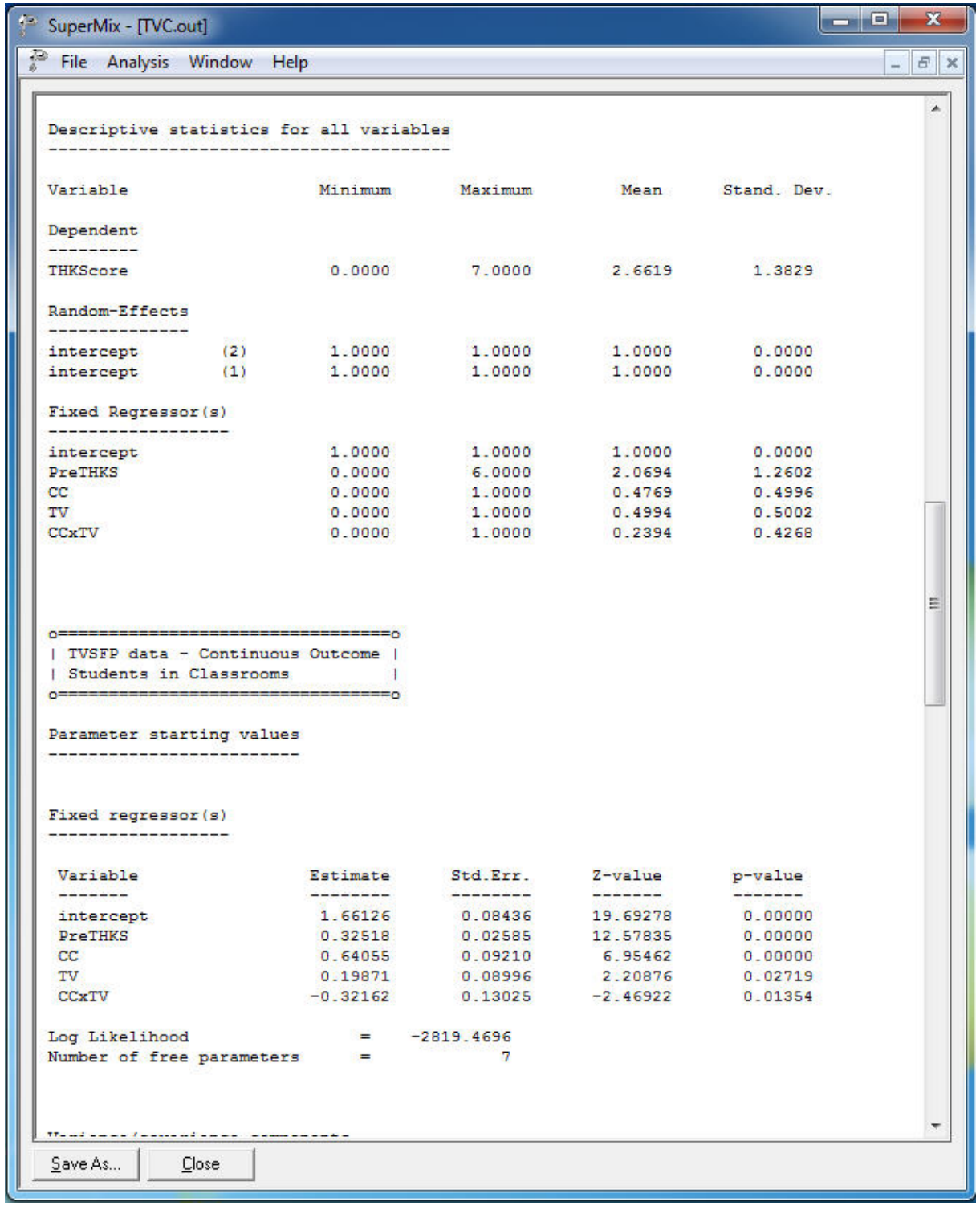
Open C:\SuperMixEn Examples\Workshop\Continuous\TVC.mum
(or C:\SuperMixEn Student Examples\Workshop\Continuous\TVC.mum)

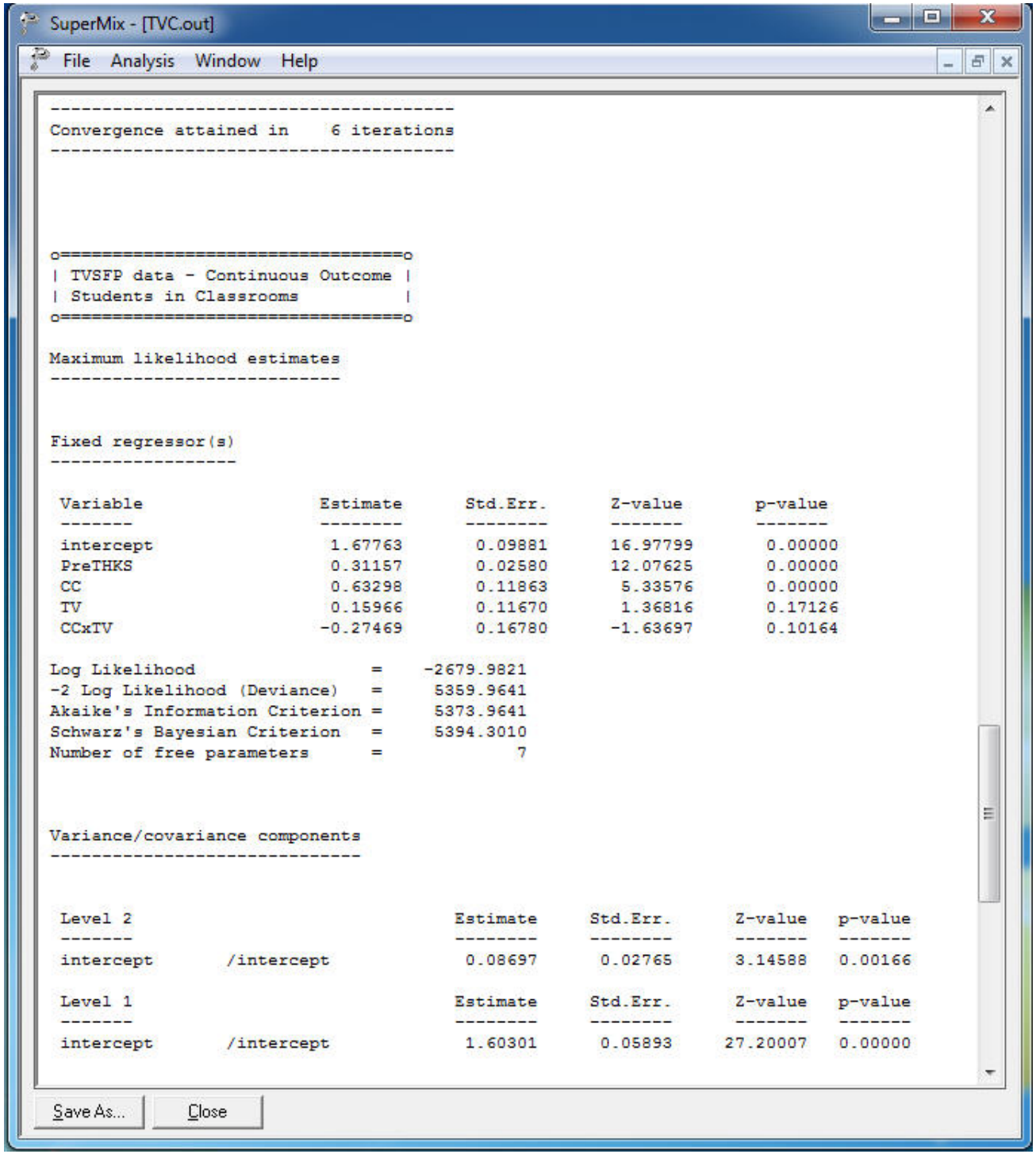



Model Setup: TVC.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Title 1:
TVSFP data - Continuous Outcome
Title 2:
Students in Classrooms
Dependent Variable Type:
continuous
Dependent Variable:
THKScore
Level-2 IDs:
Class
Level-3 IDs:
Write Bayes Estimates:
no
Convergence Criterion:
0.0001
Number of Iterations:
100
Missing Values Present:
false
Generate Table of Means:
no
Output Type:
standard
Use the arrow keys or click on the desired tab to select the category of interest for the model.


Model Setup: TVC.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Available
E
2
School
Class
THKScore
Intrcpt
PreTHKS
CC
TV
CCxTV
Explanatory Variables
E
PreTHKS
CC
TV
CCxTV
Include Intercept
L-2 Random Effects
2
Include Intercept
Use the arrow keys or click on the desired tab to select the category of interest for the model.

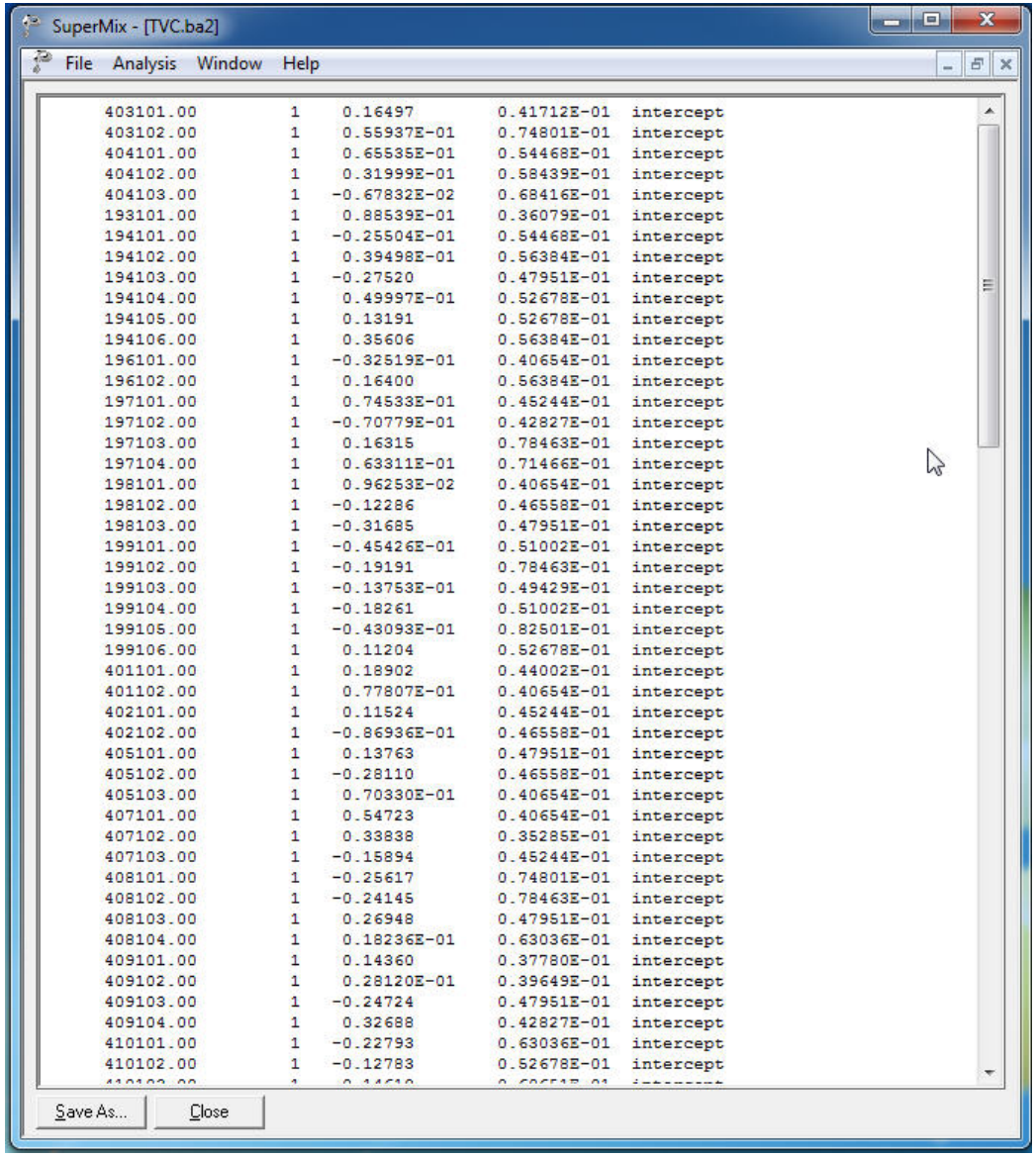

SuperMix - [TVC.out]
File Analysis Window Help
SuperMix Version 2 for Continuous Outcomes
Copyright 2005-2014
Scientific Software International, Inc.
Phone: (847)675-0720
Fax: (847)675-2140
Website: www.ssicentral.com
Support: smix@ssicentral.com
Date of analysis: December 31, 2014
Time of analysis: 12H03:24
Model specifications are as follows:
Model=Continuous;
Options Output=standard Converge=0.0001 Maxiter=100 Bayes=No;
Link=identity;
Distribution=nor;
Varnames= School Class THKScore Intrcpt PreTHKS CC TV CCxTV intercept;
Title1=TVSFP data - Continuous Outcome;
Title2=Students in Classrooms;
DataFile=C:\SuperMixEn Examples\Workshop\Continuous\TVC.dat;
Level2ID= Class;
Dependent= THKScore;
Predictors= intercept PreTHKS CC TV CCxTV;
L1Random= intercept;
L2Random= intercept;
FixPatType=Free;
Cov2PatType=Correlated;
AutoCor=None;
Numbers of observations
Level 2 observations = 135
Level 1 observations = 1600
N2 : 1 2 3 4 5 6 7 8
N1 : 20 3 11 9 5 26 11 10
N2 : 9 10 11 12 13 14 15 16
N1 : 15 12 12 10 21 10 17 19
N2 : 17 18 19 20 21 22 23 24
N1 : 2 4 21 16 15 13 2 14
Save As...
Close


SuperMix - [TVC.out]
File Analysis Window Help
Descriptive statistics for all variables
Variable Minimum Maximum Mean Stand. Dev.
Dependent
THKScore 0.0000 7.0000 2.6619 1.3829
Random-Effects
intercept (2) 1.0000 1.0000 1.0000 0.0000
intercept (1) 1.0000 1.0000 1.0000 0.0000
Fixed Regressor(s)
intercept 1.0000 1.0000 1.0000 0.0000
PreTHKS 0.0000 6.0000 2.0694 1.2602
CC 0.0000 1.0000 0.4769 0.4996
TV 0.0000 1.0000 0.4994 0.5002
CCxTV 0.0000 1.0000 0.2394 0.4268
| TVSFP data - Continuous Outcome |
| Students in Classrooms |
Parameter starting values
Fixed regressor(s)
Variable Estimate Std.Err. Z-value p-value
intercept 1.66126 0.08436 19.69278 0.00000
PreTHKS 0.32518 0.02585 12.57835 0.00000
CC 0.64055 0.09210 6.95462 0.00000
TV 0.19871 0.08996 2.20876 0.02719
CCxTV -0.32162 0.13025 -2.46922 0.01354
Log Likelihood = -2819.4696
Number of free parameters = 7
Save As...
Close


SuperMix - [TVC.out]
File Analysis Window Help
Convergence attained in 6 iterations
TVSFP data - Continuous Outcome
Students in Classrooms
Maximum likelihood estimates
Fixed regressor(s)
Variable Estimate Std.Err. Z-value p-value
intercept 1.67763 0.09881 16.97799 0.00000
PreTHKS 0.31157 0.02580 12.07625 0.00000
CC 0.63298 0.11863 5.33576 0.00000
TV 0.15966 0.11670 1.36816 0.17126
CCxTV -0.27469 0.16780 -1.63697 0.10164
Log Likelihood = -2679.9821
-2 Log Likelihood (Deviance) = 5359.9641
Akaike's Information Criterion = 5373.9641
Schwarz's Bayesian Criterion = 5394.3010
Number of free parameters = 7
Variance/covariance components
Level 2 Estimate Std.Err. Z-value p-value
intercept /intercept 0.08697 0.02765 3.14588 0.00166
Level 1 Estimate Std.Err. Z-value p-value
intercept /intercept 1.60301 0.05893 27.20007 0.00000
Save As...
Close

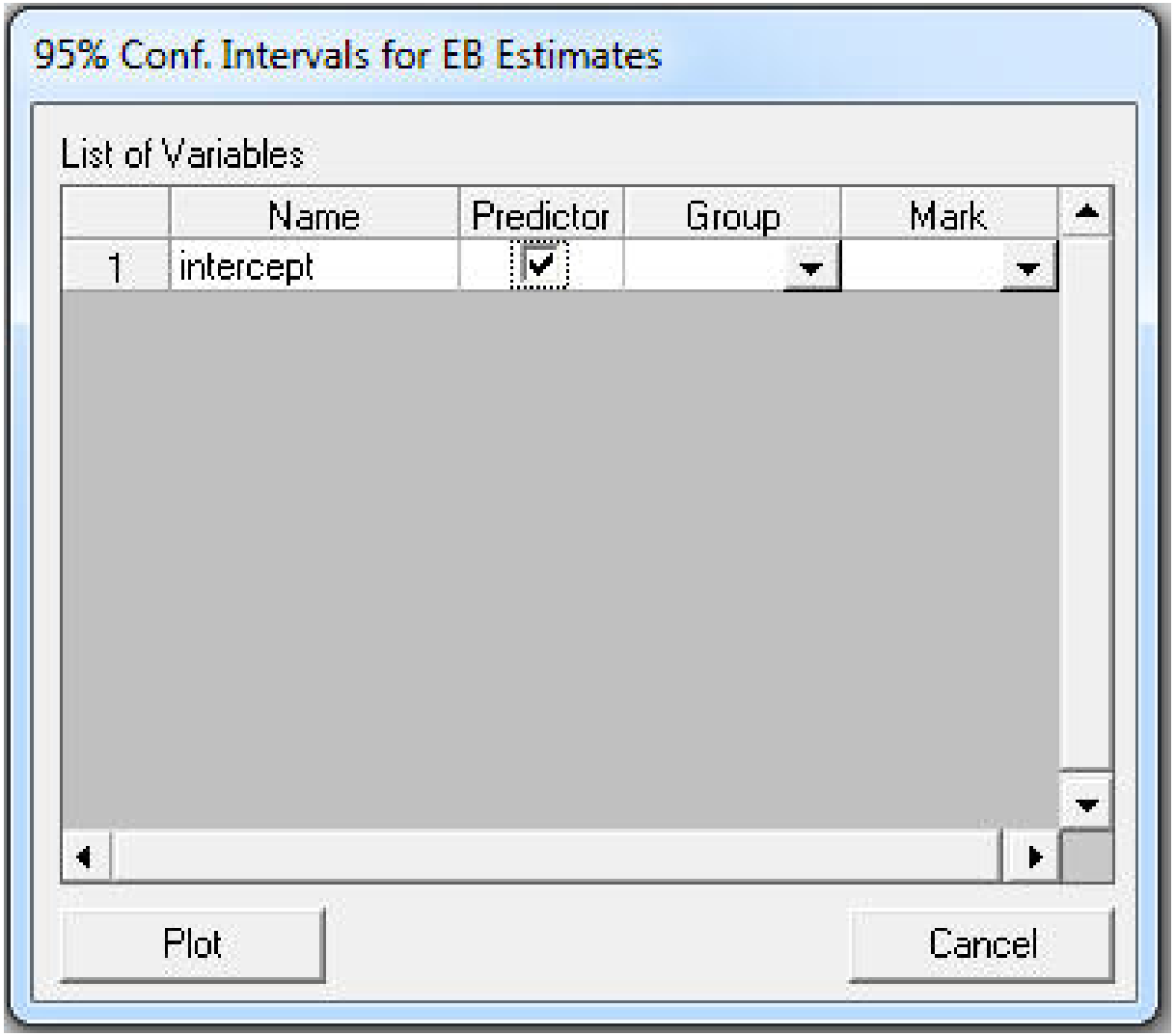
Empirical Bayes Estimates of Random Effects

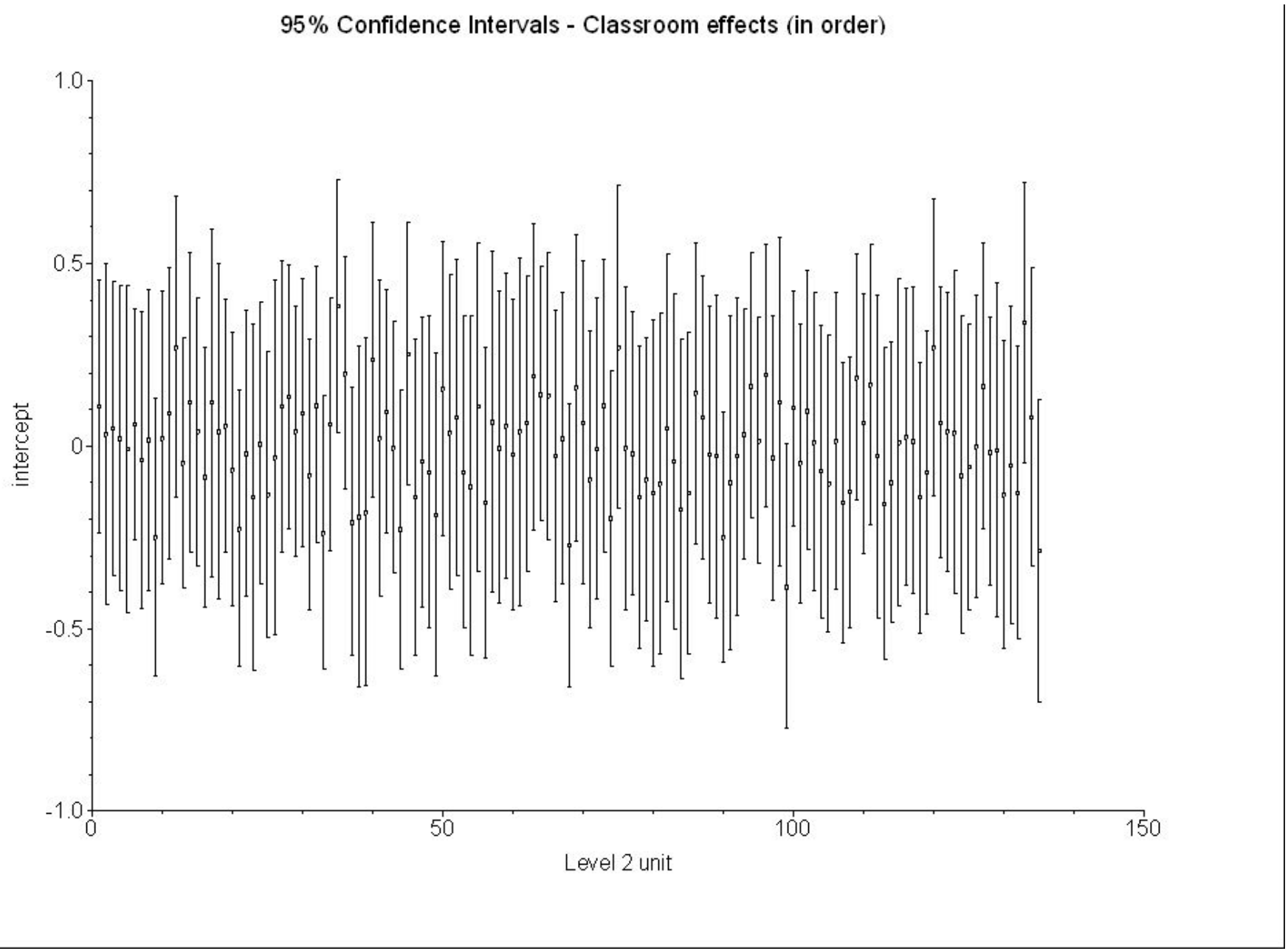
Select "Analysis" > "View Level-2 Bayes Results"



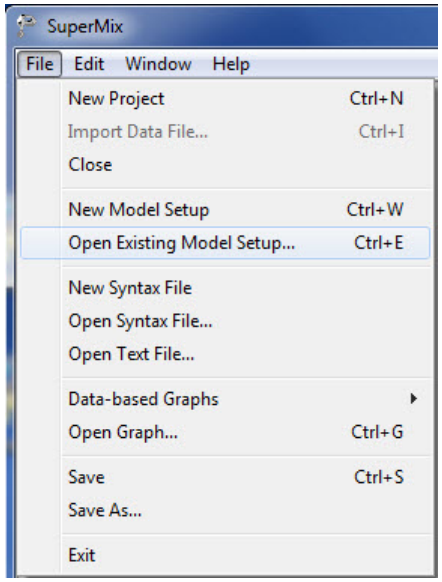
ID, random effect number, estimate, variance, name

Select "File" > "Model-based Graphs" > "Confidence Intervals'

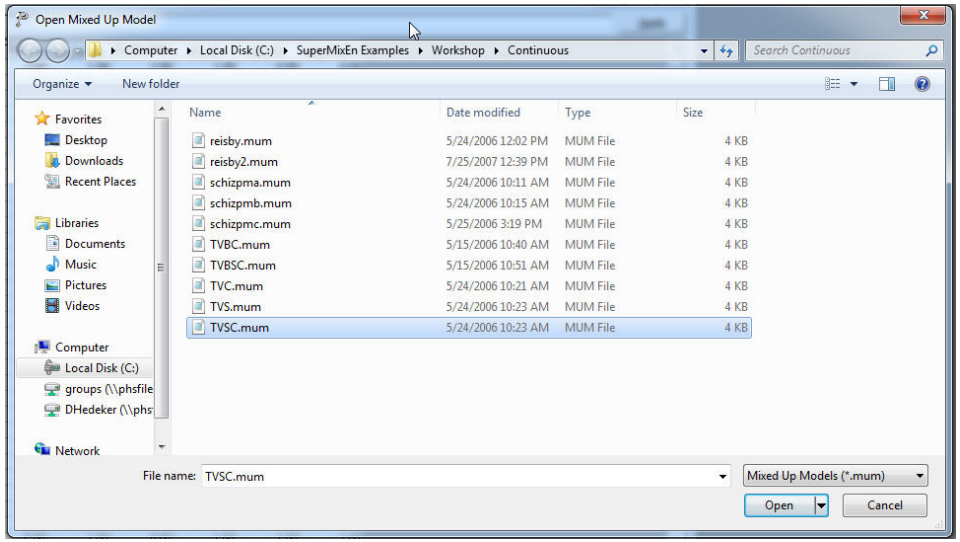


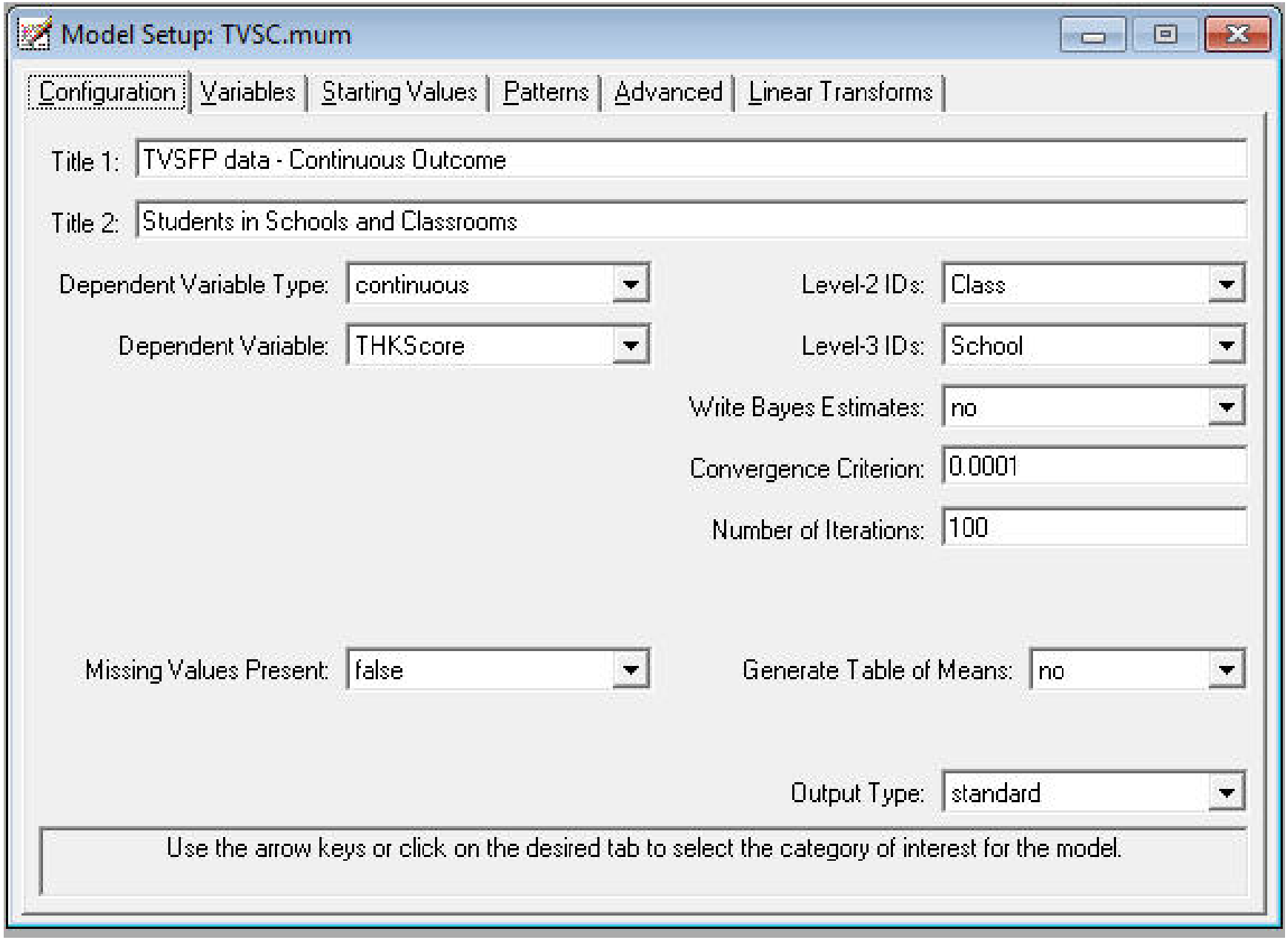

95% Confidence Intervals - Classroom effects (in order)
1.0
0.5
0
-0.5
-1.0
intercept
0
50
100
150
Level 2 unit

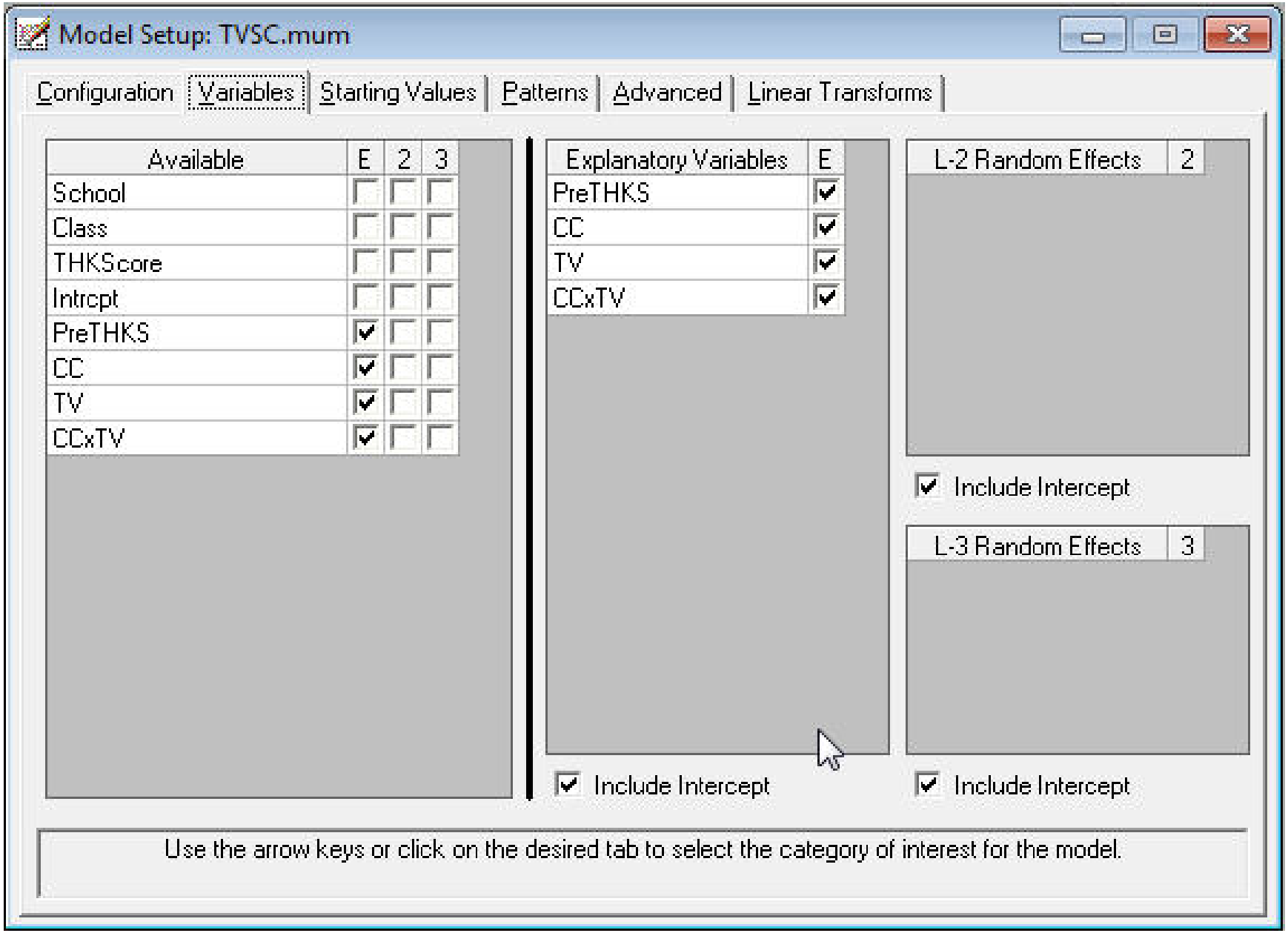
Under "File" click on "Open Existing Model Setup"

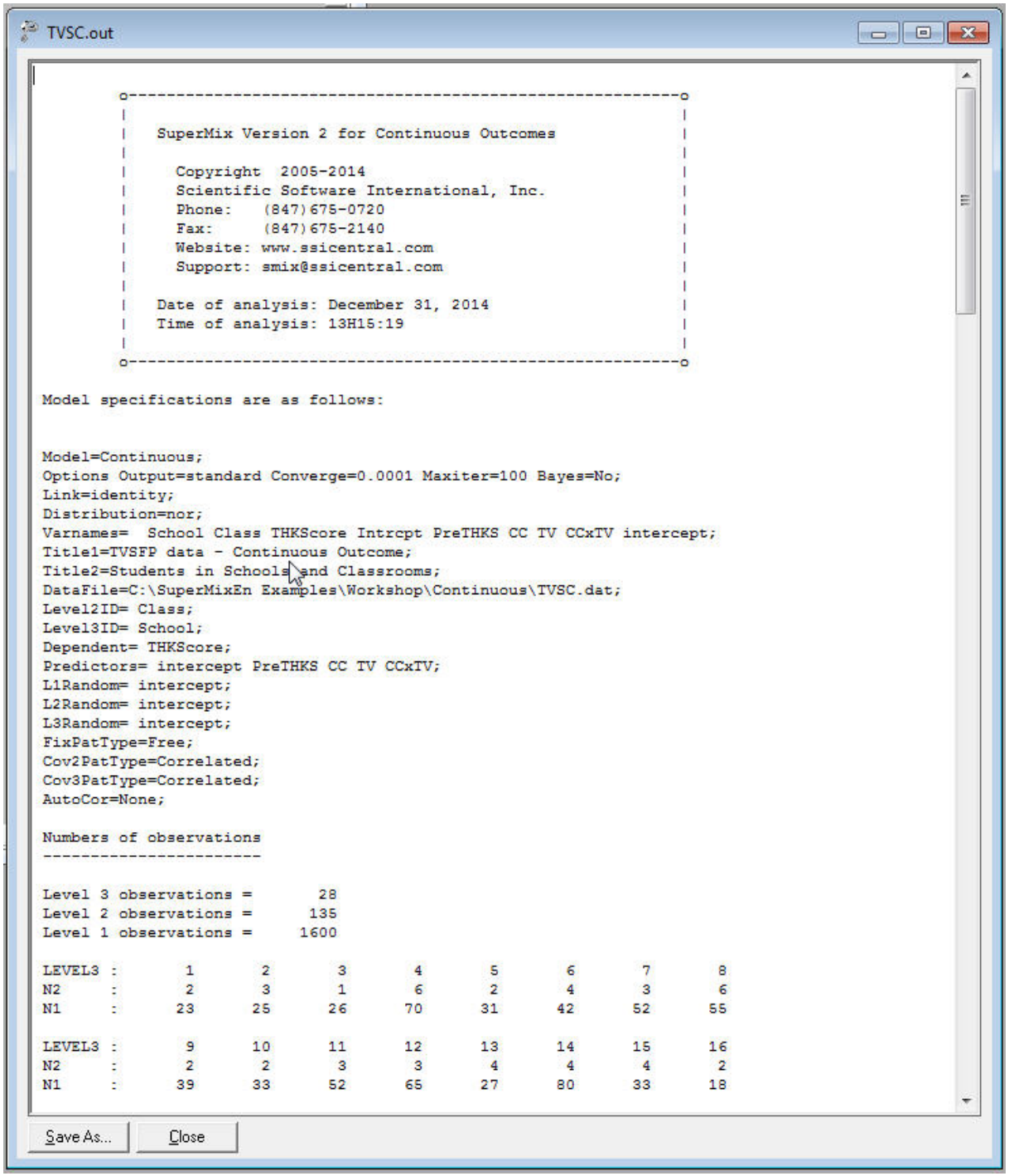


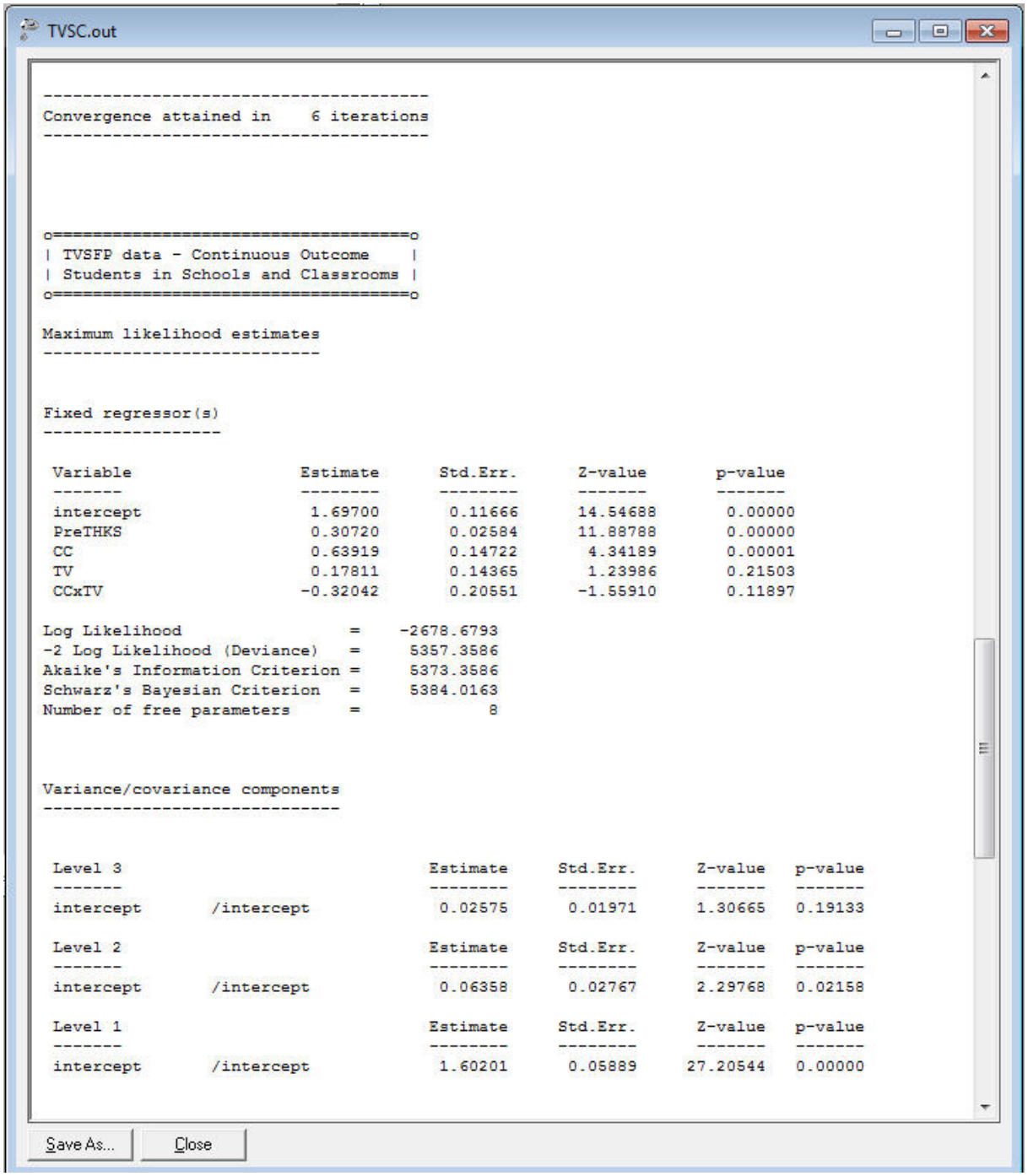
Open C:\SuperMixEn Examples\Workshop\Continuous\TVSC.mum
(or C:\SuperMixEn Student Examples\Workshop\Continuous\TVSC.mum)




Model Setup: TVSC.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Title 1:
TVSFP data - Continuous Outcome
Title 2:
Students in Schools and Classrooms
Dependent Variable Type:
continuous
Dependent Variable:
THKScore
Level-2 IDs:
Class
Level-3 IDs:
School
Write Bayes Estimates:
no
Convergence Criterion:
0.0001
Number of Iterations:
100
Missing Values Present:
false
Generate Table of Means:
no
Output Type:
standard
Use the arrow keys or click on the desired tab to select the category of interest for the model.

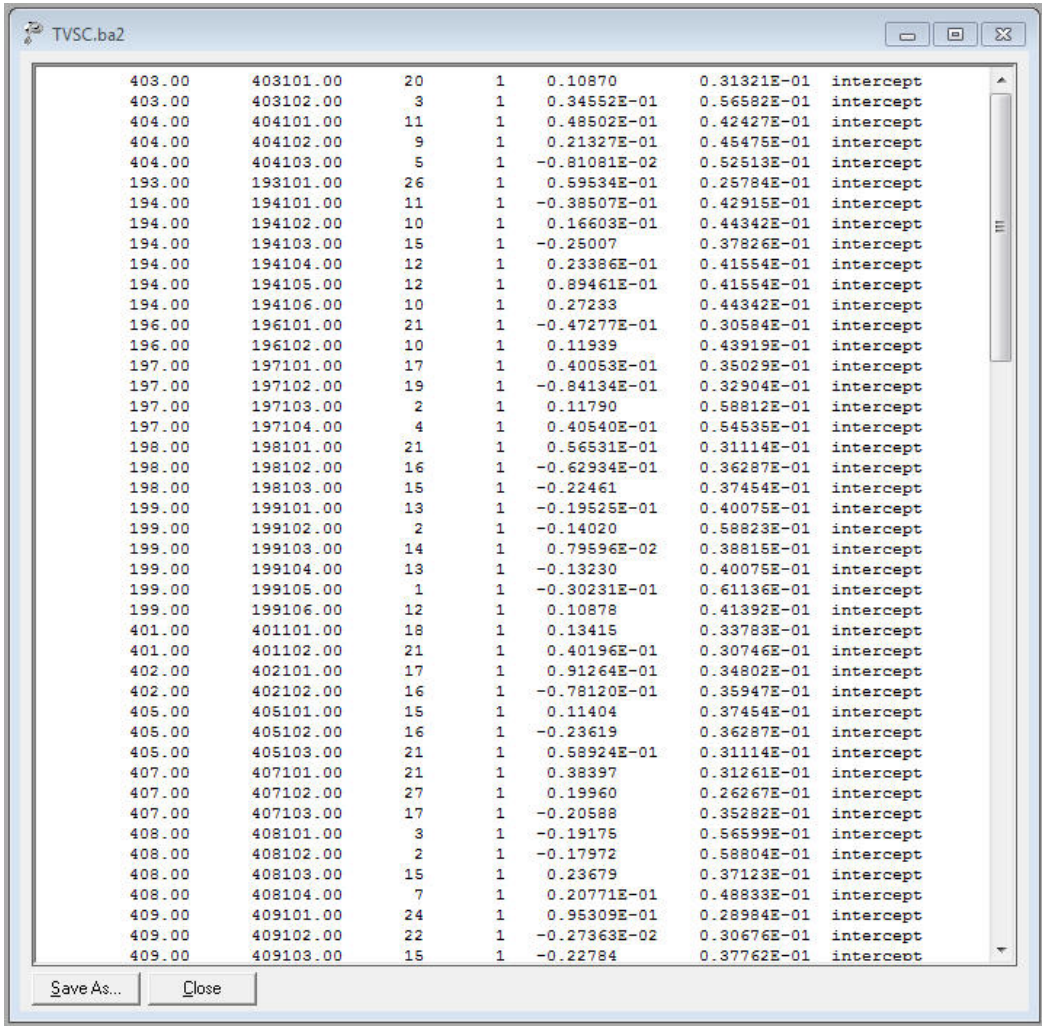

Model Setup: TVSC.mum
Configuration
Variables
Starting Values
Patterns
Advanced
Linear Transforms
Available
E
2
3
School
Class
THKScore
Intrcpt
PreTHKS
CC
TV
CCxTV
Explanatory Variables
E
PreTHKS
CC
TV
CCxTV
Include Intercept
L-2 Random Effects
2
Include Intercept
L-3 Random Effects
3
Include Intercept
Use the arrow keys or click on the desired tab to select the category of interest for the model.


TVSC.out
SuperMix Version 2 for Continuous Outcomes
Copyright 2005-2014
Scientific Software International, Inc.
Phone: (847)675-0720
Fax: (847)675-2140
Website: www.ssicentral.com
Support: smix@ssicentral.com
Date of analysis: December 31, 2014
Time of analysis: 13H15:19
Model specifications are as follows:
Model=Continuous;
Options Output=standard Converge=0.0001 Maxiter=100 Bayes=No;
Link=identity;
Distribution=nor;
Varnames= School Class THKScore Intrcpt PreTHKS CC TV CCxTV intercept;
Title1=TVSFP data - Continuous Outcome;
Title2=Students in Schools and Classrooms;
DataFile=C:\SuperMixEn Examples\Workshop\Continuous\TVSC.dat;
Level2ID= Class;
Level3ID= School;
Dependent= THKScore;
Predictors= intercept PreTHKS CC TV CCxTV;
L1Random= intercept;
L2Random= intercept;
L3Random= intercept;
FixPatType=Free;
Cov2PatType=Correlated;
Cov3PatType=Correlated;
AutoCor=None;
Numbers of observations
Level 3 observations = 28
Level 2 observations = 135
Level 1 observations = 1600
LEVEL3 : 1 2 3 4 5 6 7 8
N2 : 2 3 1 6 2 4 3 6
N1 : 23 25 26 70 31 42 52 55
LEVEL3 : 9 10 11 12 13 14 15 16
N2 : 2 2 3 3 4 4 4 2
N1 : 39 33 52 65 27 80 33 18
Save As...
Close


TVSC.out
Convergence attained in 6 iterations
o=====o
| TVSFP data - Continuous Outcome |
| Students in Schools and Classrooms |
o=====o
Maximum likelihood estimates
Fixed regressor(s)
Variable Estimate Std.Err. Z-value p-value
intercept 1.69700 0.11666 14.54688 0.00000
PreTHKS 0.30720 0.02584 11.88788 0.00000
CC 0.63919 0.14722 4.34189 0.00001
TV 0.17811 0.14365 1.23986 0.21503
CCxTV -0.32042 0.20551 -1.55910 0.11897
Log Likelihood = -2678.6793
-2 Log Likelihood (Deviance) = 5357.3586
Akaike's Information Criterion = 5373.3586
Schwarz's Bayesian Criterion = 5384.0163
Number of free parameters = 8
Variance/covariance components
Level 3 Estimate Std.Err. Z-value p-value
intercept /intercept 0.02575 0.01971 1.30665 0.19133
Level 2 Estimate Std.Err. Z-value p-value
intercept /intercept 0.06358 0.02767 2.29768 0.02158
Level 1 Estimate Std.Err. Z-value p-value
intercept /intercept 1.60201 0.05889 27.20544 0.00000
Save As...
Close

Empirical Bayes Estimates of Random Effects

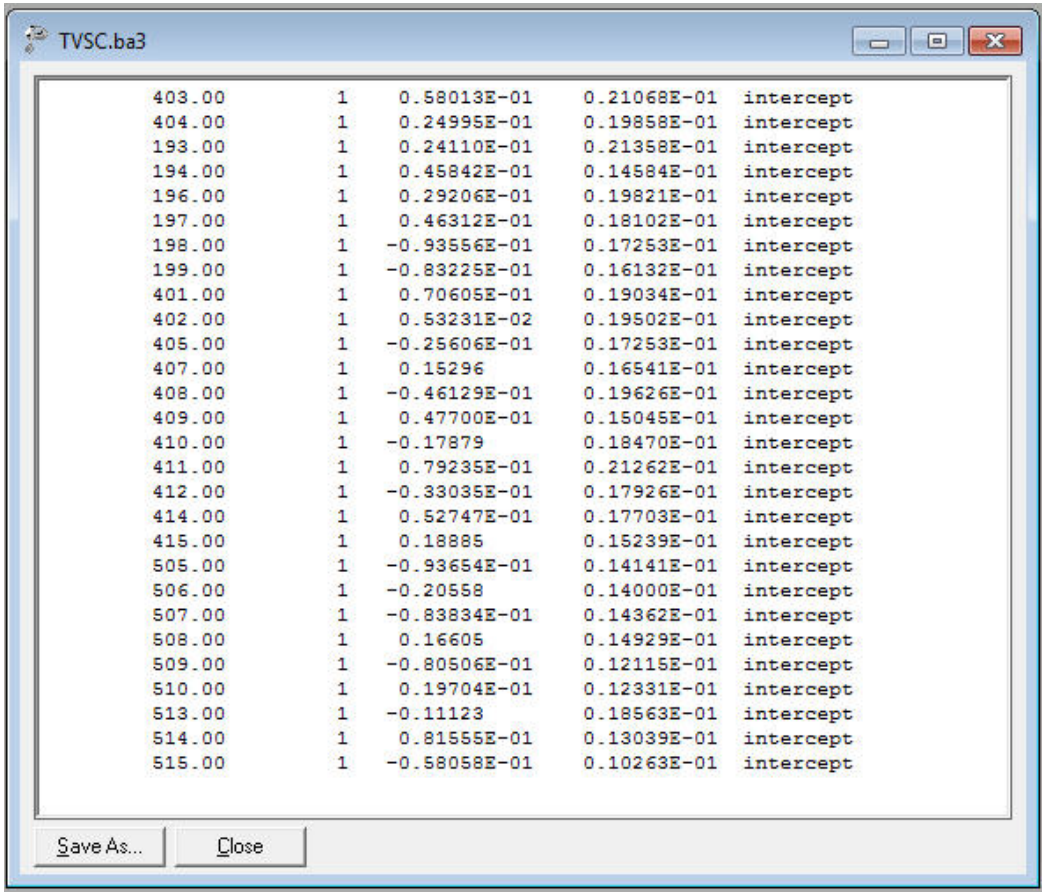
Select "Analysis" > "View Level-2 Bayes Results"



School ID, Class ID, number of observations in the class, random effect number, estimate, variance, name

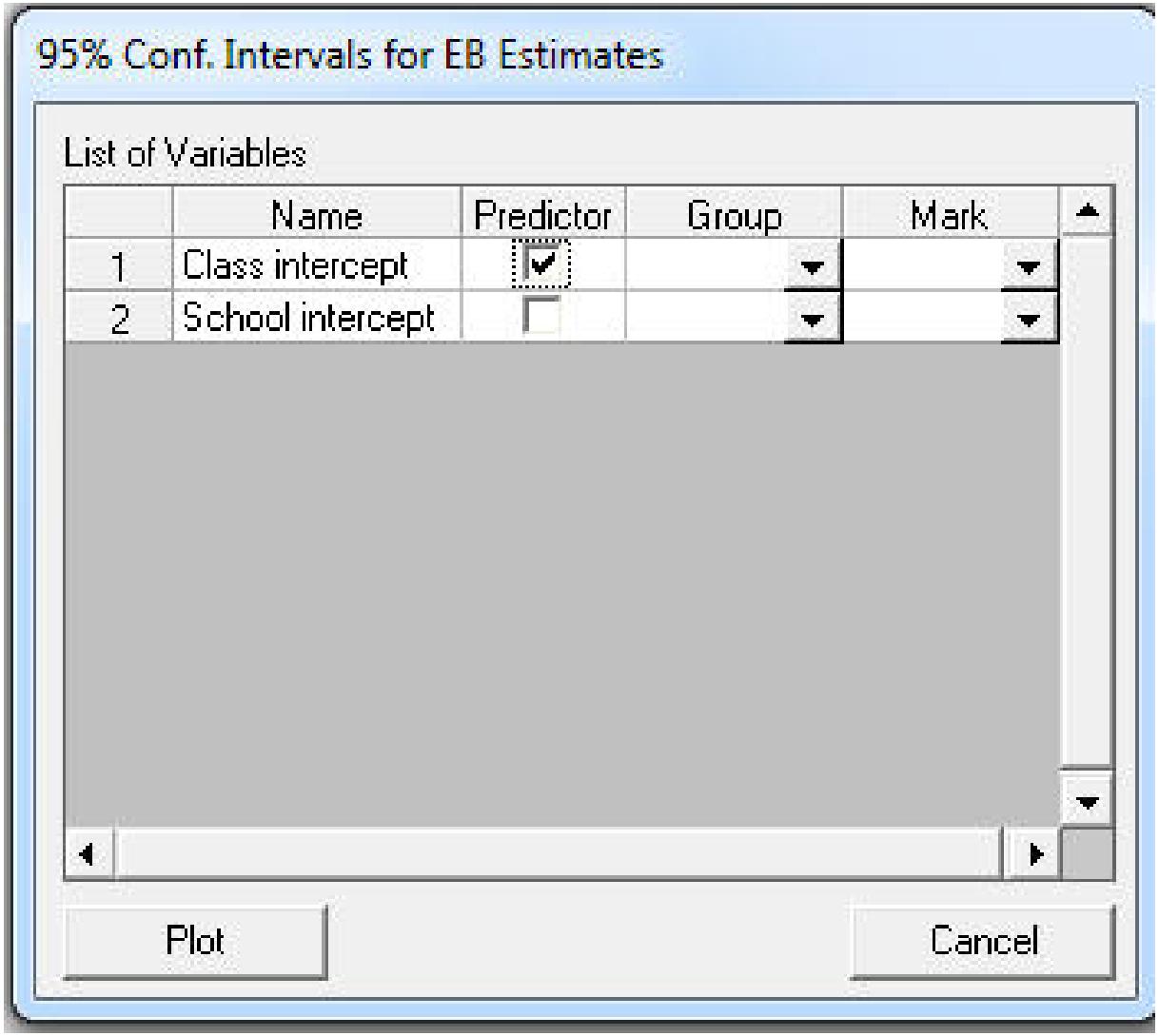
Empirical Bayes Estimates of Random Effects

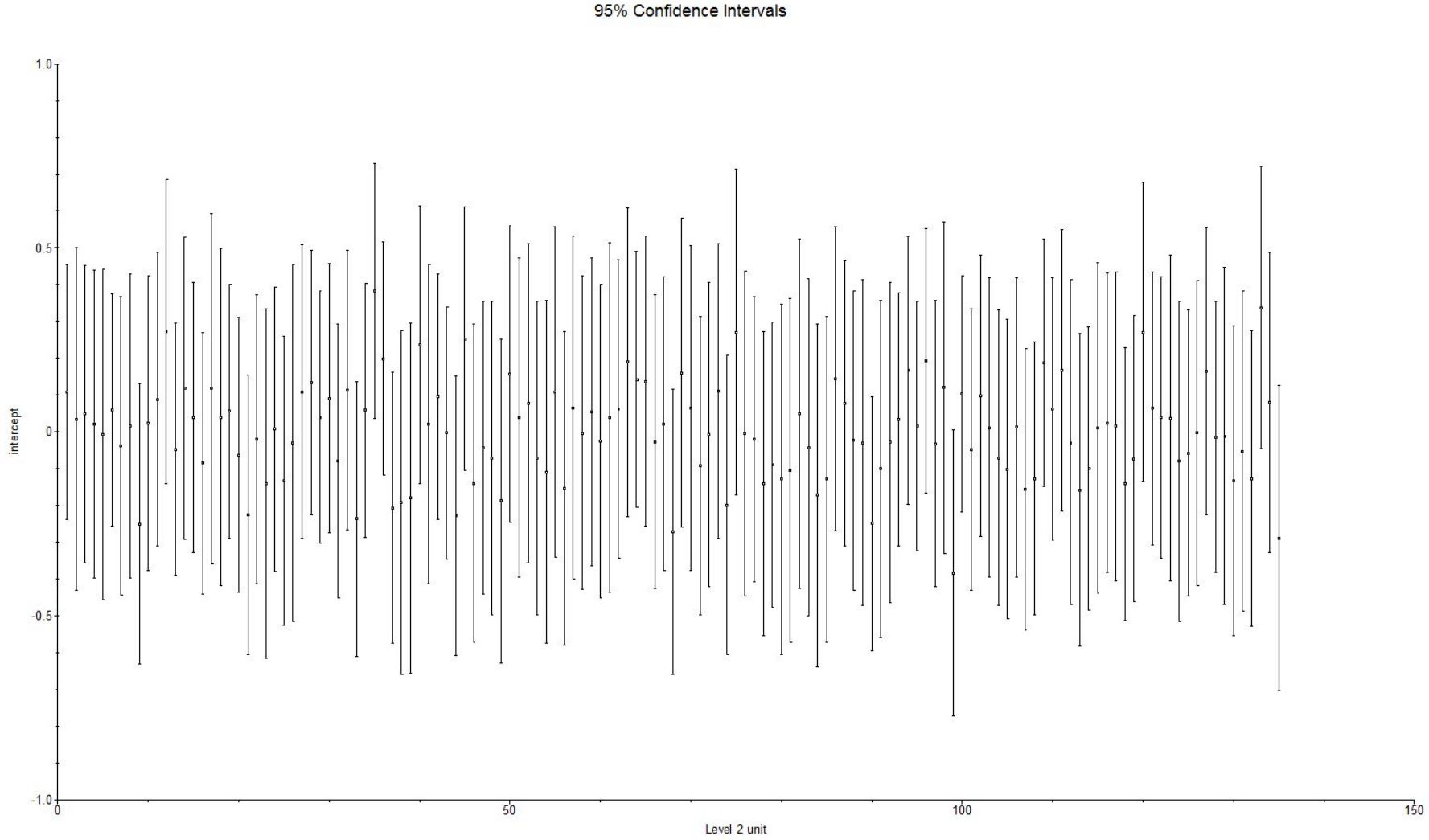
Select "Analysis" > "View Level-3 Bayes Results"



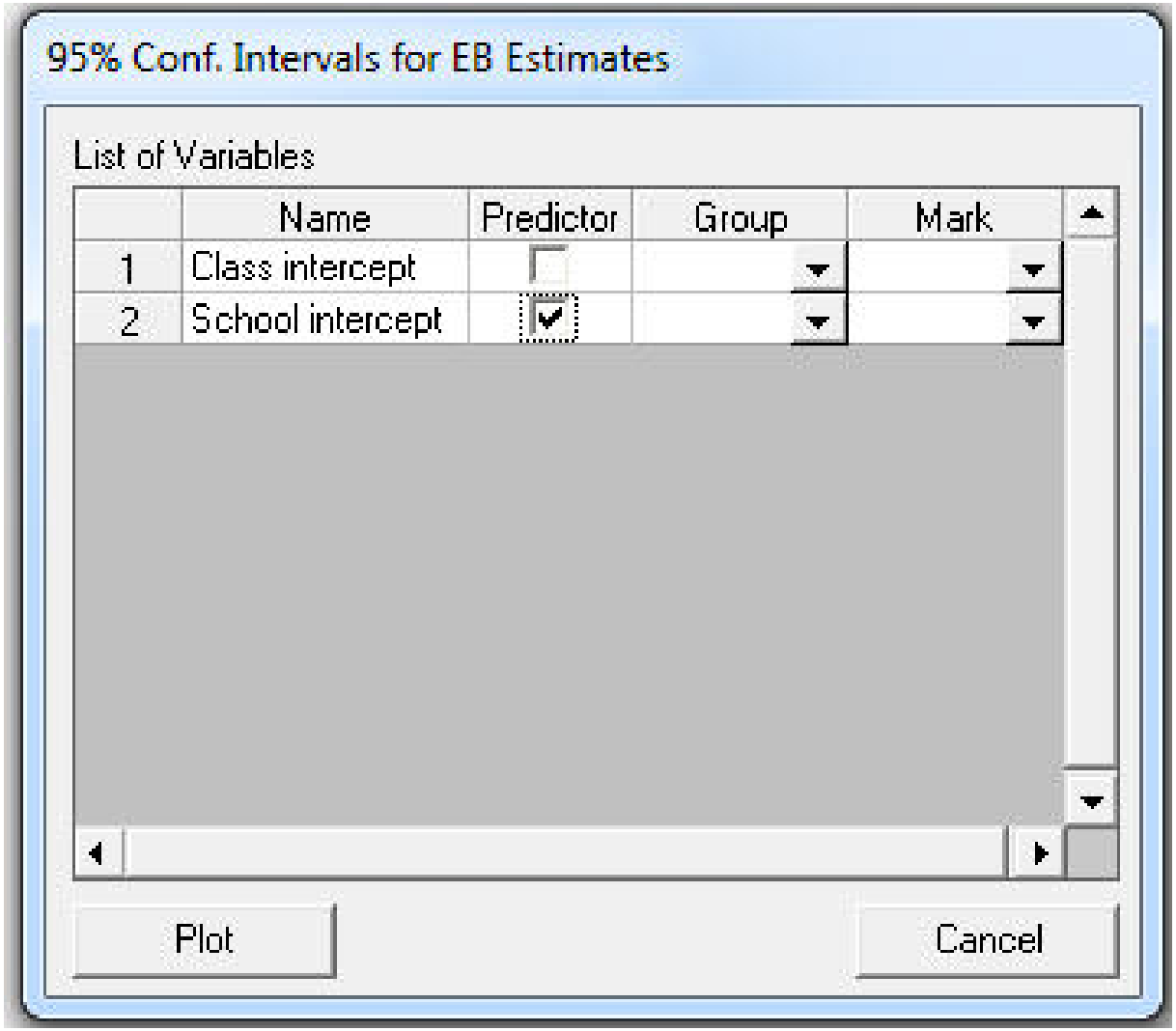
School ID, random effect number, estimate, variance, name

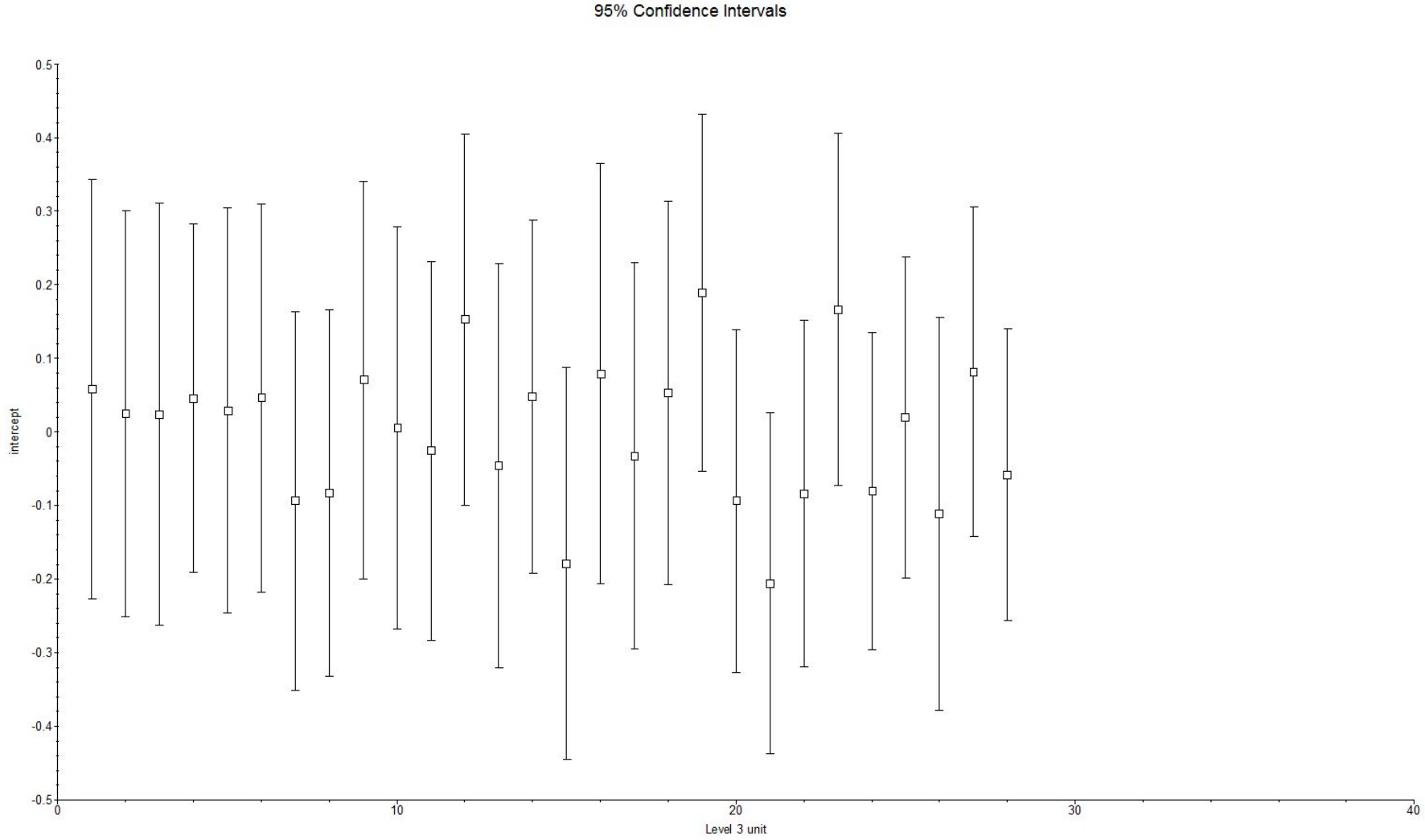
Select "File" > "Model-based Graphs" > "Confidence Intervals'




95% Confidence Intervals
1.0
0.5
0
-0.5
-1.0
intercept
0
50
100
150
Level 2 unit

Select "File" > "Model-based Graphs" > "Confidence Intervals'




95% Confidence Intervals
intercept
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
10
20
30
40
Level 3 unit

Summary

- Spreadsheet allows some data manipulation
  - add/delete columns or rows
  - transformations of variables (abs, exp, ln, sqrt, square)
  - summary statistics of variables (average, median, min, max, mode)
  - can create interaction terms and grand-mean centered variables
- Various kinds of data-based and model-based plots
- Up to 3-level models with full likelihood estimation (and empirical Bayes estimation of random effects)
- Linear transforms of parameter estimates
- Non-normal outcomes: binary, ordinal, nominal, and counts