目标和方法

问题 1：学生和学校层次的体育活动相关因素对学生的数学、阅读和科学学科成绩有何影响
问题 2：国家体育成功水平对对学生的数学、阅读和科学学科成绩有何影响
问题 3：学校层次的体育活动相关因素和国家体育成功水平如何调节学生层次的体育活动行为与他们学业成绩之间的关系
方法：Multilevel analysis
软件：数据预处理使用 spss；多层次线性回归使用 HLM6 软件

数据说明

1. 变量及数据获取途径

Variables	Data link
Student Level (within school; n=368,049)	
Family ESCS	PISA 2015: https://www.oecd.org/en/data/datasets/pisa-2015-database.html
Gender	
Participation in physical education lessons	
Moderate physical activity outside of school	
Vigorous physical activity outside of school	
Exercise before going to school	
Exercise after leaving school	
School Level (between school;n=13,591)	
School size	
Class size	
Student-Teacher ratio	
Physical education lessons in school	
Extracurricular physical activity	
Country Level (between country; n=52)	
Log GDP per capita	世界银行: https://data.worldbank.org

Sport success	国家竞技体育排名和得分系统：https://sportsrankings.world/rankings

2. 各变量数据获取途径：

（1） PISA2015 数据获取链接：
https://www.oecd.org/en/data/datasets/pisa-2015-database.html
该数据包含：1）学生数学、阅读和科学的成绩得分 2）学生在校和校外的体育活动情况 3）学校的体育活动提供情况
（2） 国家竞技体育排名和得分系统（WRCES）：

Data Preparation

数据获取后分别得到学生层次、学校层次和国家层面三份数据

Selecting and recording variables

根据本研究的分析目的和前人的研究筛选出分析的目标变量对应的问卷数据，并根据变量数据的完整性，删除所属学校没有作答学校层次问题的学生样本、没有回答任何一道学生层次体育活动相关问题的学生样本以及没有对应的 WRCES 值的样本，最终保留了 52 个国家或区域，12,569 个学校共 345,134 个学生样本。

Treatment of missing data

样本中仍有变量有缺失值，缺失情况如表所示。学校层次的 SCHSIZE, CLSIZE, and STRATIO 用对应的该国家平均值来代替。除此之外的 Missing values were supplemented with the mean value of the MI datasets, using the method of multiple imputation with m=5. 最终的 descriptive statistics for all variables are listed in table 3.

				missing	
Variables	Observations	Mean	S.D.	N	%
Student-Level					
ESCS	345134	-.156885	1.0768479	0	.0
Gender	345134			0	.0

PESCH	337543	3.01	1.405	7591	2.2
MPAOSCH	336122	4.59	2.476	9012	2.6
VPAOSCH	335412	3.80	2.230	9722	2.8
PABEFORE	315440			29694	8.6
PAAFTER	312273			32861	9.5
Student-Level					
SCHSIZE	11636	779.45	750.575	933	7.4
CLSIZE	12012	26.78	9.197	557	4.4
STRATIO	11714	14.54	9.59	855	6.8
SASCH	12088			481	3.8

Variables	Description	Abbreviation	M	SD	Value Range
Student Level (within school; n=368,049)					
Family ESCS	Index of economic, social and cultural status (WLE)	ESCS	-.16	1.08	-7.04-4.18
Gender	Gender	Gender	.51	.50	0 = male; 1 = female
Participation in physical education lessons	Average number of days per week of participation in physical education classes at school	PESCH	2.01	1.39	0-7
Moderate physical activity outside of school	Average number of days per week with at least 60 minutes of moderate PA outside of school	MPAOSCH	3.60	2.45	0-7
Vigorous physical activity outside of school	Average number of days per week with at least 20 minutes of vigorous PA outside of school	VPAOSCH	2.81	2.21	0-7
Exercise before going to school	Participation in exercising or practising a sport before going to school	PABEFORE	.49	.50	0 = no; 1 = yes
Exercise after leaving school	Participation in exercising or practising a sport after leaving school	PAAFTER	.67	.47	0 = no; 1 = yes
School Level (between school;n=13,591)					
School size	School size	SCHSIZE	781.41	723.85	0-15000
Class size	Class size	CLSIZE	26.88	9.06	13-53
Student-Teacher ratio	Student-Teacher ratio	STRATIO	14.48	8.58	1.00-100.00
Physical education lessons in school	Average number of days per week physical education is offered in schools	SCHPE	2.02	.87	0.00-7.00
Extracurricular physical activity	Availability of organised sports teams or activities in schools	SASCH	.91	.28	0 = no; 1 =yes
Country Level (between country; n=52)					
Log GDP per capita	The log of gross domestic product per capita in 2015	LNGDP	26.43	1.68	22.12-30.53
Sport success	Logarithm of the world rankings of countries in elite sport in 2015	LNWRCES	11.16	.70	10.12-12.88

Student weight

按 PISA 官方操作手册要求，学生的权重需要标准化，即权值的和等于数据集中的学生数量。设所有样本的权重和为 POPWEIGHT，设所有样本数为 SAMPN，normalization of the final student weight 的 SPSS syntax 如下。

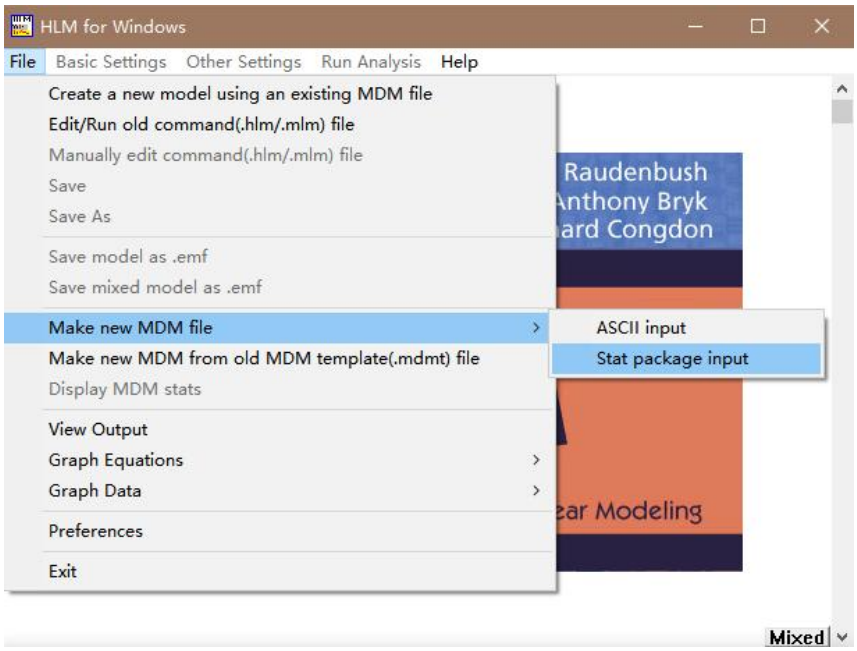
```
COMPUTE W_FSTUWT=(W_FSTUWT/POPWEIGHT)*SAMPN.
DO REPEAT A= W_FSTURWT1 TO W_FSTURWT80.

AGGREGATE/BREAK=CNT/POPCNT=SUM(W_FSTUWT).
COMPUTE W_FSTUWT=(W_FSTUWT/POPCNT)*(SAMPN/52).
```

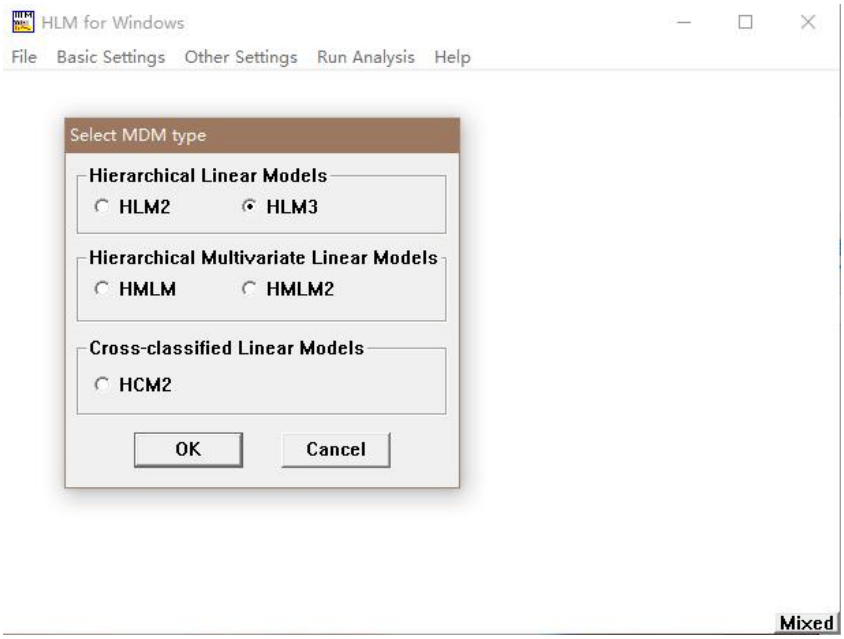
Multilevel analysis

Data entry and settings

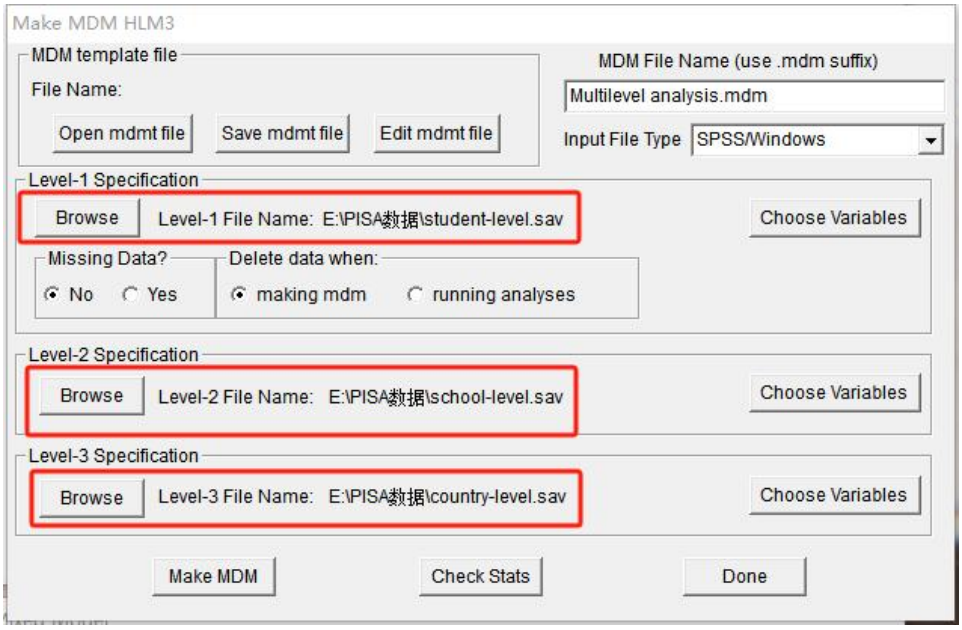
Step 1：导入数据



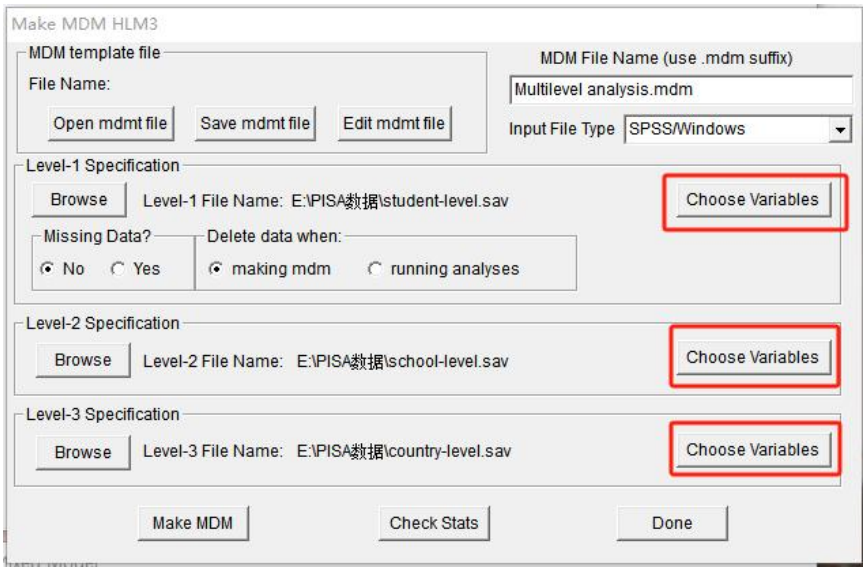
- 本分析基于学生、学校和国家三个层次，选择 HLM3。



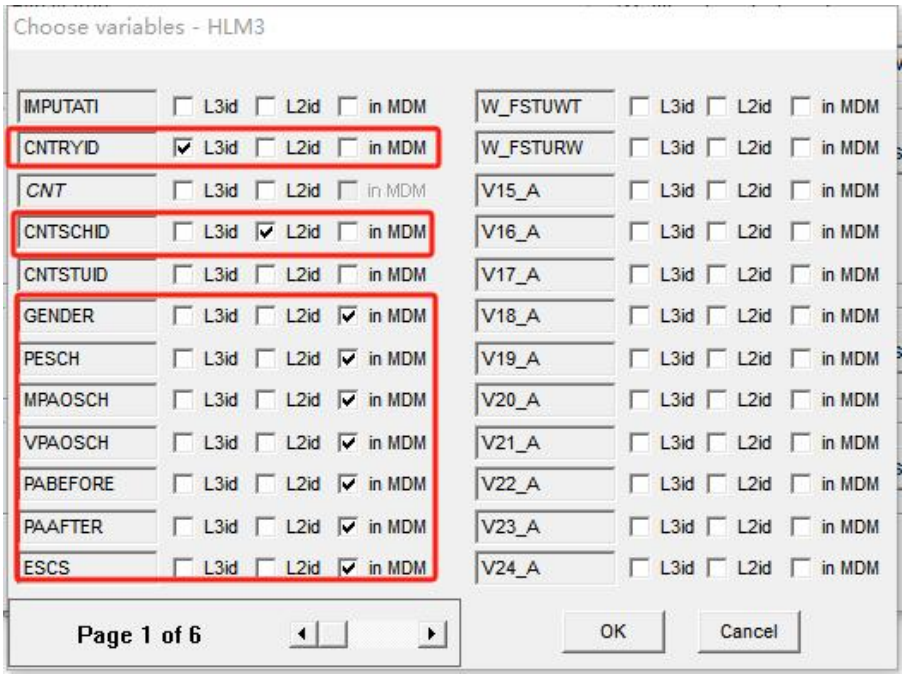
- 分别导入三个层次的数据

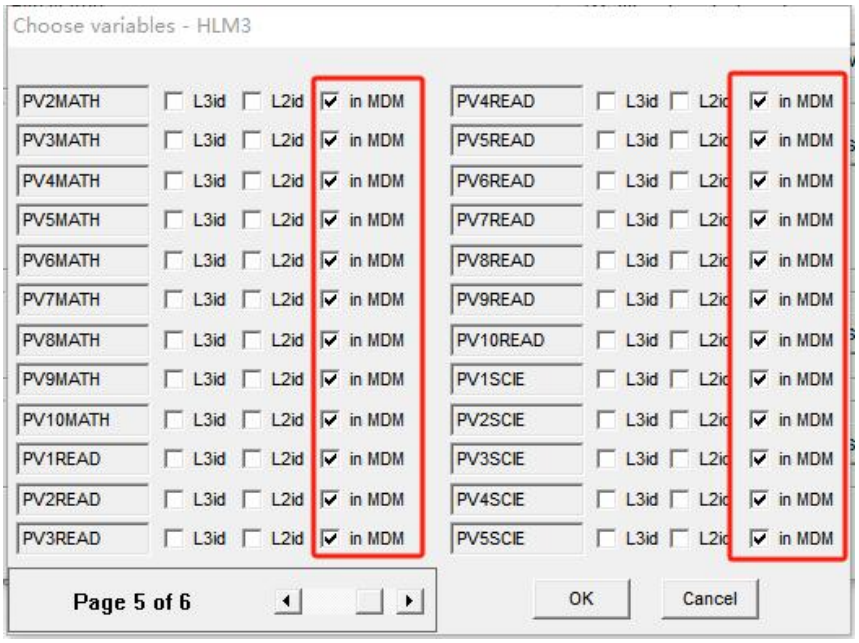


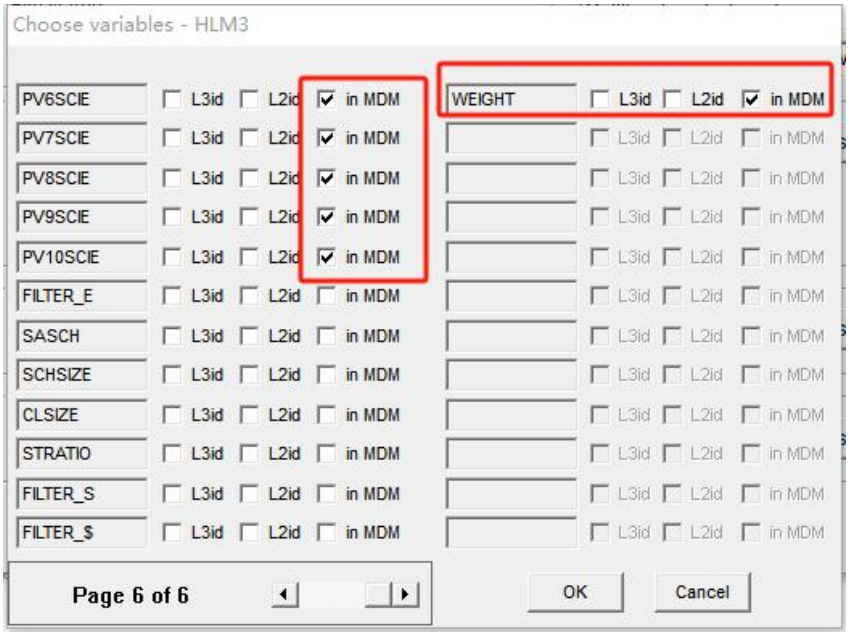
Step2：变量选择，分别选择三个层次数据集中需要纳入 HLM 分析的变量数据。



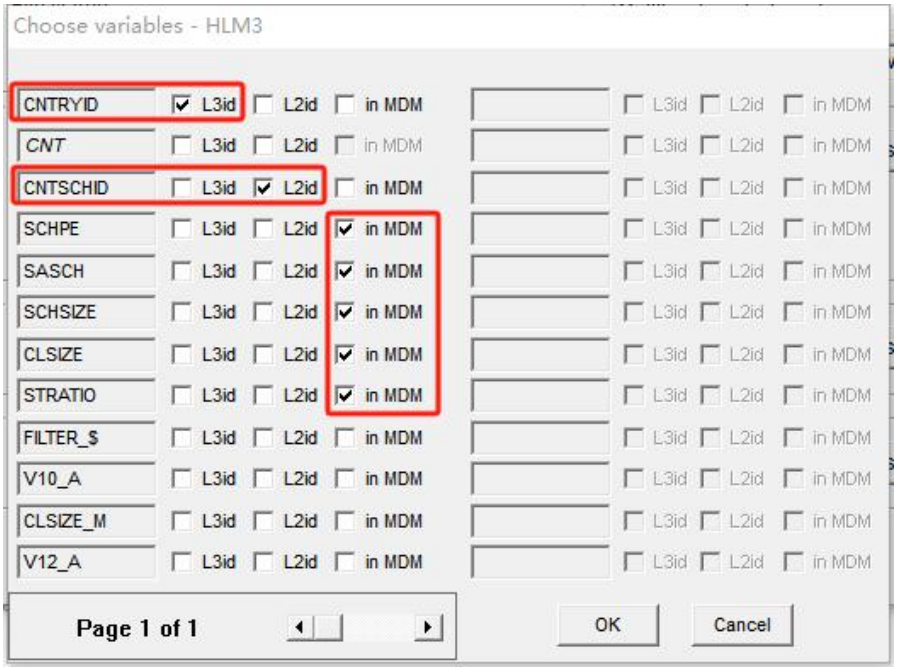
- Student-level 的变量选择：L3id 为 country-level 和 student-level 的连接标识符，在这里选择 CNTRYID（PISA 数据中的国家地区 ID）；L2id 为 School-level 和 student-level 的连接标识符，在这里选择 CNTSCHID（PISA 数据中的学校 ID）。选择完各层次的连接标识符后，选择 student-level 的自变量、因变量和样本权重（WEIGHT）。


Choose variables - HLM3
IMPUTATI L3id L2id in MDM
CNTRYID L3id L2id in MDM
CNT L3id L2id in MDM
CNTSCHID L3id L2id in MDM
CNTSTUID L3id L2id in MDM
GENDER L3id L2id in MDM
PESCH L3id L2id in MDM
MPAOSCH L3id L2id in MDM
VPAOSCH L3id L2id in MDM
PABEFORE L3id L2id in MDM
PAAFTER L3id L2id in MDM
ESCS L3id L2id in MDM
W_FSTUWT L3id L2id in MDM
W_FSTURW L3id L2id in MDM
V15_A L3id L2id in MDM
V16_A L3id L2id in MDM
V17_A L3id L2id in MDM
V18_A L3id L2id in MDM
V19_A L3id L2id in MDM
V20_A L3id L2id in MDM
V21_A L3id L2id in MDM
V22_A L3id L2id in MDM
V23_A L3id L2id in MDM
V24_A L3id L2id in MDM
Page 1 of 6
OK
Cancel

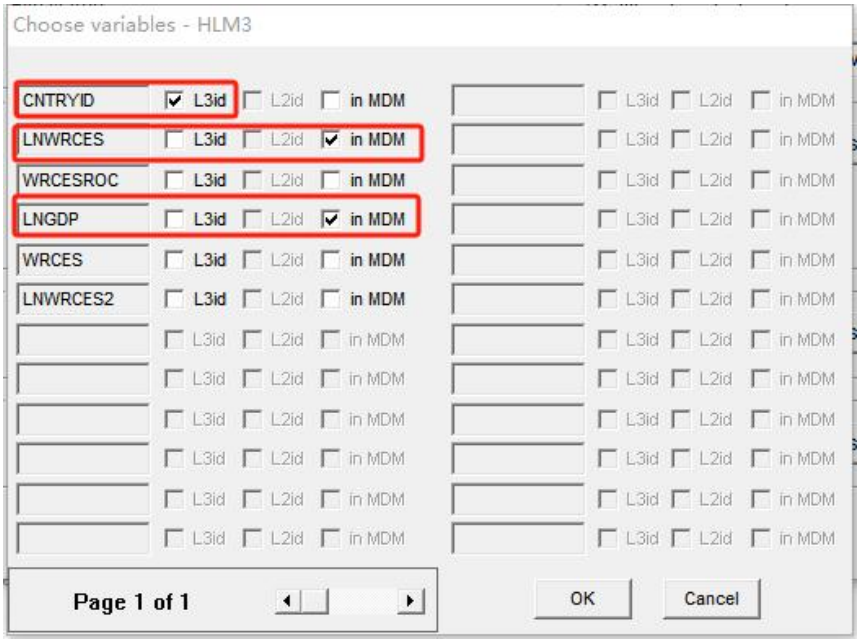

Choose variables - HLM3
PV2MATH L3id L2id in MDM
PV3MATH L3id L2id in MDM
PV4MATH L3id L2id in MDM
PV5MATH L3id L2id in MDM
PV6MATH L3id L2id in MDM
PV7MATH L3id L2id in MDM
PV8MATH L3id L2id in MDM
PV9MATH L3id L2id in MDM
PV10MATH L3id L2id in MDM
PV1READ L3id L2id in MDM
PV2READ L3id L2id in MDM
PV3READ L3id L2id in MDM
PV4READ L3id L2id in MDM
PV5READ L3id L2id in MDM
PV6READ L3id L2id in MDM
PV7READ L3id L2id in MDM
PV8READ L3id L2id in MDM
PV9READ L3id L2id in MDM
PV10READ L3id L2id in MDM
PV1SCIE L3id L2id in MDM
PV2SCIE L3id L2id in MDM
PV3SCIE L3id L2id in MDM
PV4SCIE L3id L2id in MDM
PV5SCIE L3id L2id in MDM
Page 5 of 6
OK
Cancel



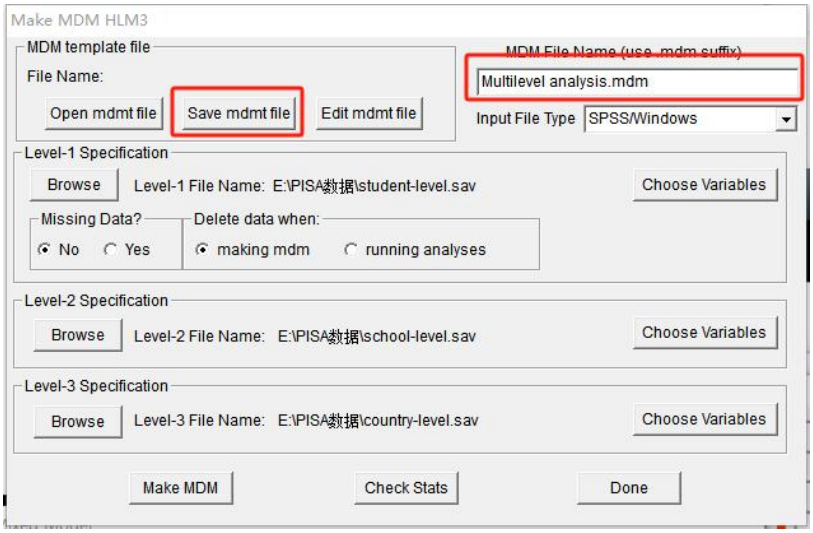
- School-level 的变量选择：



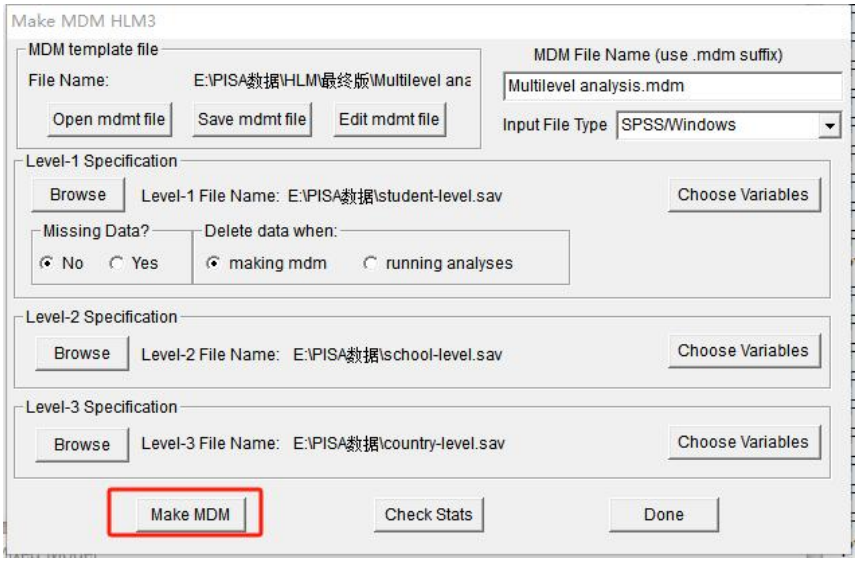
- Country-level 的变量选择：



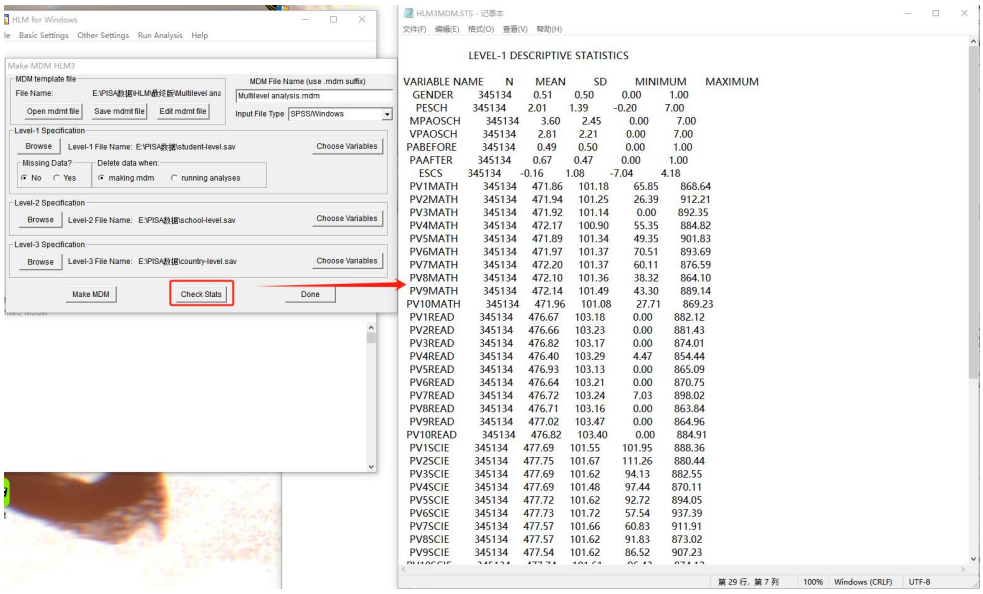
Step 3：保存并制作 MDM 文件



- 制作 MDM 文件



- MDM 文件制作成功后可以点 Check Stats 按钮，查看数据概况。最后点 Done，完成数据录入和 MDM 文件制作。

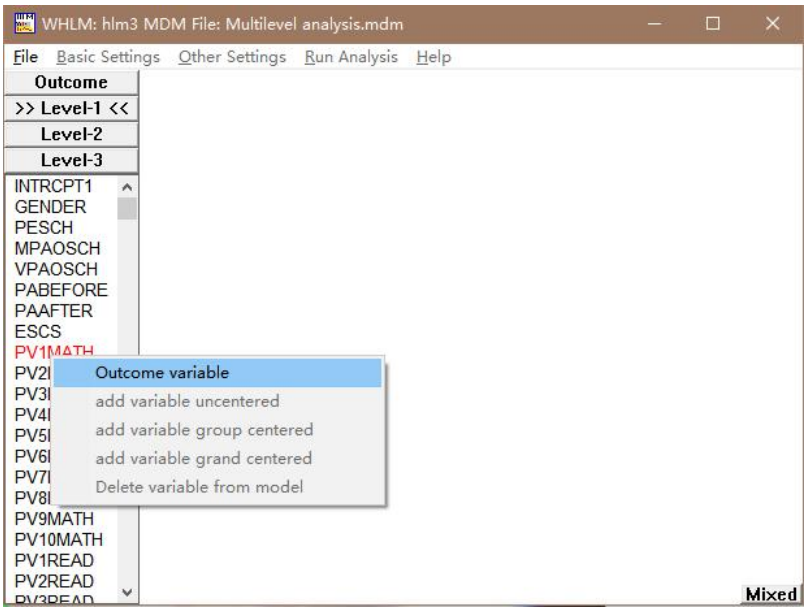


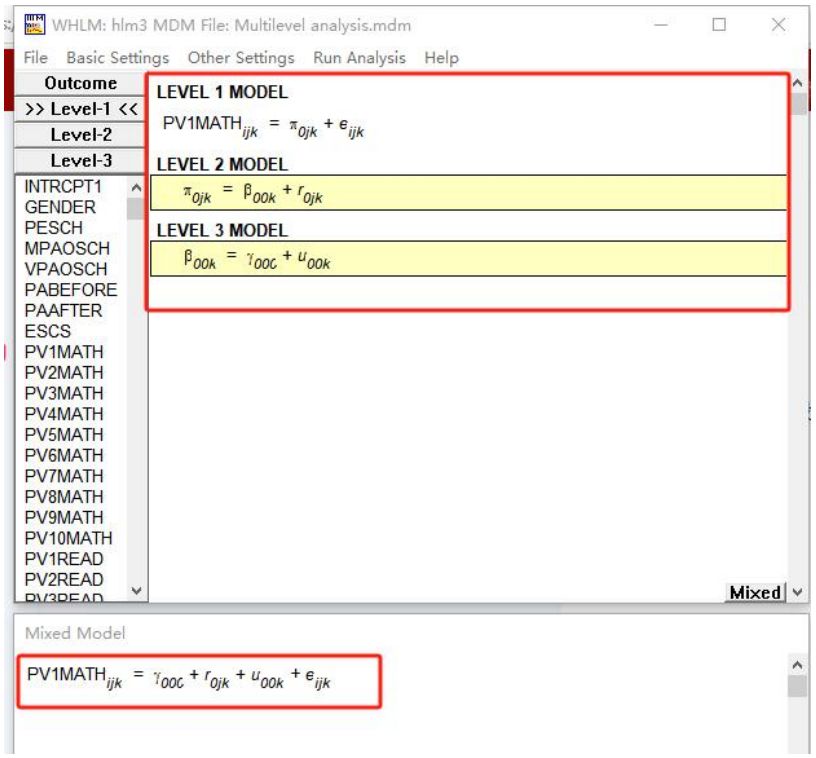
LEVEL-1 DESCRIPTIVE STATISTICS

VARIABLE NAME	N	MEAN	SD	MINIMUM	MAXIMUM
GENDER	345134	0.51	0.50	0.00	1.00
PESCH	345134	2.01	1.39	-0.20	7.00
MPAOSCH	345134	3.60	2.45	0.00	7.00
VPAOSCH	345134	2.81	2.21	0.00	7.00
PABEFORE	345134	0.49	0.50	0.00	1.00
PAAFTER	345134	0.67	0.47	0.00	1.00
ESCS	345134	-0.16	1.08	-7.04	4.18
PV1MATH	345134	471.86	101.18	65.85	868.64
PV2MATH	345134	471.94	101.25	26.39	912.21
PV3MATH	345134	471.92	101.14	0.00	892.35
PV4MATH	345134	472.17	100.90	55.35	884.82
PV5MATH	345134	471.89	101.34	49.35	901.83
PV6MATH	345134	471.97	101.37	70.51	893.69
PV7MATH	345134	472.20	101.37	60.11	876.59
PV8MATH	345134	472.10	101.36	38.32	864.10
PV9MATH	345134	472.14	101.49	43.30	889.14
PV10MATH	345134	471.96	101.08	27.71	869.23
PV1READ	345134	476.67	103.18	0.00	882.12
PV2READ	345134	476.66	103.23	0.00	881.43
PV3READ	345134	476.82	103.17	0.00	874.01
PV4READ	345134	476.40	103.29	4.47	854.44
PV5READ	345134	476.93	103.13	0.00	865.09
PV6READ	345134	476.64	103.21	0.00	870.75
PV7READ	345134	476.72	103.24	7.03	898.02
PV8READ	345134	476.71	103.16	0.00	863.84
PV9READ	345134	477.02	103.47	0.00	864.96
PV10READ	345134	476.82	103.40	0.00	884.91
PV1SCIE	345134	477.69	101.55	101.95	888.36
PV2SCIE	345134	477.75	101.67	111.26	880.44
PV3SCIE	345134	477.69	101.62	94.13	882.55
PV4SCIE	345134	477.69	101.48	97.44	870.11
PV5SCIE	345134	477.72	101.62	92.72	894.05
PV6SCIE	345134	477.73	101.72	57.54	937.39
PV7SCIE	345134	477.57	101.66	60.83	911.91
PV8SCIE	345134	477.57	101.62	91.83	873.02
PV9SCIE	345134	477.54	101.62	86.52	907.23

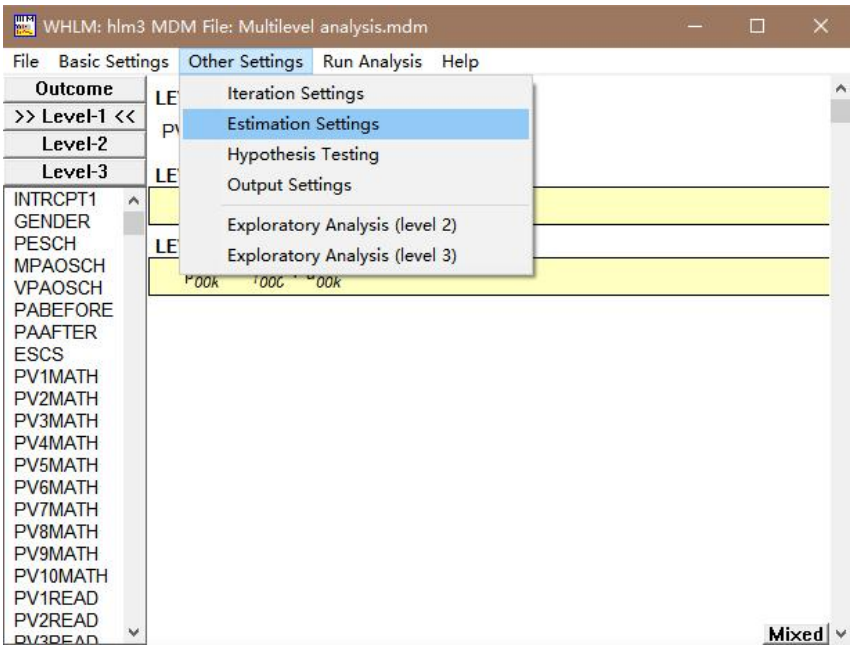
Step 4：Settings of weights and dependent variable PV values

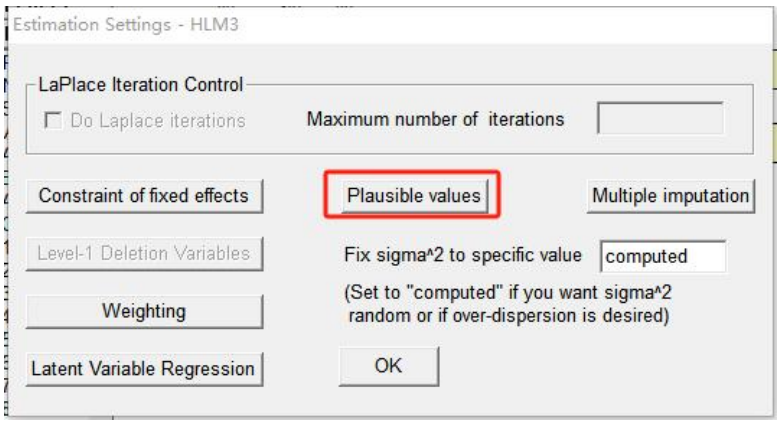
- 因变量的设置：以数学成绩为例，选择 PV1MATH 作为因变量。

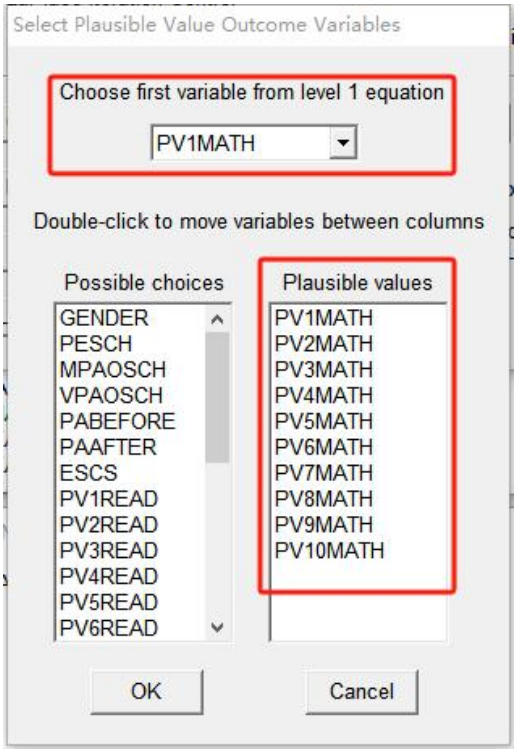




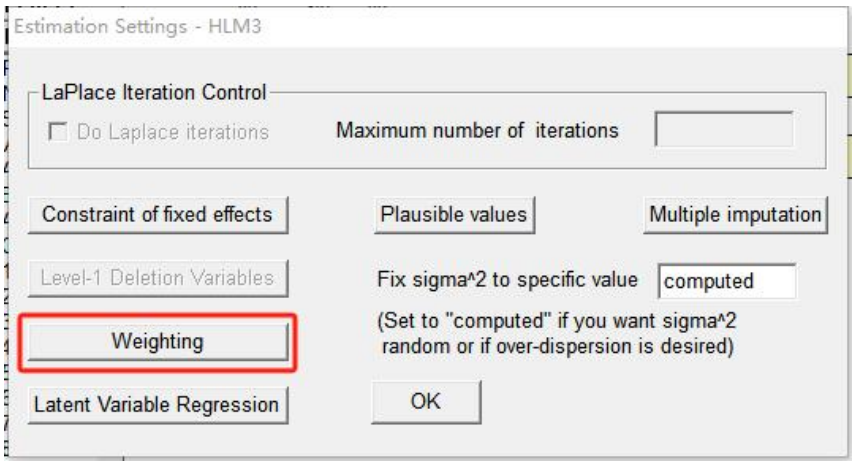
- PV1-PV10 的设置：根据 PISA 官方数据分析操作文档建议，回归分析应在 10 个 PV 值的基础上进行，这可以在 HLM 软件中实现。

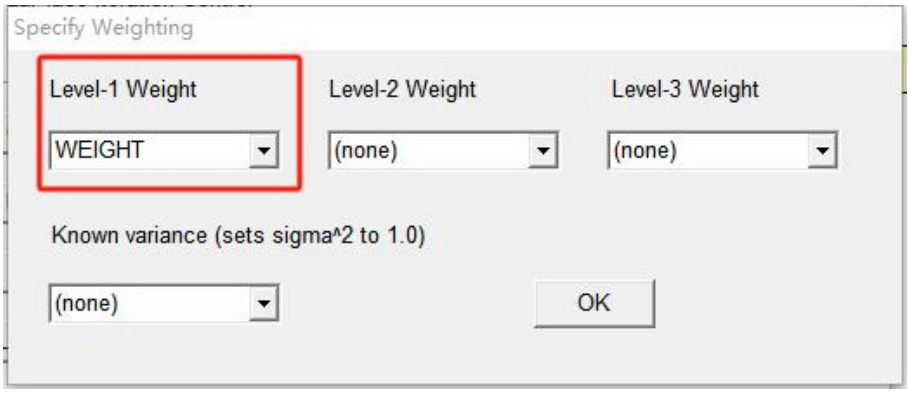

WHLM: hlm3 MDM File: Multilevel analysis.mdm
File
Basic Settings
Other Settings
Run Analysis
Help
Iteration Settings
Estimation Settings
Hypothesis Testing
Output Settings
Exploratory Analysis (level 2)
Exploratory Analysis (level 3)
Outcome
>> Level-1 <<
Level-2
Level-3
INTRCPT1
GENDER
PESCH
MPAOSCH
VPAOSCH
PABEFORE
PAAFTER
ESCS
PV1MATH
PV2MATH
PV3MATH
PV4MATH
PV5MATH
PV6MATH
PV7MATH
PV8MATH
PV9MATH
PV10MATH
PV1READ
PV2READ
Mixed


Estimation Settings - HLM3
LaPlace Iteration Control
Do Laplace iterations
Maximum number of iterations
Constraint of fixed effects
Plausible values
Multiple imputation
Level-1 Deletion Variables
Fix sigma^2 to specific value
computed
(Set to "computed" if you want sigma^2 random or if over-dispersion is desired)
Weighting
Latent Variable Regression
OK



- 权重的设置：权重使用标准化处理后的权重值 WEIGHT，只有 student-level 需要设置权重。





Three-level modelling

以数学成绩为例

Null model

空模型无任何变量，空模型的建立主要是为了计算 intraclass correlation coefficients (ICCs) 值。

The equation in the null model can be expressed as follows:

$$Y_{ijk} = \gamma_{000} + r_{0jk} + \mu_{ook} + e_{ijk} \quad (1)$$

在多层线性模型（HLM）中，ICC（Intra-Class Correlation）指的是组内相关系数，它是一个衡量组内相关性的重要指标。ICC 用于评估个体成员在某个特征上的相似程度，即不同个体在相同组别中测量结果的相似性。具体来说，ICC 是衡量聚合数据时组内差异与总差异的比例，其值介于 0 到 1 之间。当 ICC 接近 0 时，说明个体间的差异占总差异的比例很小，即个体几乎不受所属组别的影响；当 ICC 接近 1 时，说明个体间的差异占总差异的比例很大，即个体几乎完全由所属组别决定。

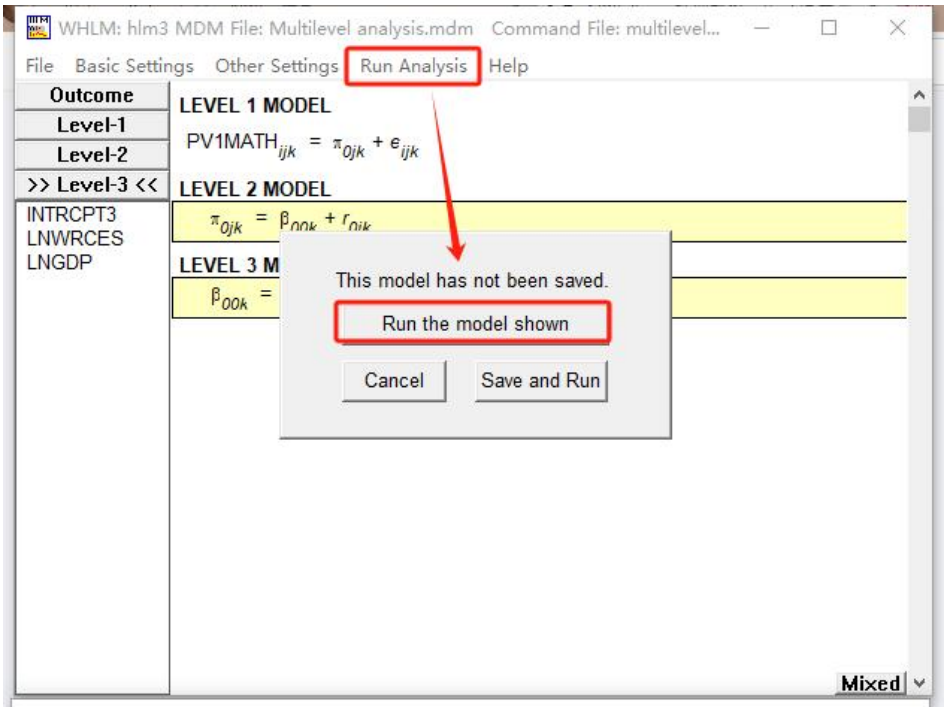
The variances at the student-, school-, and country-level are respectively σ_e^2, $\sigma_{r_0}^2$, $\sigma_{\mu_0}^2$. The method (Davis & Scott, 1995) defines the ICC values at the school and country level as:

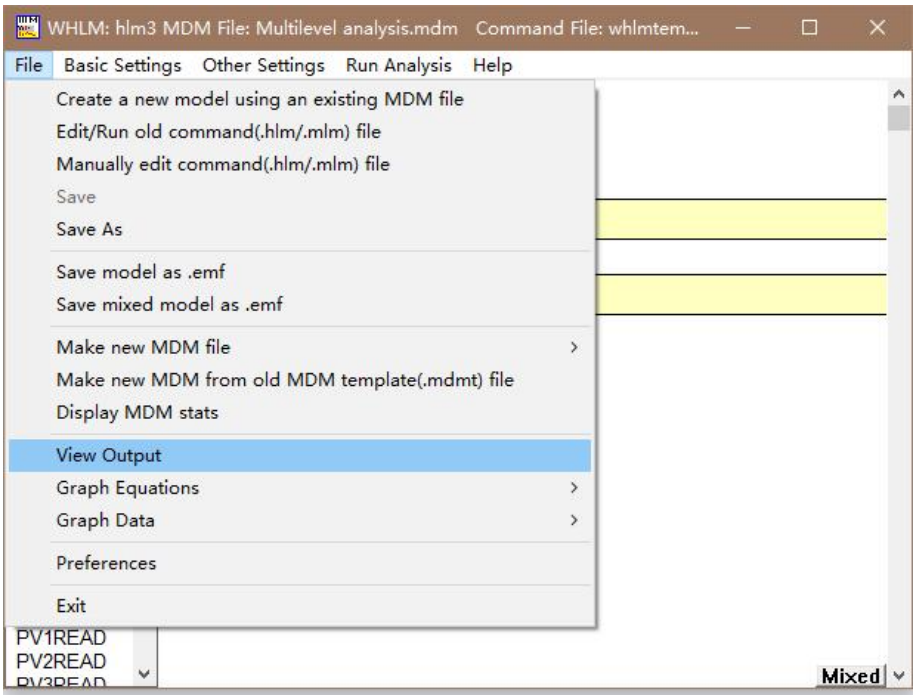
$$\rho_{school} = \frac{\sigma_{r_0}^2}{\sigma_e^2+\sigma_{r_0}^2+\sigma_{\mu_0}^2} \quad (2)$$

and:

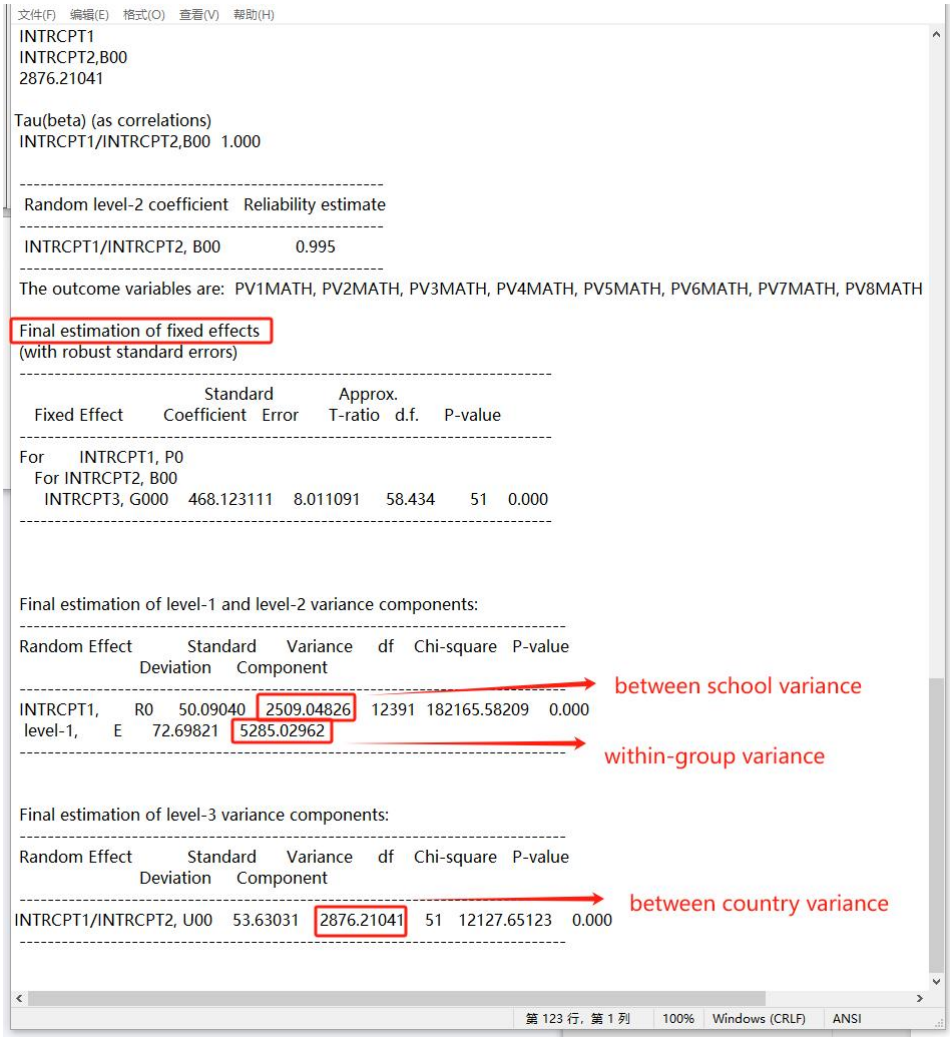
$$\rho_{country} = \frac{\sigma_{\mu_0}^2}{\sigma_e^2+\sigma_{r_0}^2+\sigma_{\mu_0}^2} \quad (3)$$

这里的组间方差是指不同组别之间的平均数差异所引起的方差，而总方差是指组间方差与组内方差的和。ICC 值越大，意味着组间（如学校、班级等）的变异占总变异的比例越大，表明组间差异对总变异的贡献越大，这通常提示使用 HLM 模型是合适的。


WHLM: hlm3 MDM File: Multilevel analysis.mdm Command File: multilevel...
File Basic Settings Other Settings Run Analysis Help
Outcome
Level-1
Level-2
>> Level-3 <<
INTRCPT3
LNWRCES
LNGDP
LEVEL 1 MODEL
PV1MATH$_{ijk}$ = π_{0jk} + e_{ijk}
LEVEL 2 MODEL
π_{0jk} = β_{00k} + r_{0jk}
LEVEL 3 M
β_{00k} =
This model has not been saved.
Run the model shown
Cancel
Save and Run
Mixed


WHLM: hlm3 MDM File: Multilevel analysis.mdm Command File: whlmtem...
File Basic Settings Other Settings Run Analysis Help
Create a new model using an existing MDM file
Edit/Run old command(.hlm/.mlm) file
Manually edit command(.hlm/.mlm) file
Save
Save As
Save model as .emf
Save mixed model as .emf
Make new MDM file
Make new MDM from old MDM template(.mdmt) file
Display MDM stats
View Output
Graph Equations
Graph Data
Preferences
Exit
PV1READ
PV2READ
Mixed

结果:



如图, the between-country variance $\sigma^2_{\mu_0}$ was 2876.21, the between-school variance $\sigma^2_{r_0}$ was 2509.05, the within-group variance σ^2_e was 5285.03 and the total unexplained variance $\sigma^2_{\mu_0} + \sigma^2_{r_0} + \sigma^2_e$ was 10123.42. The intraclass correlation coefficients for country was:

$$\frac{\text{between country variance}}{\text{total vairance}} = \frac{\sigma^2_{\mu_0}}{\sigma^2_e+\sigma^2_{r_0}+\sigma^2_{\mu_0}} = 0.235$$

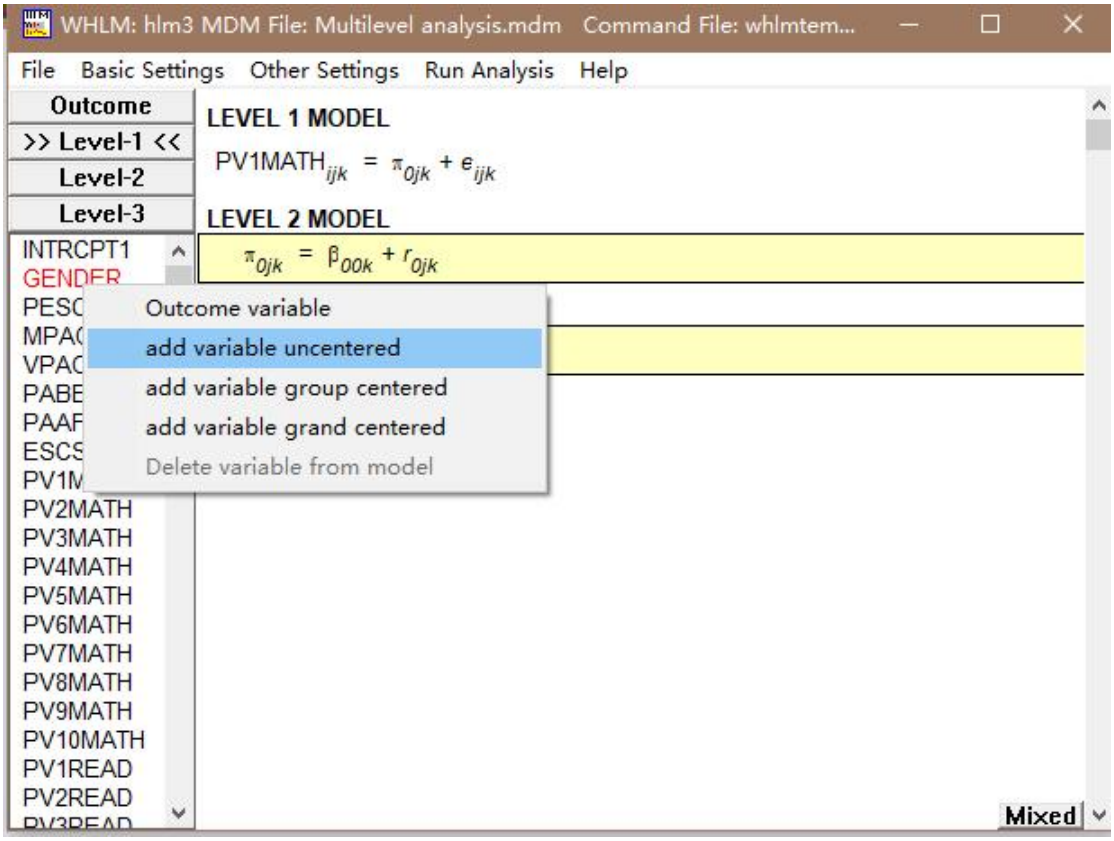
The intraclass correlation coefficients for school was:

$$\frac{\text{between school variance}}{\text{total vairance}} = \frac{\sigma^2_{r_0}}{\sigma^2_e+\sigma^2_{r_0}+\sigma^2_{\mu_0}} = 0.270$$

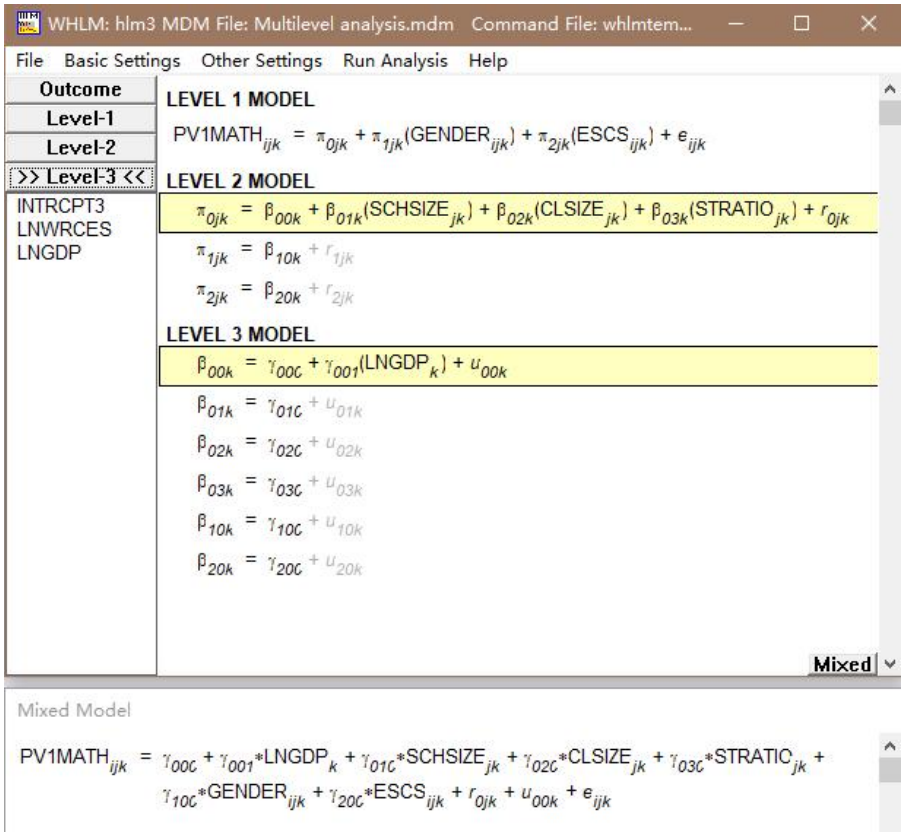
According to the result, ICCs of the three levels for all disciplines were all above 0.059, which indicated the existence of variations in student academic achievement between schools and countries and proved the validity of conducting HLM analysis (Cohen, 1988).

Model 1

Model 1：加入三个层次的控制变量



加入各层次控制变量后，完整的 model 1 构建如下图所示：



构建完后点击“Run Analysis”，待运行完毕后点击“File”——>“View Output”。结果如下图所示：各层次的控制变量都表现出了显著性。

Final estimation of fixed effects
(with robust standard errors)

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
For INTRCPT2, B00					
INTRCPT3, G000	236.915121	101.750022	2.328	50	0.024
LNGDP, G001	8.089608	3.768428	2.147	50	0.036
For SCHSIZE, B01					
INTRCPT3, G010	0.014695	0.002862	5.134	12439	0.000
For CLSIZE, B02					
INTRCPT3, G020	0.860688	0.227981	3.775	12439	0.000
For STRATIO, B03					
INTRCPT3, G030	-0.313966	0.123363	-2.545	2054	0.011
For GENDER slope, P1					
For INTRCPT2, B10					
INTRCPT3, G100	-11.343282	1.083161	-10.472	3186	0.000
For ESCS slope, P2					
For INTRCPT2, B20					
INTRCPT3, G200	17.076785	1.112612	15.348	52148	0.000

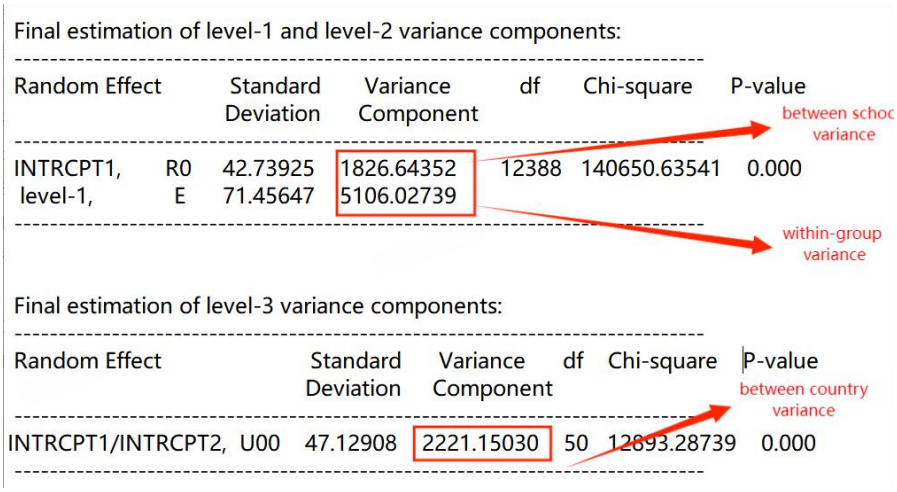
Then, the f^2 was calculated, which reflects the proportion of the original residual variance explained by the variables incorporated into the model (e.g., Hu & Wang, 2022a). This value enables an assessment of these variables' contribution to the model's explanatory power. The values f^2 at 0.02, 0.15, and 0.35 indicate small,

medium, and large effects, respectively (Hox, 2010). 学生、学校和国家每个层次的 f^2 具体是由该模型的各层次的方差与空模型对应的各层次的方差的差值除以空模型对应层次的方差得到的。以 model 1 的 student-level 的 f^2 值为例：

$$f^2 = \frac{\text{within} - \text{group variance in model 1} - \text{within} - \text{group variance in model 0}}{\text{within} - \text{group variance in model 0}}$$

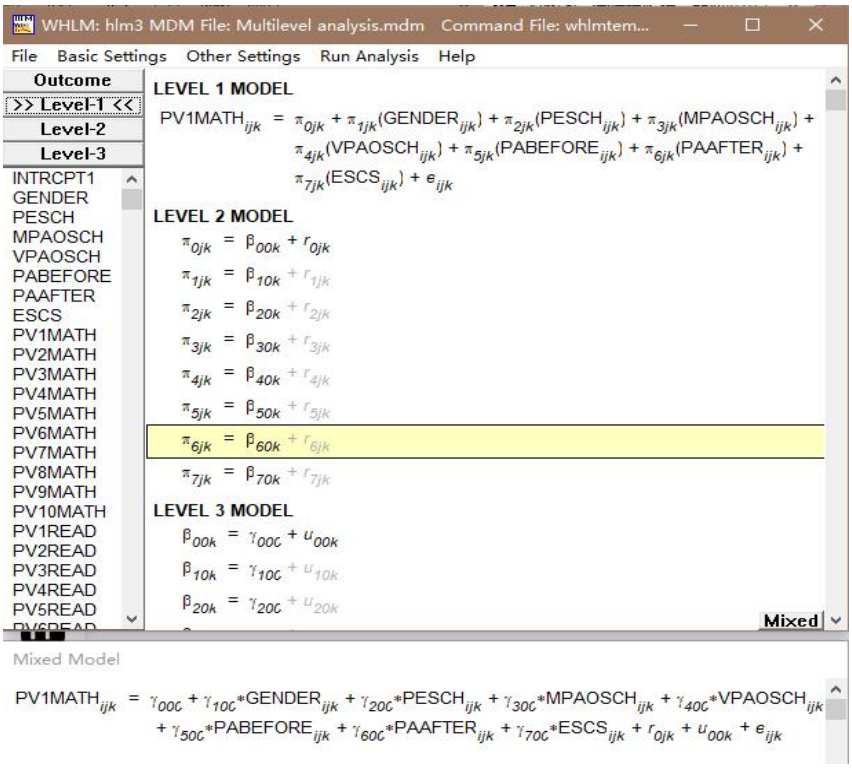
$$= \frac{5106.02739 - 5285.02692}{5285.02692} = 0.034$$

由此得到 school-level 的 f^2 值为 0.272，country-level 的 f^2 值为 0.228。



Model 2

Model 2：为探索学生层次的体育活动相关因素对学生数学成绩的影响，加入 student-level 的控制变量和体育活动相关的自变量。



结果：由下图可见 student-level 的变量的回归系数，其中 p-value 说明 PAAFTER 的结果不具显著性。

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
For INTRCPT2, B00					
INTRCPT3, G000	497.185778	7.742714	64.213	51	0.000
For GENDER slope, P1					
For INTRCPT2, B10					
INTRCPT3, G100	-15.789162	1.058697	-14.914	2199	0.000
For PESCH slope, P2					
For INTRCPT2, B20					
INTRCPT3, G200	-6.863335	0.451439	-15.203	5910	0.000
For MPAOSCH slope, P3					
For INTRCPT2, B30					
INTRCPT3, G300	2.961808	0.182940	16.190	3314	0.000
For VPAOSCH slope, P4					
For INTRCPT2, B40					
INTRCPT3, G400	-1.035208	0.171968	-6.020	2171	0.000
For PABEFORE slope, P5					
For INTRCPT2, B50					
INTRCPT3, G500	-23.149359	1.418993	-16.314	68829	0.000
For PAAFTER slope, P6					
For INTRCPT2, B60					
INTRCPT3, G600	0.241902	0.822755	0.294	4084	0.769
For ESCS slope, P7					
For INTRCPT2, B70					
INTRCPT3, G700	17.234676	1.067714	16.142	39312	0.000

并计算得到 student-level, school-level and country-level 的 f^2 各为 0.073, 0.292 and 0.275.

Final estimation of level-1 and level-2 variance components:

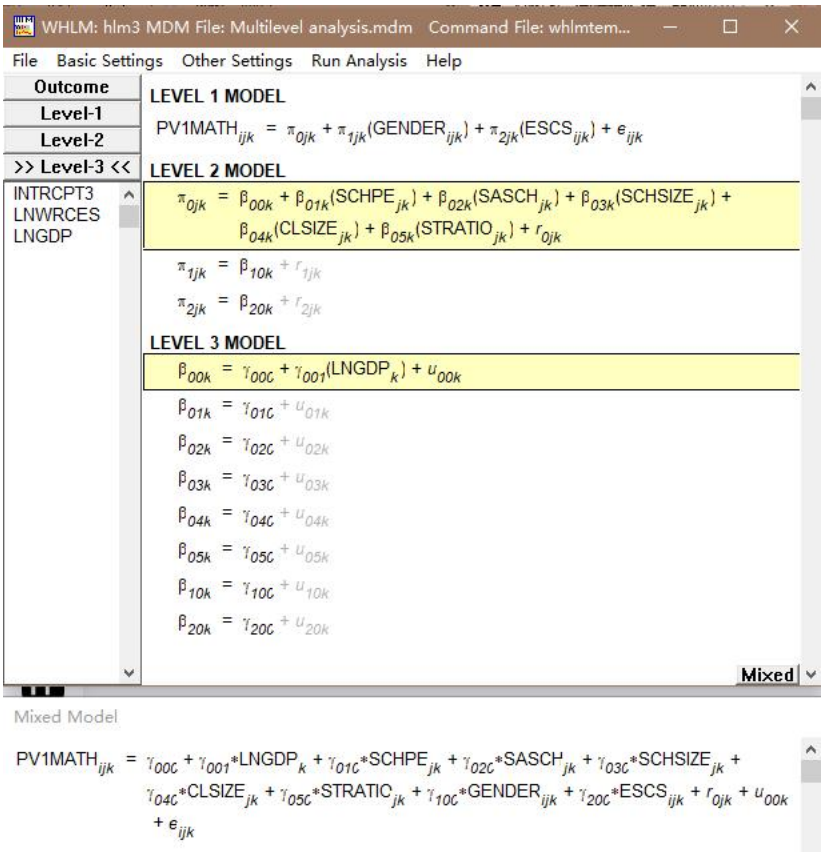
Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1, level-1,	R0	42.14520	1776.21824	12391	142326.78525	0.000
	E	69.98880	4898.43213			

Final estimation of level-3 variance components:

Random Effect	Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1/INTRCPT2, U00	45.66923	2085.67838	51	12080.21840	0.000

Model 3

Model 3：为探索学校层次的体育活动相关因素对学生数学成绩的影响，加入 student-level 和 country-level 的控制变量，并加入 school-level 全部变量，得到 Model 3 如下图所示。



结果：如下图结果所示，school-level 的变量都具备一定的显著性。

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
For INTRCPT2, B00					
INTRCPT3, G000	277.619835	97.934361	2.835	50	0.007
LNGDP, G001	7.324020	3.637755	2.013	50	0.049
For SCHPE, B01					
INTRCPT3, G010	-12.835804	2.440447	-5.260	12437	0.000
For SASCH, B02					
INTRCPT3, G020	8.751922	2.157263	4.057	1472	0.000
For SCHSIZE, B03					
INTRCPT3, G030	0.012862	0.002565	5.015	12437	0.000
For CLSIZE, B04					
INTRCPT3, G040	0.811049	0.231587	3.502	12437	0.001
For STRATIO, B05					
INTRCPT3, G050	-0.296767	0.110384	-2.689	1351	0.008
For GENDER slope, P1					
For INTRCPT2, B10					
INTRCPT3, G100	-11.405315	1.083803	-10.523	3198	0.000
For ESCS slope, P2					
For INTRCPT2, B20					
INTRCPT3, G200	17.066157	1.113535	15.326	51835	0.000

并计算得到 student-level, school-level and country-level 的 f^2 各为 0.034, 0.300 and 0.249.

Final estimation of level-1 and level-2 variance components:

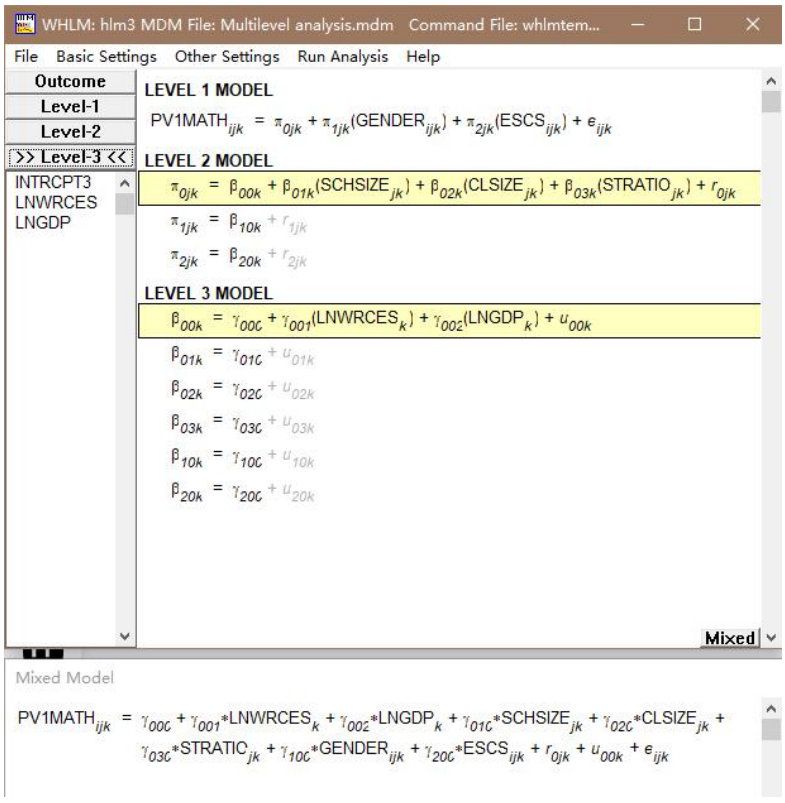
Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1,	R0	42.14520	1776.21824	12391	142326.78525	0.000
level-1,	E	69.98880	4898.43213			

Final estimation of level-3 variance components:

Random Effect	Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1/INTRCPT2, U00	45.66923	2085.67838	51	12080.21840	0.000

Model 4

Model 4：为探索国家体育成功水平对学生学业成绩的影响，加入 student-level 和 school-level 的控制变量并加入国家体育水平和 LNGDP。



结果：如下图结果所示，国家体育成功水平的回归系数为 27.761，结果具备一定的显著性。LNGDP 结果不显著，在之后建立的模型中将不加入该控制变量。

Final estimation of fixed effects
(with robust standard errors)

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
For INTRCPT2, B00					
INTRCPT3, G000	120.206497	118.648927	1.013	49	0.316
LNWRCES, G001	27.760856	11.356941	2.444	49	0.018
LNGDP, G002	0.725491	4.243245	0.171	49	0.865
For SCHSIZE, B01					
INTRCPT3, G010	0.014702	0.002866	5.131	12439	0.000
For CLSIZE, B02					
INTRCPT3, G020	0.862612	0.227810	3.787	12439	0.000
For STRATIO, B03					
INTRCPT3, G030	-0.314603	0.123274	-2.552	2049	0.011
For GENDER slope, P1					
For INTRCPT2, B10					
INTRCPT3, G100	-11.343599	1.083154	-10.473	3186	0.000
For ESCS slope, P2					
For INTRCPT2, B20					
INTRCPT3, G200	17.075528	1.113008	15.342	52229	0.000

并计算得到 student-level, school-level and country-level 的 f^2 各为 0.034, 0.272 and 0.303.

Final estimation of level-1 and level-2 variance components:

Random Effect	Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1, R0	42.73962	1826.67521	12388	140654.06797	0.000
level-1, E	71.45645	5106.02397			

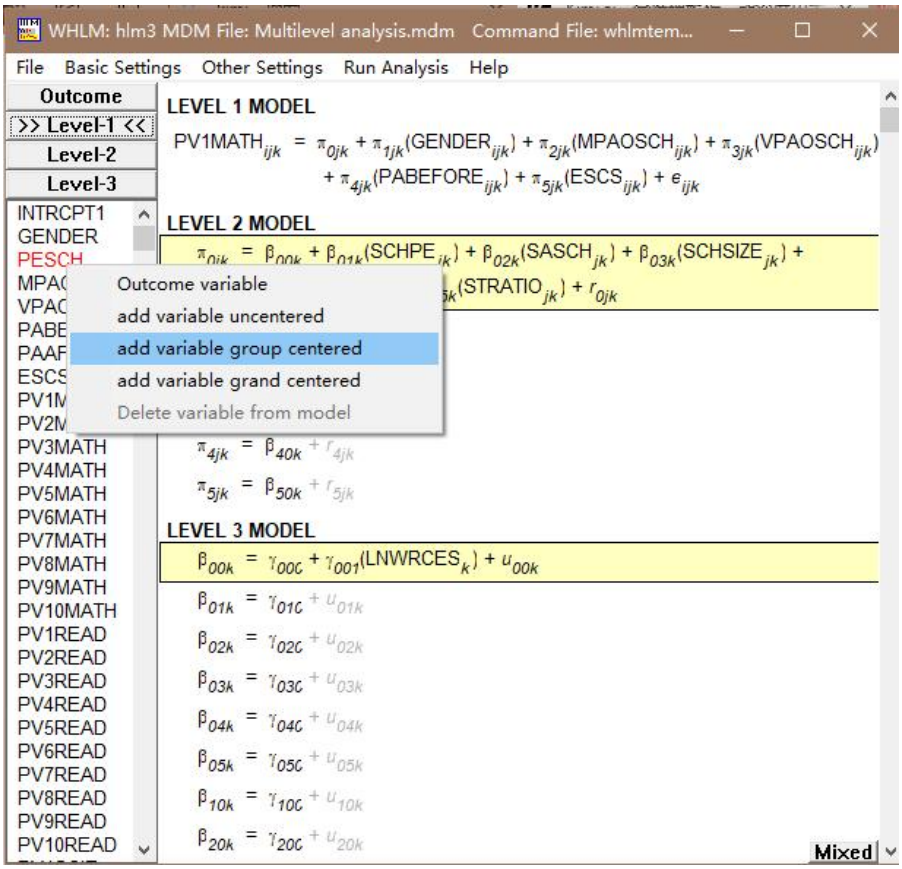
Final estimation of level-3 variance components:

Random Effect	Standard Deviation	Variance Component	df	Chi-square	P-value
NTRCPT1/INTRCPT2, U00	44.78245	2005.46791	49	11335.71316	0.000

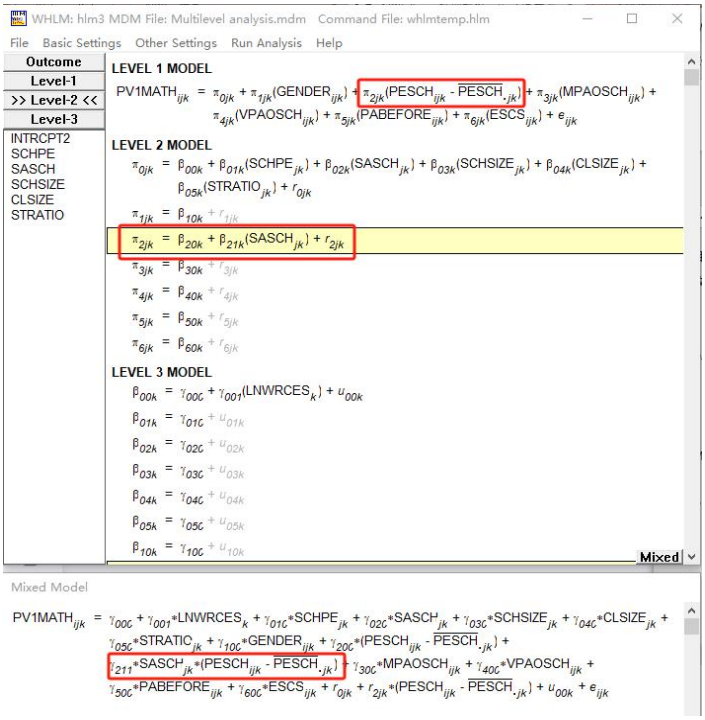
Model 5

为探索学校层次的体育活动相关因素和国家体育成功水平是否会调节学生的体育活动行为与他们学业成绩之间的关系，构建 Model 5.

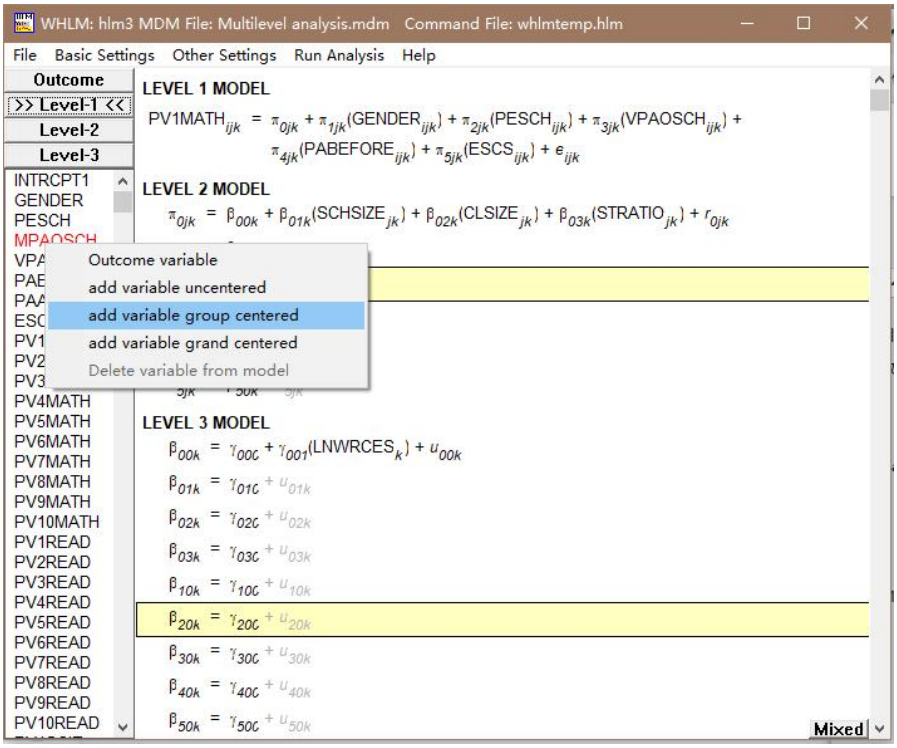
- Step1：针对学生层次的每个自变量分别加入学校层次的自变量作为调节变量，找出对学生层次体育活动相关因素和学生学业成绩之间的关系具有调节作用的学校层次变量。先以 PESCH 为例，构建含调节变量的模型需令涉及到交互项的学校层次的变量 group centered，学校层次的变量 grand centered：

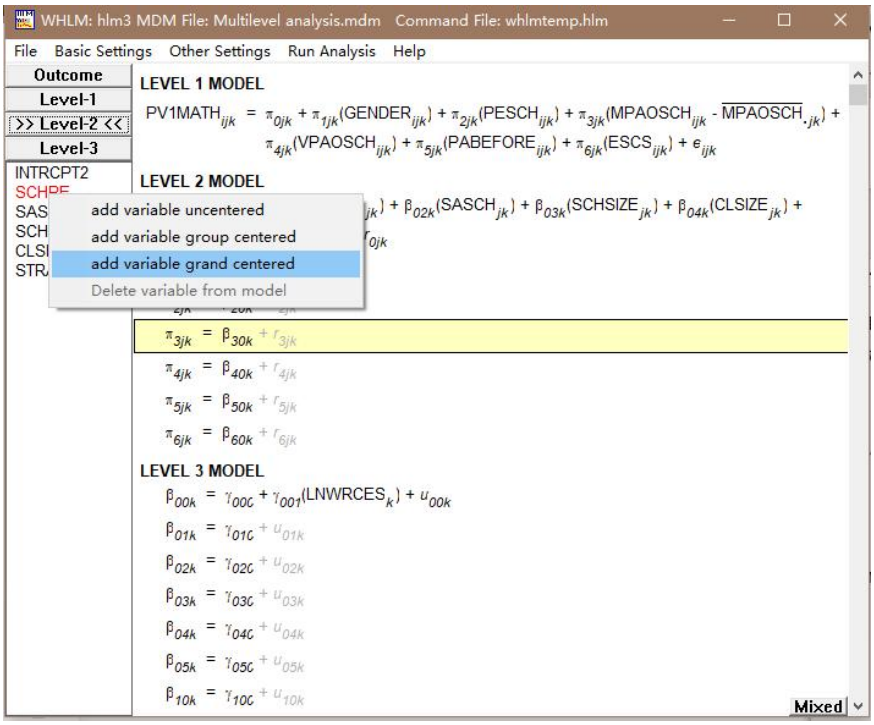


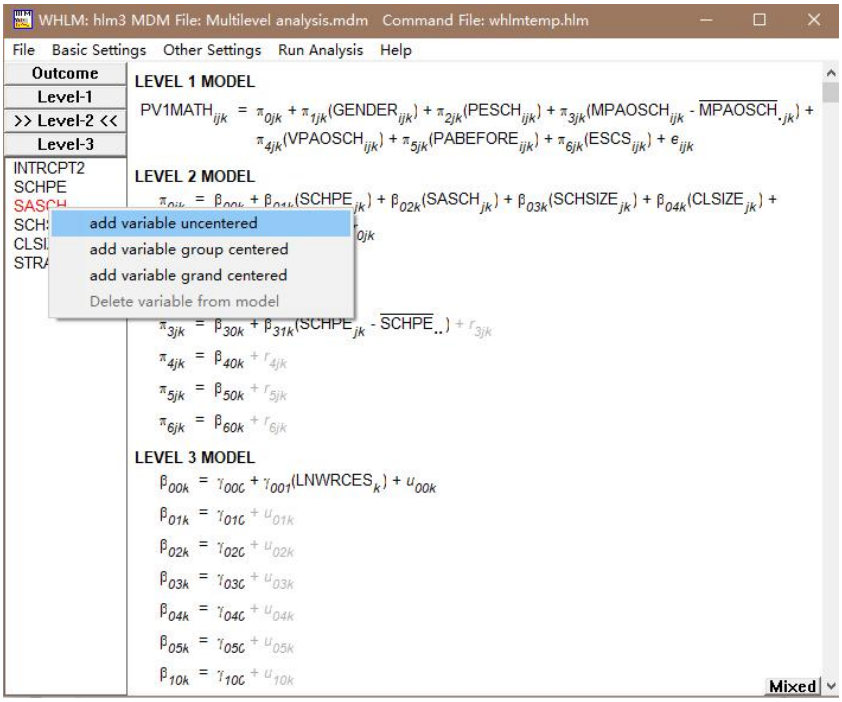
特别注意的是二分类变量无需 group centered 和 grand centered

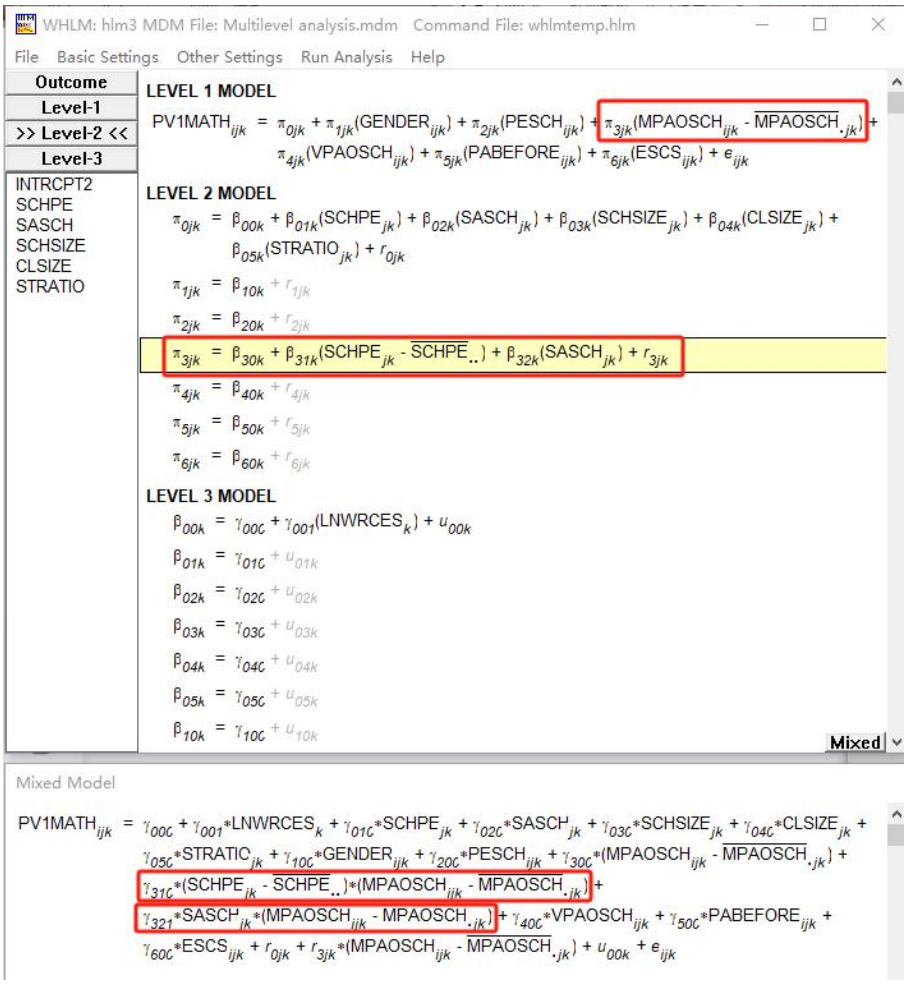


再以 MPAOSCH 为例，添加 SCHPE 和 SASCH 学校层次变量与 MPAOSCH 的交互项：


WHLM: hlm3 MDM File: Multilevel analysis.mdm Command File: whlmtemp.hlm
File Basic Settings Other Settings Run Analysis Help
Outcome
>> Level-1 <<
Level-2
Level-3
INTRCPT1
GENDER
PESCH
MPAOSCH
VPA
PAE
PAA
ESC
PV1
PV2
PV3
PV4MATH
PV5MATH
PV6MATH
PV7MATH
PV8MATH
PV9MATH
PV10MATH
PV1READ
PV2READ
PV3READ
PV4READ
PV5READ
PV6READ
PV7READ
PV8READ
PV9READ
PV10READ
Outcome variable
add variable uncentered
add variable group centered
add variable grand centered
Delete variable from model
LEVEL 1 MODEL
PV1MATH_ijk = π0jk + π1jk(GENDER_ijk) + π2jk(PESCH_ijk) + π3jk(VPAOSCH_ijk) + π4jk(PABEFORE_ijk) + π5jk(ESCS_ijk) + e_ijk
LEVEL 2 MODEL
π0jk = β00k + β01k(SCHSIZE_jk) + β02k(CLSIZE_jk) + β03k(STRATIO_jk) + r0jk
LEVEL 3 MODEL
β00k = γ00C + γ001(LNWRCES_k) + u00k
β01k = γ01C + u01k
β02k = γ02C + u02k
β03k = γ03C + u03k
β10k = γ10C + u10k
β20k = γ20C + u20k
β30k = γ30C + u30k
β40k = γ40C + u40k
β50k = γ50C + u50k
Mixed


WHLM: hlm3 MDM File: Multilevel analysis.mdm Command File: whlmtemp.hlm
File Basic Settings Other Settings Run Analysis Help
Outcome
Level-1
>> Level-2 <<
Level-3
INTRCPT2
SCHPE
SAS
SCH
CLSI
STRA
add variable uncentered
add variable group centered
add variable grand centered
Delete variable from model
LEVEL 1 MODEL
PV1MATH_ijk = π0jk + π1jk(GENDER_ijk) + π2jk(PESCH_ijk) + π3jk(MPAOSCH_ijk - MPAOSCH_.jk) + π4jk(VPAOSCH_ijk) + π5jk(PABEFORE_ijk) + π6jk(ESCS_ijk) + e_ijk
LEVEL 2 MODEL
jk) + β02k(SASCH_jk) + β03k(SCHSIZE_jk) + β04k(CLSIZE_jk) +
r0jk
π3jk = β30k + r3jk
π4jk = β40k + r4jk
π5jk = β50k + r5jk
π6jk = β60k + r6jk
LEVEL 3 MODEL
β00k = γ00C + γ001(LNWRCES_k) + u00k
β01k = γ01C + u01k
β02k = γ02C + u02k
β03k = γ03C + u03k
β04k = γ04C + u04k
β05k = γ05C + u05k
β10k = γ10C + u10k
Mixed


WHLM: hlm3 MDM File: Multilevel analysis.mdm Command File: whlmtemp.hlm
File Basic Settings Other Settings Run Analysis Help
Outcome
Level-1
>> Level-2 <<
Level-3
INTRCPT2
SCHPE
SASCH
SCH:
CLSI
STRA
add variable uncentered
add variable group centered
add variable grand centered
Delete variable from model
LEVEL 1 MODEL
PV1MATH_ijk = π0jk + π1jk(GENDER_ijk) + π2jk(PESCH_ijk) + π3jk(MPAOSCH_ijk - MPAOSCH_.jk) + π4jk(VPAOSCH_ijk) + π5jk(PABEFORE_ijk) + π6jk(ESCS_ijk) + e_ijk
LEVEL 2 MODEL
π0jk = β00k + β01k(SCHPE_jk) + β02k(SASCH_jk) + β03k(SCHSIZE_jk) + β04k(CLSIZE_jk) + r0jk
π3jk = β30k + β31k(SCHPE_jk - SCHPE_..) + r3jk
π4jk = β40k + r4jk
π5jk = β50k + r5jk
π6jk = β60k + r6jk
LEVEL 3 MODEL
β00k = γ00c + γ001(LNWRCES_k) + u00k
β01k = γ01c + u01k
β02k = γ02c + u02k
β03k = γ03c + u03k
β04k = γ04c + u04k
β05k = γ05c + u05k
β10k = γ10c + u10k
Mixed


WHLM: hlm3 MDM File: Multilevel analysis.mdm Command File: whlmtemp.hlm
File Basic Settings Other Settings Run Analysis Help
Outcome
Level-1
>> Level-2 <<
Level-3
INTRCPT2
SCHPE
SASCH
SCHSIZE
CLSIZE
STRATIO
LEVEL 1 MODEL
PV1MATH_ijk = π0jk + π1jk(GENDER_ijk) + π2jk(PESCH_ijk) + π3jk(MPAOSCH_ijk - MPAOSCH_.jk) + π4jk(VPAOSCH_ijk) + π5jk(PABEFORE_ijk) + π6jk(ESCS_ijk) + e_ijk
LEVEL 2 MODEL
π0jk = β00k + β01k(SCHPE_jk) + β02k(SASCH_jk) + β03k(SCHSIZE_jk) + β04k(CLSIZE_jk) + β05k(STRATIO_jk) + r0jk
π1jk = β10k + r1jk
π2jk = β20k + r2jk
π3jk = β30k + β31k(SCHPE_jk - SCHPE_..) + β32k(SASCH_jk) + r3jk
π4jk = β40k + r4jk
π5jk = β50k + r5jk
π6jk = β60k + r6jk
LEVEL 3 MODEL
β00k = γ00c + γ001(LNWRCES_k) + u00k
β01k = γ01c + u01k
β02k = γ02c + u02k
β03k = γ03c + u03k
β04k = γ04c + u04k
β05k = γ05c + u05k
β10k = γ10c + u10k
Mixed
Mixed Model
PV1MATH_ijk = γ00c + γ001*LNWRCES_k + γ01c*SCHPE_jk + γ02c*SASCH_jk + γ03c*SCHSIZE_jk + γ04c*CLSIZE_jk + γ05c*STRATIC_jk + γ10c*GENDER_ijk + γ20c*PESCH_ijk + γ30c*(MPAOSCH_ijk - MPAOSCH_.jk) + γ31c*(SCHPE_jk - SCHPE_..)*(MPAOSCH_ijk - MPAOSCH_.jk) + γ321*SASCH_jk*(MPAOSCH_ijk - MPAOSCH_.jk) + γ40c*VPAOSCH_ijk + γ50c*PABEFORE_ijk + γ60c*ESCS_ijk + r0jk + r3jk*(MPAOSCH_ijk - MPAOSCH_.jk) + u00k + e_ijk

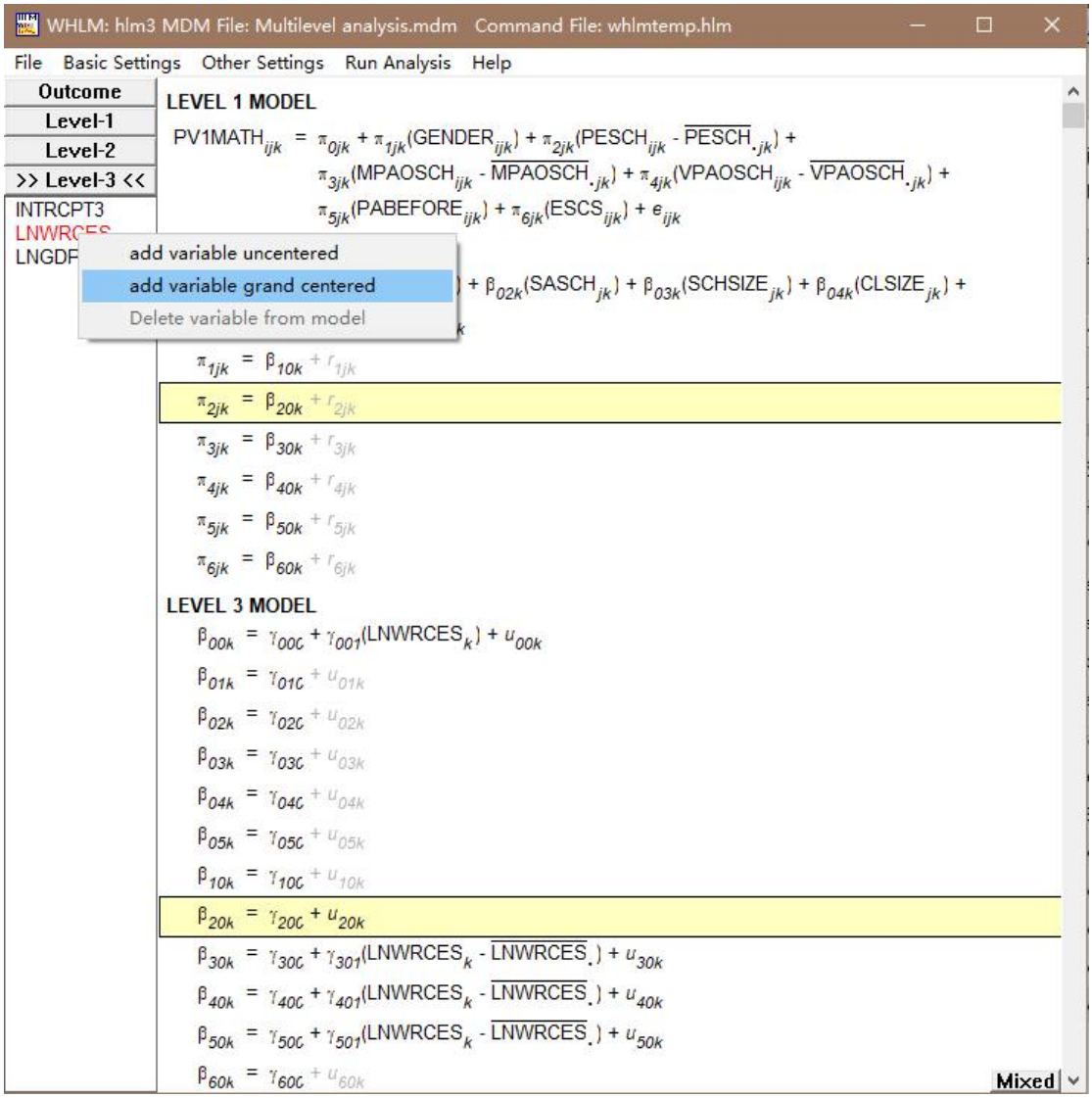
结果：由下图可见，SCHPE 和 SASCH 对 MPAOSCH 与学业成绩之间的关系有调节作用。

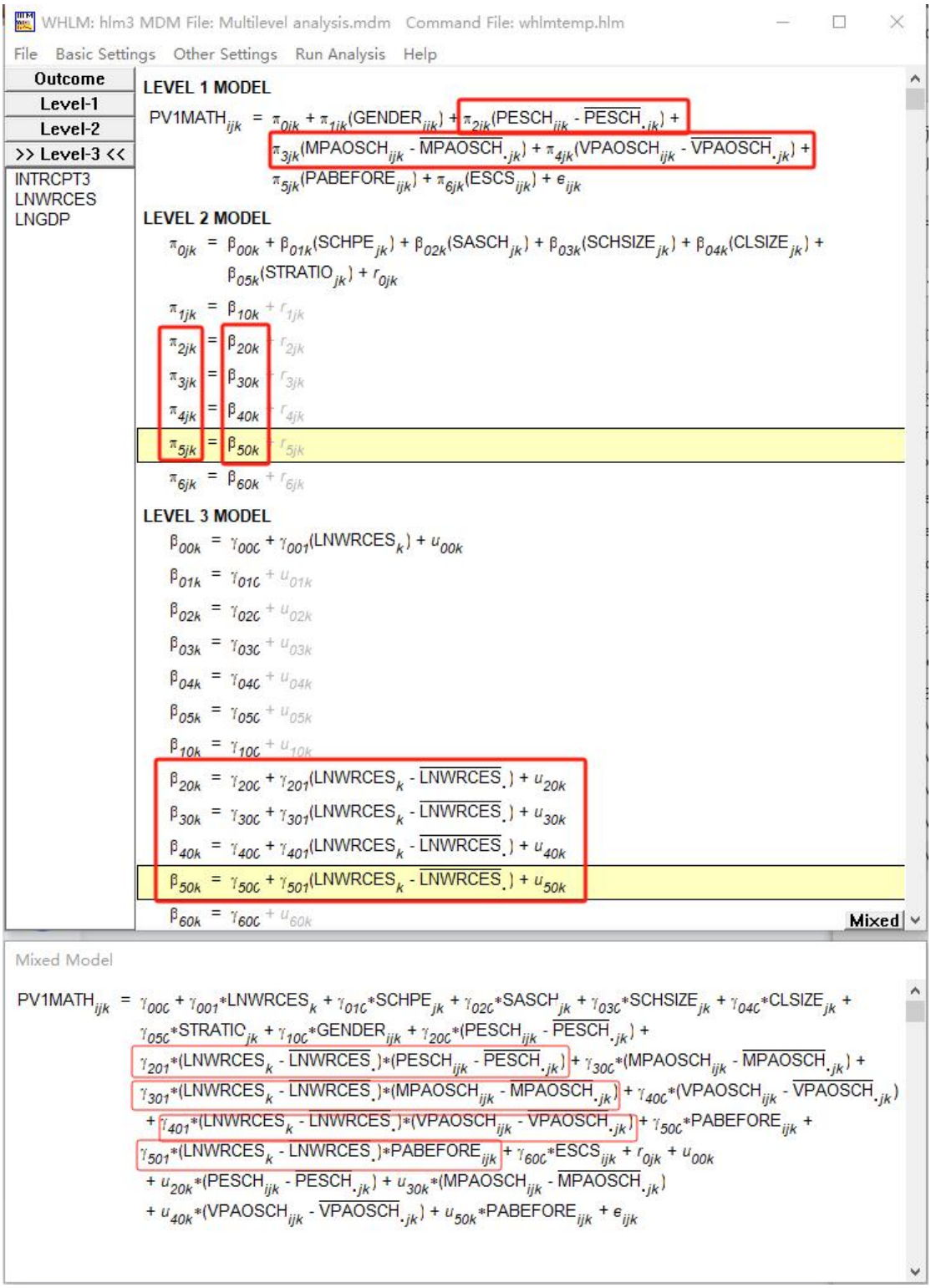
Final estimation of fixed effects
(with robust standard errors)

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
For INTRCPT2, B00					
INTRCPT3, G000	92.233449	109.310978	0.844	50	0.403
LNWRCES, G001	33.150270	9.464554	3.503	50	0.001
For SCHPE, B01					
INTRCPT3, G010	-8.014232	2.740953	-2.924	12437	0.004
For SASCH, B02					
INTRCPT3, G020	10.131765	2.279707	4.444	1613	0.000
For SCHSIZE, B03					
INTRCPT3, G030	0.015066	0.002938	5.127	12437	0.000
For CLSIZE, B04					
INTRCPT3, G040	1.000174	0.258863	3.864	12437	0.000
For STRATIO, B05					
INTRCPT3, G050	-0.376378	0.122206	-3.080	1558	0.003
For GENDER slope, P1					
For INTRCPT2, B10					
INTRCPT3, G100	-16.797680	1.079392	-15.562	2215	0.000
For PESCH slope, P2					
For INTRCPT2, B20					
INTRCPT3, G200	-6.778498	0.455721	-14.874	4825	0.000
For MPAOSCH slope, P3					
For INTRCPT2, B30					
INTRCPT3, G300	4.090622	0.417433	9.799	2581	0.000
For SCHPE, B31					
INTRCPT3, G310	0.345473	0.174198	1.983	775	0.047
For SASCH, B32					
INTRCPT3, G320	-1.000686	0.410267	-2.439	2991	0.015
For VPAOSCH slope, P4					
For INTRCPT2, B40					
INTRCPT3, G400	-0.590718	0.190680	-3.098	1950	0.002
For PABEFORE slope, P5					
For INTRCPT2, B50					
INTRCPT3, G500	-22.555019	1.360859	-16.574	106961	0.000

接下来也分别考虑 SCHPE 和 SASCH 学校层次变量与其他学生体育活动行为相关因素(VPAOSCH & PABEFORE)的交互项，从而确认 SCHPE 和 SASCH 对哪些学生体育活动相关因素和学业成绩因变量之间的关系具有调节作用。

- Step2：针对学生层次的自变量加入国家层次的体育成功水平作为调节变量，探究国家体育成功水平是否可以调节学生体育活动行为情况与学业成绩之间的关系。


WHLM: hlm3 MDM File: Multilevel analysis.mdm Command File: whlmtemp.hlm
File
Basic Settings
Other Settings
Run Analysis
Help
Outcome
Level-1
Level-2
>> Level-3 <<
INTRCPT3
LNWRCES
LNGDP
add variable uncentered
add variable grand centered
Delete variable from model
LEVEL 1 MODEL
PV1MATH_ijk = π0jk + π1jk(GENDER_ijk) + π2jk(PESCH_ijk - PESCH_.jk) +
π3jk(MPAOSCH_ijk - MPAOSCH_.jk) + π4jk(VPAOSCH_ijk - VPAOSCH_.jk) +
π5jk(PABEFORE_ijk) + π6jk(ESCS_ijk) + e_ijk
+ β02k(SASCH_jk) + β03k(SCHSIZE_jk) + β04k(CLSIZE_jk) +
π1jk = β10k + r1jk
π2jk = β20k + r2jk
π3jk = β30k + r3jk
π4jk = β40k + r4jk
π5jk = β50k + r5jk
π6jk = β60k + r6jk
LEVEL 3 MODEL
β00k = γ000 + γ001(LNWRCES_k) + u00k
β01k = γ010 + u01k
β02k = γ020 + u02k
β03k = γ030 + u03k
β04k = γ040 + u04k
β05k = γ050 + u05k
β10k = γ100 + u10k
β20k = γ200 + u20k
β30k = γ300 + γ301(LNWRCES_k - LNWRCES_.) + u30k
β40k = γ400 + γ401(LNWRCES_k - LNWRCES_.) + u40k
β50k = γ500 + γ501(LNWRCES_k - LNWRCES_.) + u50k
β60k = γ600 + u60k
Mixed

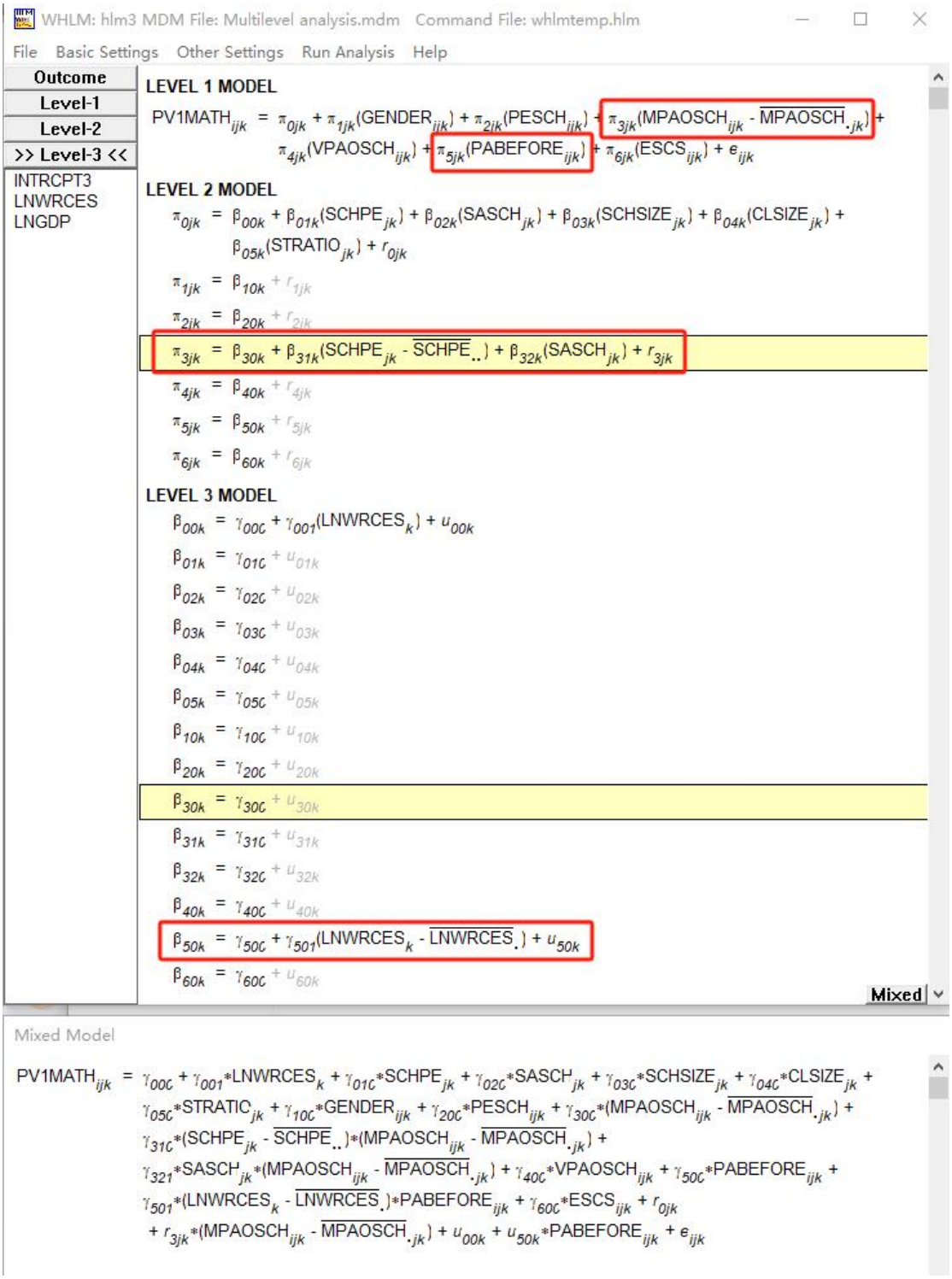


结果：由下图可见，LNWRCES 与 PABEFORE 的交互作用效果显著。

Final estimation of fixed effects
(with robust standard errors)

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
For INTRCPT2, B00					
INTRCPT3, G000	480.973184	8.986202	53.524	50	0.000
LNWRCES, G001	31.168370	9.248936	3.370	50	0.002
For SCHPE, B01					
INTRCPT3, G010	-12.115362	2.415008	-5.017	12437	0.000
For SASCH, B02					
INTRCPT3, G020	8.940073	2.115102	4.227	1352	0.000
For SCHSIZE, B03					
INTRCPT3, G030	0.012507	0.002538	4.927	12437	0.000
For CLSIZE, B04					
INTRCPT3, G040	0.806953	0.228726	3.528	12437	0.001
For STRATIO, B05					
INTRCPT3, G050	-0.290828	0.107733	-2.700	1191	0.007
For GENDER slope, P1					
For INTRCPT2, B10					
INTRCPT3, G100	-15.955226	1.041091	-15.325	2042	0.000
For PESCH slope, P2					
For INTRCPT2, B20					
INTRCPT3, G200	-7.123137	0.495179	-14.385	50	0.000
LNWRCES, G201	1.143174	0.642773	1.779	50	0.081
For MPAOSCH slope, P3					
For INTRCPT2, B30					
INTRCPT3, G300	2.910354	0.177169	16.427	50	0.000
LNWRCES, G301	0.084225	0.258770	0.325	50	0.746
For VPAOSCH slope, P4					
For INTRCPT2, B40					
INTRCPT3, G400	-0.954932	0.179001	-5.335	50	0.000
LNWRCES, G401	0.337492	0.269820	1.251	50	0.217
For PABEFORE slope, P5					
For INTRCPT2, B50					
INTRCPT3, G500	-23.013129	1.427911	-16.117	50	0.000
LNWRCES, G501	-5.311433	2.495406	-2.128	50	0.038
For ESCS slope, P6					
For INTRCPT2, B60					
INTRCPT3, G600	16.899476	1.066349	15.848	37498	0.000

- Step3：将 step1 和 step2 得出的具有统计显著性的学校层次和国家层次的交互项加入模型中构建模型 5，即 full model



结果：

由下图结果得，SCHPE 对 MPAOSCH 与数学成绩之间的关系不具调节作用（p value>0.05），而 SASCH 对 MPAOSCH 与数学成绩之间的关系具一定调节作用（p value<0.05）。在国家层面，国家体育成功水平对 PABEFORE 与数学成绩之间的关系也不具备调节作用。

Final estimation of fixed effects
(with robust standard errors)

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
For INTRCPT2, B00					
INTRCPT3, G000	472.584636	8.325446	56.764	50	0.000
LNWRCES, G001	31.200561	9.191757	3.394	50	0.002
For SCHPE, B01					
INTRCPT3, G010	-6.502034	2.428948	-2.677	12437	0.008
For SASCH, B02					
INTRCPT3, G020	9.359557	2.057543	4.549	1138	0.000
For SCHSIZE, B03					
INTRCPT3, G030	0.012358	0.002574	4.800	12437	0.000
For CLSIZE, B04					
INTRCPT3, G040	0.800617	0.229311	3.491	12437	0.001
For STRATIO, B05					
INTRCPT3, G050	-0.279883	0.108071	-2.590	1130	0.010
For GENDER slope, P1					
For INTRCPT2, B10					
INTRCPT3, G100	-15.712756	1.072864	-14.646	2147	0.000
For PESCH slope, P2					
For INTRCPT2, B20					
INTRCPT3, G200	-6.656649	0.456936	-14.568	5129	0.000
For MPAOSCH slope, P3					
For INTRCPT2, B30					
INTRCPT3, G300	3.708581	0.430154	8.622	3476	0.000
For SCHPE, B31					
INTRCPT3, G310	0.309158	0.166772	1.854	1025	0.064
For SASCH, B32					
INTRCPT3, G320	-0.896232	0.428310	-2.092	3701	0.036
For VPAOSCH slope, P4					
For INTRCPT2, B40					
INTRCPT3, G400	-0.938996	0.177620	-5.287	1553	0.000
For PABEFORE slope, P5					
For INTRCPT2, B50					
INTRCPT3, G500	-23.097065	1.410454	-16.376	50	0.000
LNWRCES, G501	-4.608809	2.326781	-1.981	50	0.053
For ESCS slope, P6					
For INTRCPT2, B60					
INTRCPT3, G600	16.973351	1.076156	15.772	41576	0.000

Final estimation of level-1 and level-2 variance components:

Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1,	R0	41.15232	1693.51357	12217	136248.39598	0.000
MPAOSCH slope,	R3	1.79740	3.23065	12271	14269.70376	0.000
level-1,	E	69.71247	4859.82828			

Final estimation of level-3 variance components:

Random Effect	Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1/INTRCPT2, U00	44.58588	1987.90026	50	11203.54675	0.000
PABEFORE/INTRCPT2, U50	9.01087	81.19576	50	1237.25724	0.000