Multilevel modeling

1. Introduction

In practice, many multivariate data sets are obtained by using complex sampling designs. Cluster sampling is a very popular sampling method if the target population has a multilevel (hierarchical) structure such as educational target populations for which students are nested within schools that are again nested in education departments. It is a well-known fact that alternative statistical methods are required to analyze multilevel data sets in an appropriate fashion (see e.g. Goldstein (1987, 1995)). Statistical software such as MLWin, SAS PROC MIXED, and HLM are used to fit linear and nonlinear models appropriately to hierarchical data sets.

The statistical application MULTILEV8 of LISREL 8.80 for Windows (Jöreskog & Sörbom 2006) may also be used to fit linear and nonlinear models appropriately to hierarchical data sets. More details on MULTILEV8 are available in Du Toit & Du Toit (2001) while comprehensive technical details on the corresponding statistical methods are provided in Jöreskog et al (2001).

In this note, MULTILEV8 is used to analyze air traffic control data and multivariate education data. The air traffic control data set is described in the next section. Thereafter, a variance decomposition model and a non-linear model without and with additional variables are fitted to the air traffic control data. A multivariate educational data set is described in Section 4. In Section 5, a multivariate multilevel analysis of the educational data is performed.

2. The air traffic control data

The data used in this example are described in Kanfer & Ackerman (1989). The data consist of information for 141 U.S. Air Force enlisted personnel. The personnel carried out a computerized air traffic controller task developed by Kanfer and Ackerman.

The subjects were instructed to accept planes into their hold pattern and land them safely and efficiently on one of four runways, varying in length and compass directions, according to rules governing plane movements and landing requirements. For each subject, the success of a series of between three and six 10-minute trials was recorded. The measurement employed was the number of correct landings per trial. The Armed Services Vocational Battery (ASVB) was also administered to each subject. A global measure of cognitive ability, obtained from the sum of scores on the 10 subscales, is also included in the data. The raw data are provided in the PRELIS System File (PSF) ***KANFER.PSF***. This file is located in ***C:\LISREL 8.8 Student Examples\MLEVELEX***. The first potion of this file is shown in the following PSF window.

KANFER.PSF

	control	time	measure	ability	constant	timesq
1	1.000	1.000	24.000	142.160	1.000	1.000
2	1.000	2.000	27.000	142.160	1.000	4.000
3	1.000	3.000	30.000	142.160	1.000	9.000
4	1.000	4.000	32.000	142.160	1.000	16.000
5	1.000	5.000	38.000	142.160	1.000	25.000
6	1.000	6.000	41.000	142.160	1.000	36.000
7	2.000	1.000	2.000	-7.630	1.000	1.000
8	2.000	2.000	3.000	-7.630	1.000	4.000
9	2.000	3.000	9.000	-7.630	1.000	9.000
10	2.000	4.000	13.000	-7.630	1.000	16.000
11	2.000	5.000	13.000	-7.630	1.000	25.000
12	2.000	6.000	14.000	-7.630	1.000	36.000
13	3.000	1.000	12.000	-67.430	1.000	1.000
14	3.000	2.000	18.000	-67.430	1.000	4.000
15	3.000	3.000	24.000	-67.430	1.000	9.000

The variables in the data set above are the identifying number of the air traffic controller (***control***), the number of the trial (ranging from 1 to 6) (***time***), the number of successful landings for the trial (***measure***), the cognitive ability score (combined ASVB score) (***ability***), the intercept term (***constant***), with value 1 throughout and the square value of the number of the trial (***timesq***).

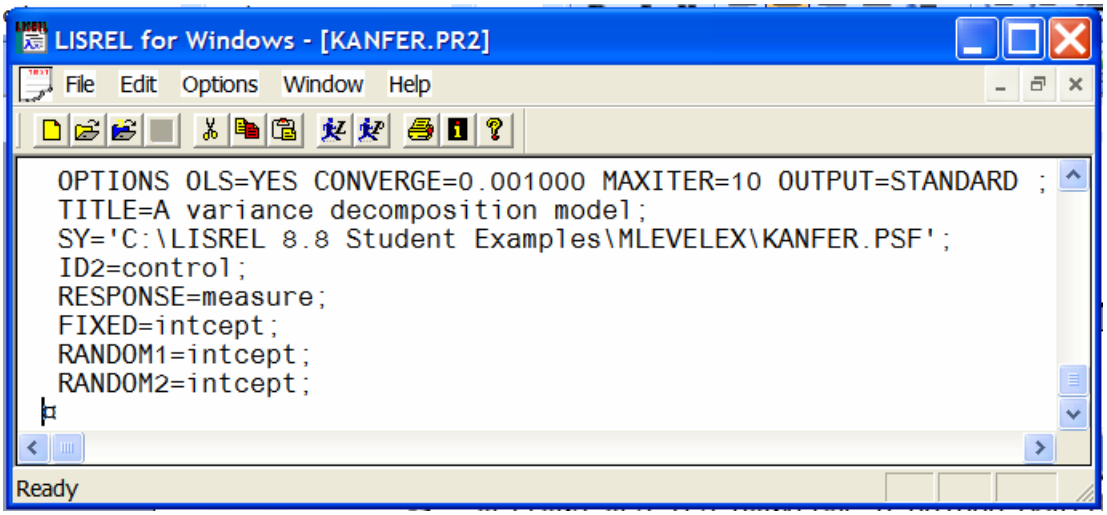
3. The analysis of the air traffic control data

The variance decomposition model

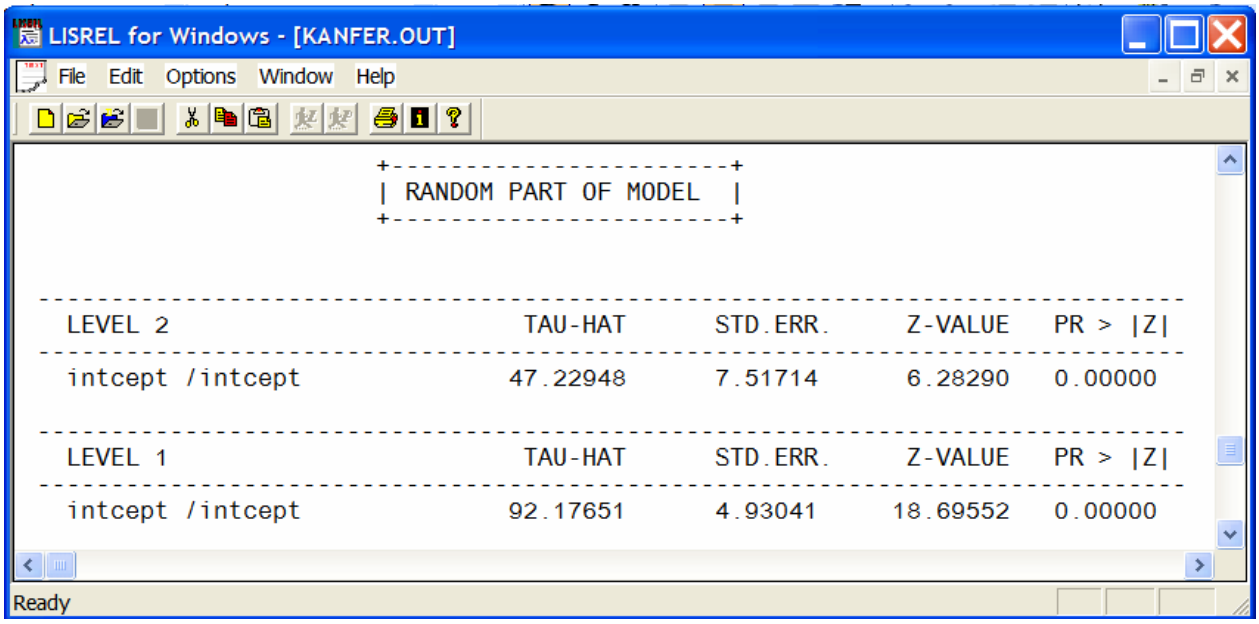
In the case of the air traffic control data, the variance decomposition model enables us to investigate the variation in the number of correct trials over subjects and also over the six measurements for each subject.

- Select the ***Open*** option on the ***File*** menu to load the ***Open*** dialog box.
- Select the ***PRELIS data (*.psf)*** option from the ***Files of type:*** dropdown list box.
- Browse for the location ***C:\LISREL 8.8 Student Examples\MLEVELEX***.
- Select the file ***KANFER.PSF*** by clicking on it.
- Click on the ***Open*** button to open ***KANFER.PSF*** in a PSF window.
- Select the ***Title and Options*** option on the ***Linear Model*** pop-up menu of the ***Multilevel*** menu of the PSF window to load the ***Title and Options*** dialog box.
- Enter ***A variance decomposition model*** in the ***Title*** string field.
- Click on the ***Next*** button to load the ***Identification variables*** dialog box.
- Select the variable ***control*** by clicking on it.
- Click on the ***Add*** button of the ***Level 2 ID Variable*** section.
- Click on the ***Next*** button to load the ***Select Response and Fixed Variables*** dialog box.

- Select the variable ***measure*** by clicking on it.
- Click on the ***Add*** button of the ***Response Variables*** section.
- Click on the ***Next*** button to load the ***Random Variables*** dialog box.
- Click on the ***Finish*** button to open the following text editor window for ***KANFER.PR2***.

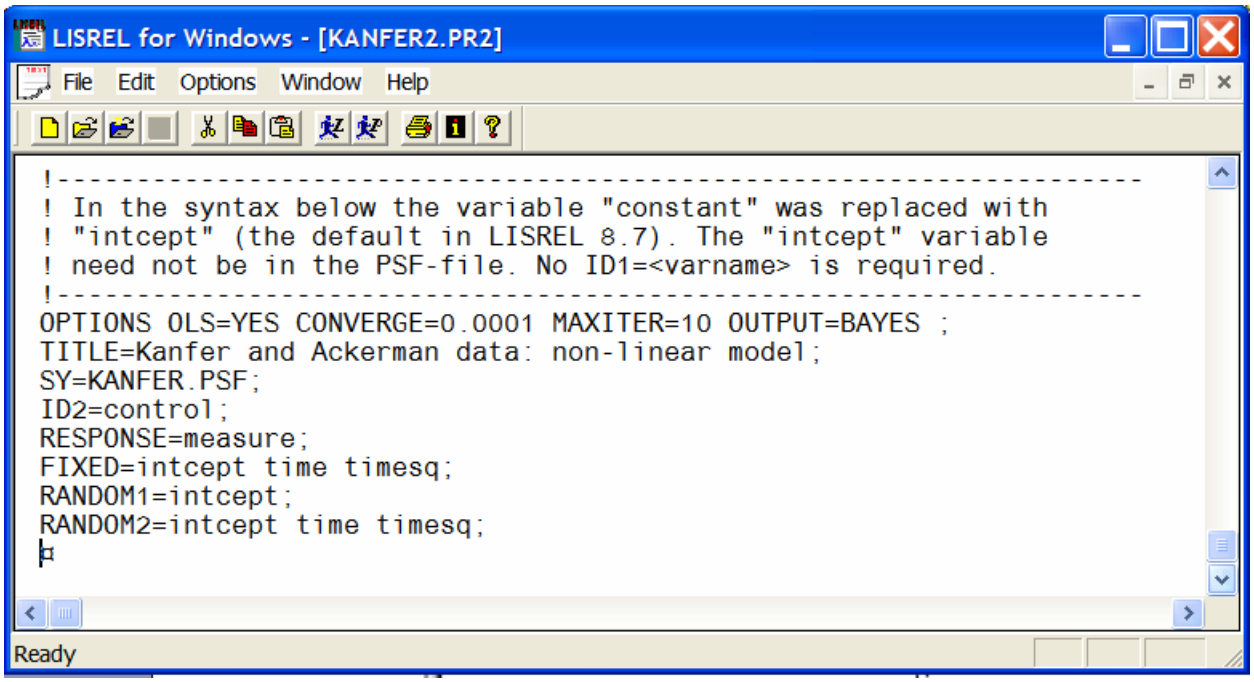


- Click on the ***Run PRELIS*** icon on the main toolbar to produce the following text editor window for ***KANFER.OUT***.



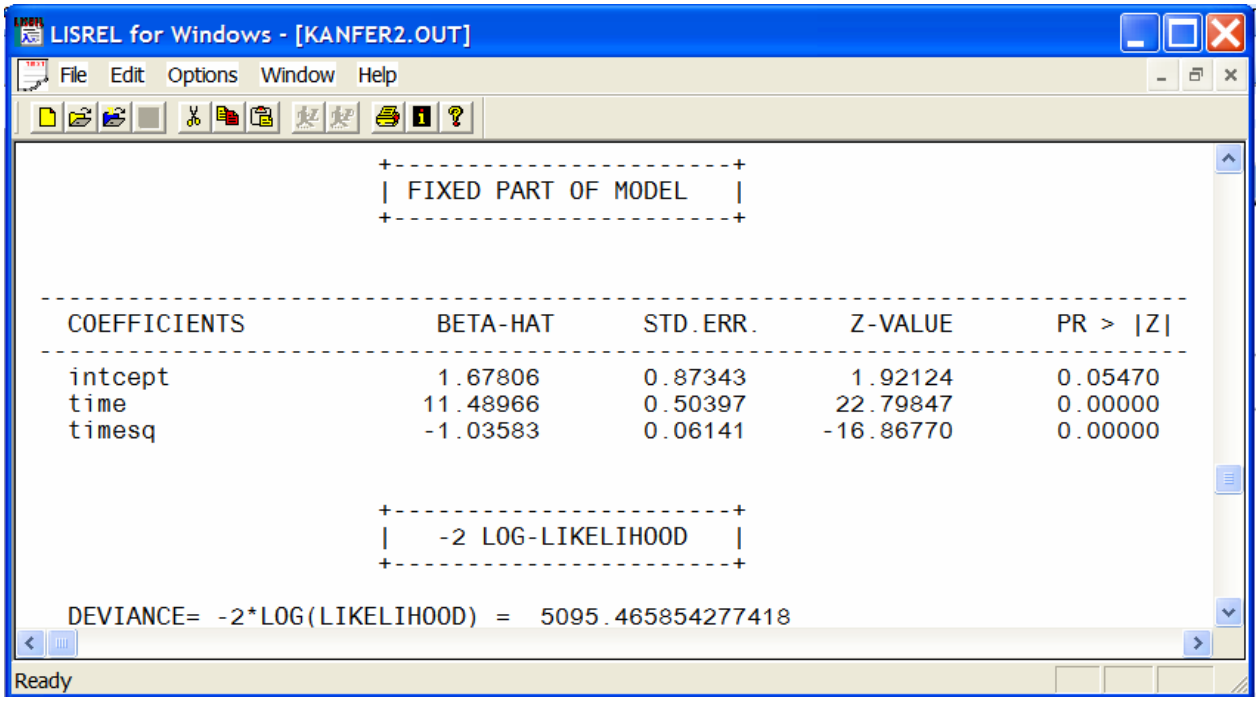
A Non-linear Growth Model

- Select the ***Close all*** option on the ***Window*** menu to close all open windows.
- Select the ***Open*** option on the ***File*** menu to load the ***Open*** dialog box.
- Browse for the location ***C:\LISREL 8.8 Student Examples\MLEVELEX***.
- Select the file ***KANFER2.PR2*** by clicking on it.
- Click on the ***Open*** button to open the following text editor window for ***KANFER2.PR2***.



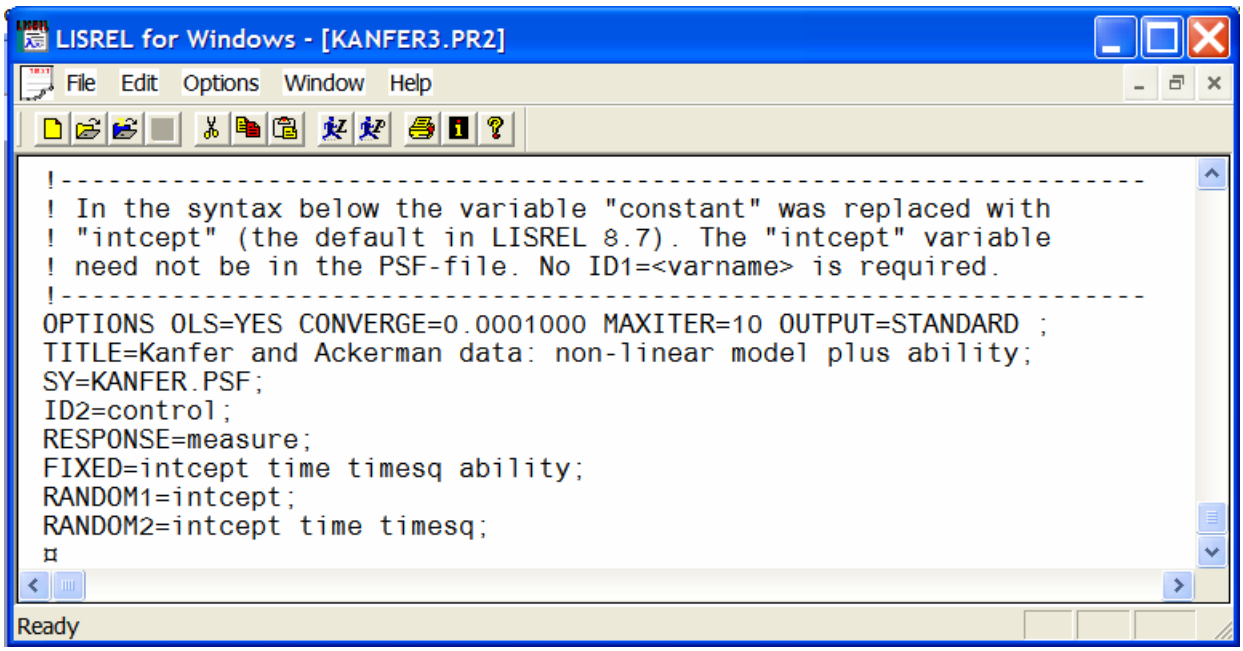
Line 6 specifies the options for the multilevel modeling method.
Line 7 specifies a title for the analysis.
Line 8 specifies the raw data source.
Lines 9 specifies the identification variable for the second level.
Line 10 specifies the response variable.
Line 11 specifies the fixed variables.
Lines 12 and 13 specify the random variables for the two levels.

- Click on the ***Run PRELIS*** icon on the main toolbar to produce the following text editor window for ***KANFER2.OUT***.



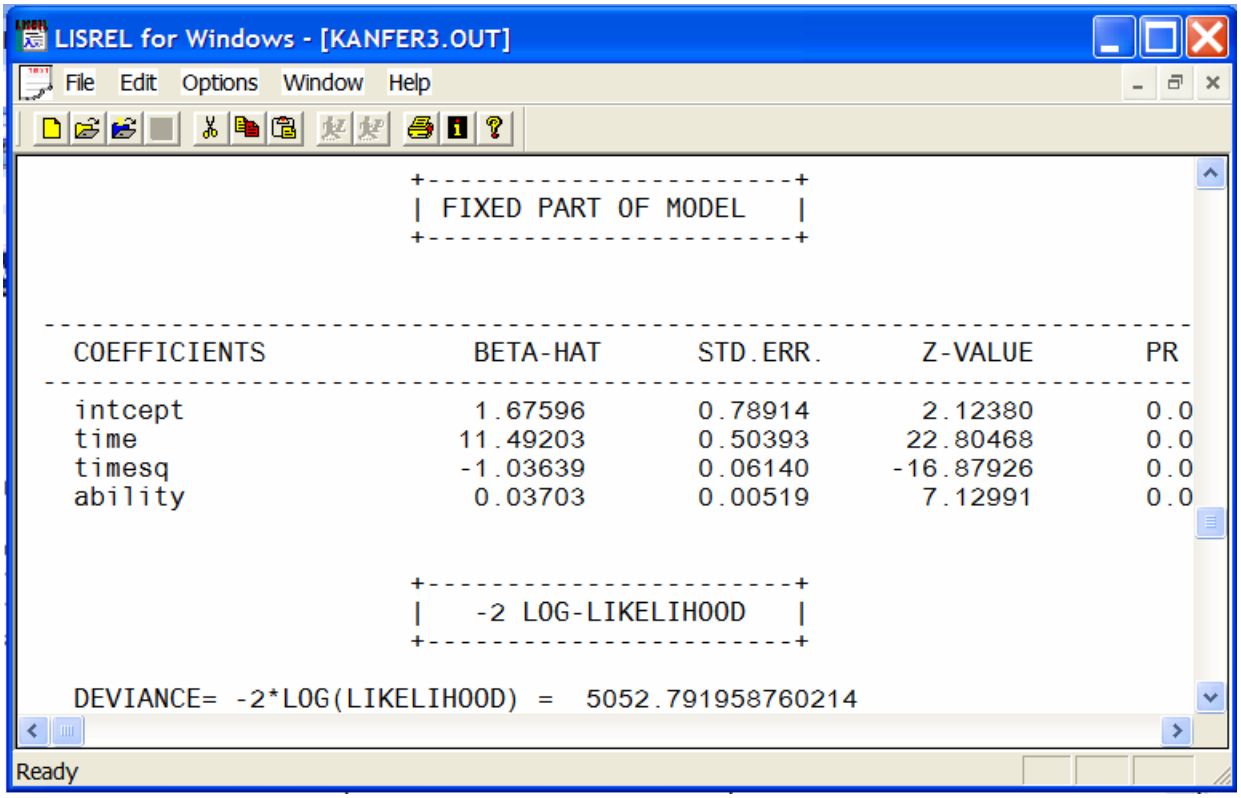
A Non-linear Growth Model with an Additional Variable

- Select the ***Close all*** option on the ***Window*** menu to close all open windows.
- Select the ***Open*** option on the ***File*** menu to load the ***Open*** dialog box.
- Browse for the location ***C:\LISREL 8.8 Student Examples\MLEVELEX***.
- Select the file ***KANFER3.PR2*** by clicking on it.
- Click on the ***Open*** button to open the following text editor window for ***KANFER3.PR2***.



Line 6 specifies the options for the multilevel modeling method.
Line 7 specifies a title for the analysis.
Line 8 specifies the raw data source.
Line 9 specifies the identification variable for the second level.
Line 10 specifies the response variable.
Line 11 specifies the fixed variables.
Lines 12 and 13 specify the random variables for the two levels.

- Click on the ***Run PRELIS*** icon on the main toolbar to produce the following text editor window for ***KANFER3.OUT***.



4. The Educational Data

The data set used in this section forms part of the data library of the Multilevel Project at the University of London and comes from the Junior School Project (Mortimer,et al.,1988). Mathematics and language tests were administered in three consecutive years to more than 1000 students from 50 primary schools, which were randomly selected from primary schools maintained by the Inner London Education Authority. The raw data are provided in the PRELIS System File (PSF) ***JSP.PSF***. This file is available in ***C:\LISREL 8.8 Student Examples\MLEVELEX***. The first potion of this file is shown in the following PSF window.

JSP.PSF

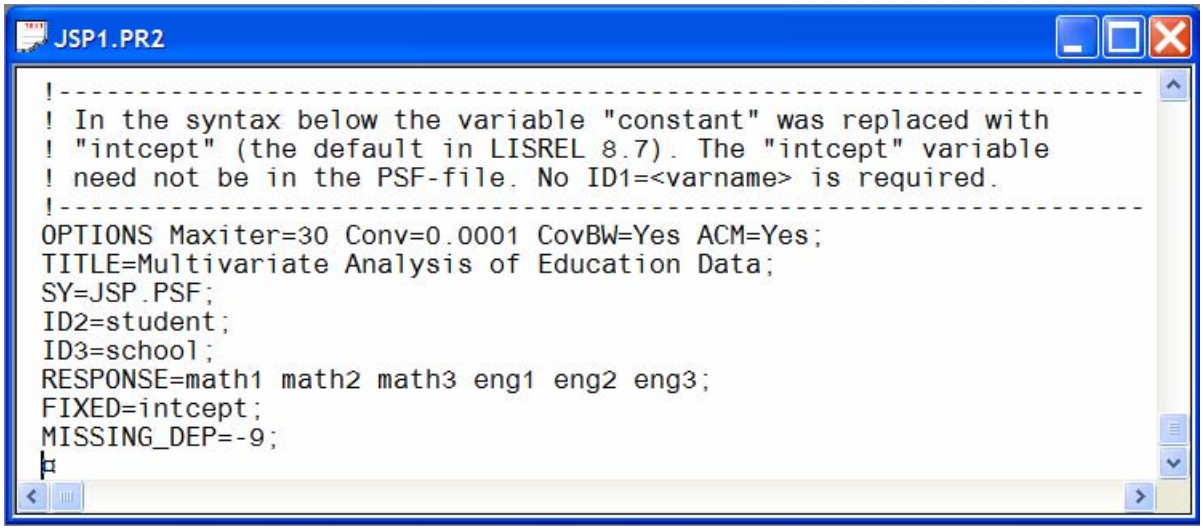
	school	student	gender	ravens	math1	math2
1	1.000	1.000	0.000	23.000	23.000	24.000
2	1.000	2.000	1.000	15.000	14.000	11.000
3	1.000	3.000	1.000	22.000	36.000	32.000
4	1.000	4.000	1.000	14.000	24.000	26.000
5	1.000	5.000	0.000	19.000	22.000	23.000
6	1.000	6.000	0.000	16.000	19.000	23.000
7	1.000	7.000	1.000	17.000	22.000	22.000
8	1.000	8.000	0.000	21.000	18.000	29.000
9	1.000	9.000	1.000	30.000	30.000	31.000
10	1.000	10.000	0.000	25.000	29.000	29.000
11	1.000	11.000	0.000	32.000	31.000	28.000
12	1.000	12.000	0.000	15.000	18.000	26.000
13	1.000	13.000	0.000	25.000	23.000	-9.000
14	1.000	14.000	0.000	29.000	39.000	35.000
15	1.000	15.000	0.000	34.000	24.000	30.000

Note that the –9.000 entries represent missing values.
The variables in ***JSP.PSF*** are the school code (1 to 50) (***school***), Student ID (***student***), gender (***gender***), ravens test score in year 1 (***ravens***), score on mathematics test in year 1 (***math1***), score on mathematics test in year 2 (***math2***), score on mathematics test in year 3 (***math3***), score on language test in year 1 (***eng1***), score on language test in year 2 (***eng2***), score on language test in year 3 (***eng3***) and the intercept value (***constant***).

5. The Analysis of the Education Data

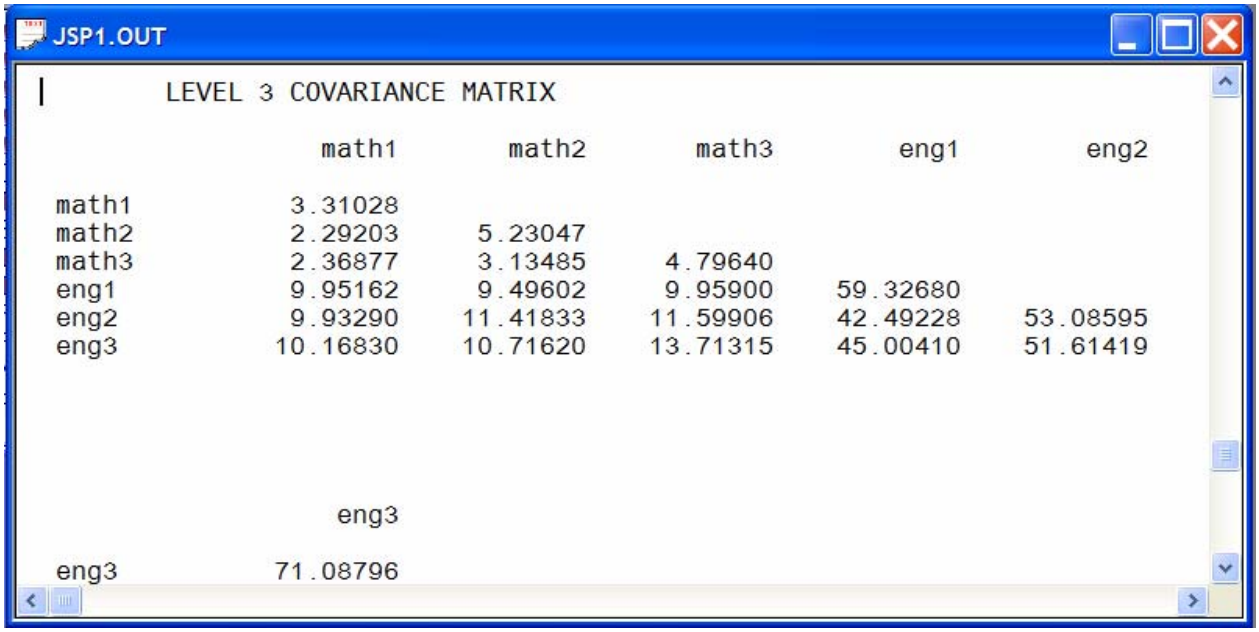
The Variance Decomposition Model

- Select the ***Close all*** option on the ***Window*** menu to close all open windows.
- Select the ***Open*** option on the ***File*** menu to load the ***Open*** dialog box.
- Browse for the location ***C:\LISREL 8.8 Student Examples\MLEVELEX***.
- Select the file ***JSP1.PR2*** by clicking on it.
- Click on the ***Open*** button to open the following text editor window for ***JSP1.PR2***.



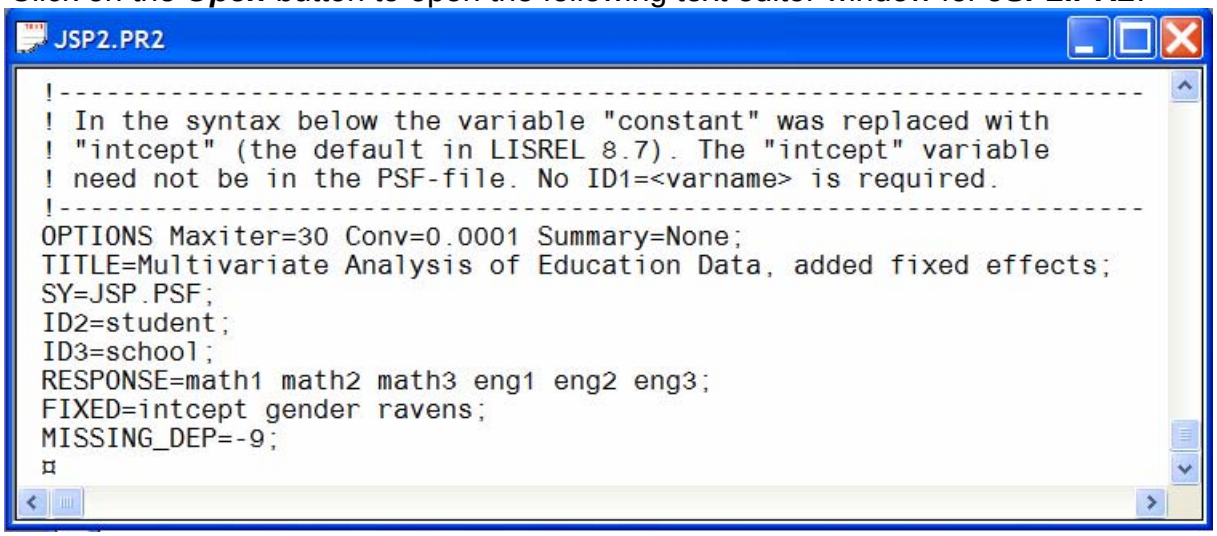
Line 6 specifies the default options for the multilevel modeling method.
Line 7 specifies a title for the analysis.
Line 8 specifies the raw data source.
Lines 9 and 10 specify the identification variables for levels 2 and 3 respectively.
Line 11 specifies the response variables.
Line 12 specifies the fixed variable.
Line 13 specifies the missing value code as –9.0.

- Click on the ***Run PRELIS*** icon on the main toolbar to produce the following text editor window for ***JSP1.OUT***.



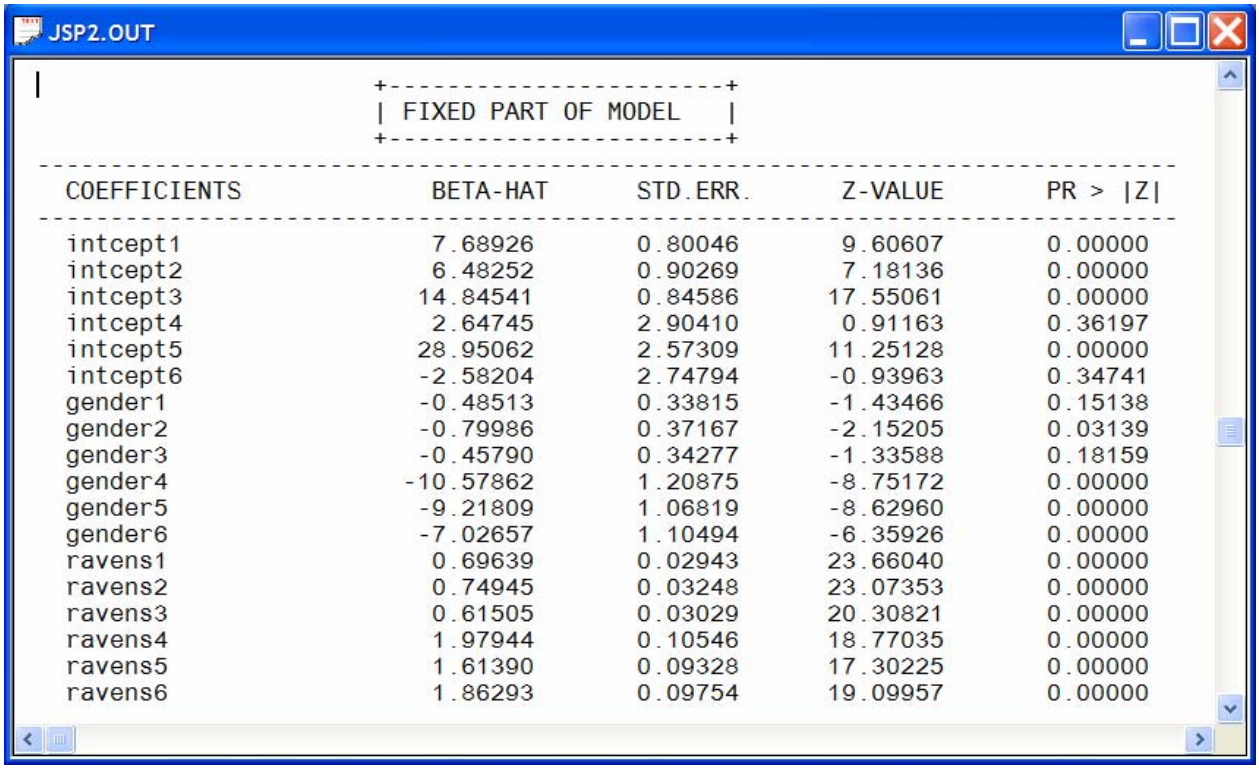
A Model with Explanatory Variables

- Select the ***Close all*** option on the ***Window*** menu to close all open windows.
- Select the ***Open*** option on the ***File*** menu to load the ***Open*** dialog box.
- Browse for the location ***C:\LISREL 8.8 Student Examples\MLEVELEX***.
- Select the file ***JSP2.PR2*** by clicking on it.
- Click on the ***Open*** button to open the following text editor window for ***JSP2.PR2***.



Line 6 specifies the default options for the multilevel modeling method.
Line 7 specifies a title for the analysis.
Line 8 specifies the raw data source.
Lines 9 and 10 specify the identification variables for levels 2 and 3 respectively.
Line 11 specifies the response variables.
Line 12 specifies the fixed variables.
Line 13 specifies the missing value code as –9.0.

- Click on the ***Run PRELIS*** icon on the main toolbar to produce the following text editor window for ***JSP2.OUT***.



COEFFICIENTS	BETA-HAT	STD.ERR.	Z-VALUE	PR > |Z|
intcept1	7.68926	0.80046	9.60607	0.00000
intcept2	6.48252	0.90269	7.18136	0.00000
intcept3	14.84541	0.84586	17.55061	0.00000
intcept4	2.64745	2.90410	0.91163	0.36197
intcept5	28.95062	2.57309	11.25128	0.00000
intcept6	-2.58204	2.74794	-0.93963	0.34741
gender1	-0.48513	0.33815	-1.43466	0.15138
gender2	-0.79986	0.37167	-2.15205	0.03139
gender3	-0.45790	0.34277	-1.33588	0.18159
gender4	-10.57862	1.20875	-8.75172	0.00000
gender5	-9.21809	1.06819	-8.62960	0.00000
gender6	-7.02657	1.10494	-6.35926	0.00000
ravens1	0.69639	0.02943	23.66040	0.00000
ravens2	0.74945	0.03248	23.07353	0.00000
ravens3	0.61505	0.03029	20.30821	0.00000
ravens4	1.97944	0.10546	18.77035	0.00000
ravens5	1.61390	0.09328	17.30225	0.00000
ravens6	1.86293	0.09754	19.09957	0.00000

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