CHAPTER 5

5 AN APPLICATION TO GREEK EDUCATIONAL DATA

In this Chapter we apply a statistical analysis to a real dataset obtained by the Greek Ministry of Education, Lifelong Learning and Religious Affairs referring to the years 2006 up to 2009. The aim of the analysis is to assess the effectiveness of Greek Lyceums and to detect the factors that affect students' performance in high school, especially according to the National Exams for their access in the National Universities and Technical Institutions.

The hierarchical structure of the data is profound. Students are nested in schools and schools are nested in prefectures, so the influences of this grouping must be taken into account. Thus, as described in previous Chapters, multilevel modeling is required for the analysis of such data, where students represent the 1^{st} Level, schools the 2^{nd} Level and prefectures the 3^{rd} Level of analysis. It should be noticed that this is the first time multilevel analysis is carried out in the particular educational system of access which is described in the following paragraph.

The scope, therefore, of this Chapter is to apply Multilevel Techniques as described in previous chapters, in this particular situation, to discuss firstly on the results of the analysis themselves but, moreover to discuss on the advantages and the applicability of the use of Multilevel Analysis in this real example.

5.1 Description of the Educational System

In order to detect the variables of interest for the analysis, let us give a brief description of the Greek educational system in the Greek Lyceums (at the years of interest 2006-2009) as described in the website of the Greek Ministry of Education, Lifelong Learning and Religious Affairs (www.ypepth.gr). Studies in Lyceum are optional and last for three years. All students during their studies are asked to choose one of the three "Scientific Orientations" (Human Sciences, Exact Sciences, and Technical Sciences) which, more or less, "direct" their studies. Technical scientific orientation is further divided in two cycles of studies (Technology & Production and Informatics & Services). In the third class of Lyceum, students are examined at a

National level, in four subjects of orientation and two (or three-as will be described later) subjects of general education. According to their marks on these six (or seven) subjects students receive the so-called "General Admission Grade" (ranging from 0 to 20) which is the first basis for the calculation of the "Final Admission Grade ("moria")" used for the access of students to the National Universities and Technical Institutions. The calculation of the "Final Admission Grade ("moria")" is somehow complicated and depends on the "weight" given in each of the six (or seven) subjects according to the new Scientific Area ("Pedio") chosen by the students prior to their potential access to a University or Technical Institution. There are five "scientific areas" and are chosen by the students who apply for the selection process for their access to a University or Technical Institution independently of their initial choice of "Scientific Orientation". Students of the first four "scientific areas" are examined in six subjects, while students of the 5^{th} "scientific area" are examined in seven. Moreover, according to the National Exams Regulations, in order a student to be eligible to apply for the selection process for the access to a University or Technical Institution (and, therefore, in order the "Final Admission Grade ("moria")" to be calculated) the "General Admission Grade" of the student has to be at least 10. These restrictions in the calculation of the "Final Admission Grade" (not calculated for all students and, when it is calculated, the formula is different for each student) should be taken into account in the analysis.

5.2 Variables

Having in mind all the above considerations, we can now refer to the variables that will be used in the analysis. The "General Admission Grade" will be the response variable, since it is calculated in a "common" basis for all the students, and the potential independent factors that might affect students' performance and schools' effectiveness are the Gender of the student, the Scientific Orientation of Studies, the Type of School and the Year of Examination in which the General Admission Grade corresponds. Also possible interactions between factors will be examined. We should notice that all potential explanatory variables are categorical and no appropriate continuous explanatory variables can be used. More specifically:

Response Variable

The General Admission Grade is the most appropriate measure to be used as the response variable in order to detect student's performance and schools' effectiveness, since it is calculated for the whole of students directly by the performance of the students in the National Exams in the six (or seven) pre-determined subjects. The two subjects of general education are "New Hellenic Grammar" (compulsory) and one of "History of Modern World", "Mathematics & Elements of Statistics" or "Biology & Physics". For the 5th scientific area the 7th subject is "Elements of Economical Theory". Also, according to the initial Scientific Orientation, the four subjects of orientation are:

- "Ancient Greek", "Latin", "New Hellenic Literature" and "History" for the Human Sciences Orientation.
- "Biology", "Mathematics", "Physics" and "Chemistry" for the Exact Sciences Orientation.
- "Electrology", "Mathematics", "Physics" and "Chemistry/Biochemistry" for the 1st cycle (Technology & Production) of Technical Sciences Orientation.
- "Mathematics", "Physics", "Elements of Business Administration" and "Applications Development in Programming Environment" for the 2nd cycle (Informatics & Services) of Technical Sciences Orientation.

The score of the General Admission Grade ranges from 0 to 20 and, according to initial goodness-of-fit analysis, the original scores were used, without the need of any transformation.

Explanatory Variables

As mentioned before, there is no continuous explanatory variable used in the analysis, since there were no such appropriate available variables. This should be taken into account, since as mentioned in almost all previous references (Goldstein, 1993 for instance), an explanatory variable is usually used as an "adjustment" for the existing achievements of the students. The categorical explanatory variables (factors) used in the analysis are the following:

1. The Type of School is a profound potential factor (2nd Level variable) to be used in the analysis. There are two types of schools of interest, Public and

Private schools. The variable indicating the type of school is a dummy dichotomous variable coded 1 for public schools and 0 for private.

2. The Gender of students is also an important explanatory variable (1st Level variable). It is also a dummy variable coded 1 for male students and 0 for female.
3. The initial Scientific Orientation of Studies is also an interesting potential factor which might affects the response variable. It was preferred from the "Scientific Area (pedio)" as possible explanatory variable because it exists for all students, while the latter is present only for the "eligible" students. Also it should be mentioned that Technical Scences Orientation was examined as it is and was not separated into the two cycles of studies, due to the very small number of students examined in the first cycle (Technology & Production). The categorical variable "Scientific Orientation" has three categories, so we need 2 dummy variables in order to make the appropriate comparisons between the three orientations. More specifically, the 1st dummy variable is coded 1 for the 1st scientific orientation (Human Sciences) and 0 for all the others. The 2nd dummy variable is coded 1 for the 2nd scientific orientation (Exact Sciences) and 0 for all the others, while the 3rd scientific orientation (Technical Scences) is the base category.
4. Another important factor to be examined for its effect on the response variable is the Year of Examination. We should notice that, in order to avoid duplications, if the same student had taken the National Exams more than once within the time period of interest (2006-2009) only their first General Admission Grade was taken into account. For example, if a student had examined in the years 2006, 2007 and 2008, only the score in 2006 was used in the analysis and the two other scores were omitted. The categorical variable "Year of Examination" has four values (2006, 2007, 2008, 2009) so three dummy variables were needed in order to make the appropriate comparisons between years. The last year (2009) was used as the base category.

5.3 Descriptive Statistics

Before any further analysis we present some descriptive statistics for our data concerning the number of units in each level of analysis as well as the General Admission Grade according to the explanatory variables of the analysis.

As shown in the following table (Table 5.1) in the total dataset there are 325724 students (1st Level units), nested within 1387 schools (2nd Level units), nested within 54 prefectures (3rd Level units). In the year 2006 there are 98333 unique students, nested within 1345 schools nested within 54 prefectures. In 2007 77311 unique students nested within 1354 schools, in 2008 76917 unique students nested in 1360 schools and in 2009 73163 students nested within 1365 schools. As mentioned in the previous Chapter, all students participating in the analysis are unique, that is only the General Admission Grade from their first year of examination was taken into account. Of course, the vast majority of the school units and all 54 prefectures participated in the analysis every year.

Table 5.1: No of units (students/schools/prefectures) for each Year of Examination

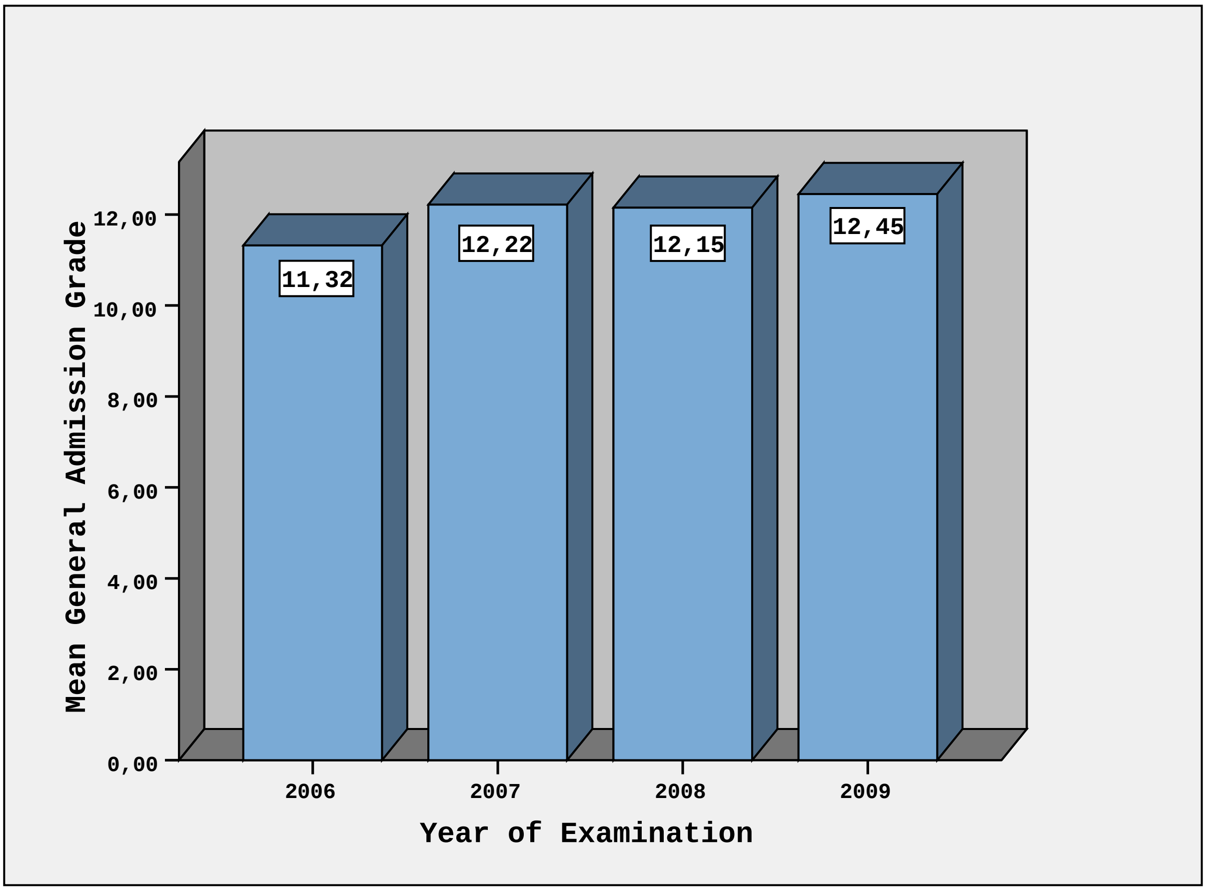
Year of Examination	No of Students	No of Schools	No of prefectures
2006	98333	1345	54
2007	77311	1354	54
2008	76917	1360	54
2009	73163	1365	54
Total	**325724**	**1387**	**54**

The following tables (Table 5.2-5.5) and the corresponding figures (Figure 5.1-5.4) refer to the descriptive statistics of the General Admission Grade according to the explanatory variables. We should notice that 15663 students were omitted from the analysis because of missing of their General Admission Grade and, therefore, the final analysis was based on 310061 students. The total mean for General Admission Grade for the whole period of interest (2006-2009) is 11.99 (±4.66).

Table 5.2: Descriptive Statistics for the General Admission Grade according to the Year of Examination

Variable	Year of Examination	Mean	Std. Dev.	Minimum	Maximum	N of cases
	2006	11.32	4.43	.02	19.93	92814
General	2007	12.22	4.56	.04	19.91	73142
Admission	2008	12.15	4.78	.03	19.88	73513
Grade	2009	12.45	4.84	.05	19.95	70592
	Total	**11.99**	**4.66**	**.02**	**19.95**	**310061**

Figure 5.1: Figure for the Mean General Admission Grade according to the Year of Examination



As shown in the above table (Table 5.2) and the corresponding figure (Figure 5.1) the highest mean score of the General Admission Grade (12.45) with respect to the year of examination was observed by students examined in 2009. In contrast, students examined in 2006 seem to have the worst performance (mean General Admission Grade=11.32). This result can be probably explained by the fact that 2006 was the first year of application of the particular education system of access, so students were not yet adapted to this new system.

Table 5.3: Descriptive Statistics for the General Admission Grade according to the Gender of Students

Variable	Gender	Mean	Std. Dev.	Minimum	Maximum	N of cases
General	Male	11.37	4.81	.03	19.90	140621
Admission	Female	12.50	4.47	.02	19.95	169440
Grade	**Total**	**11.99**	**4.66**	**.02**	**19.95**	**310061**

Figure 5.2: Figure for the Mean General Admission Grade according to the Gender of Students

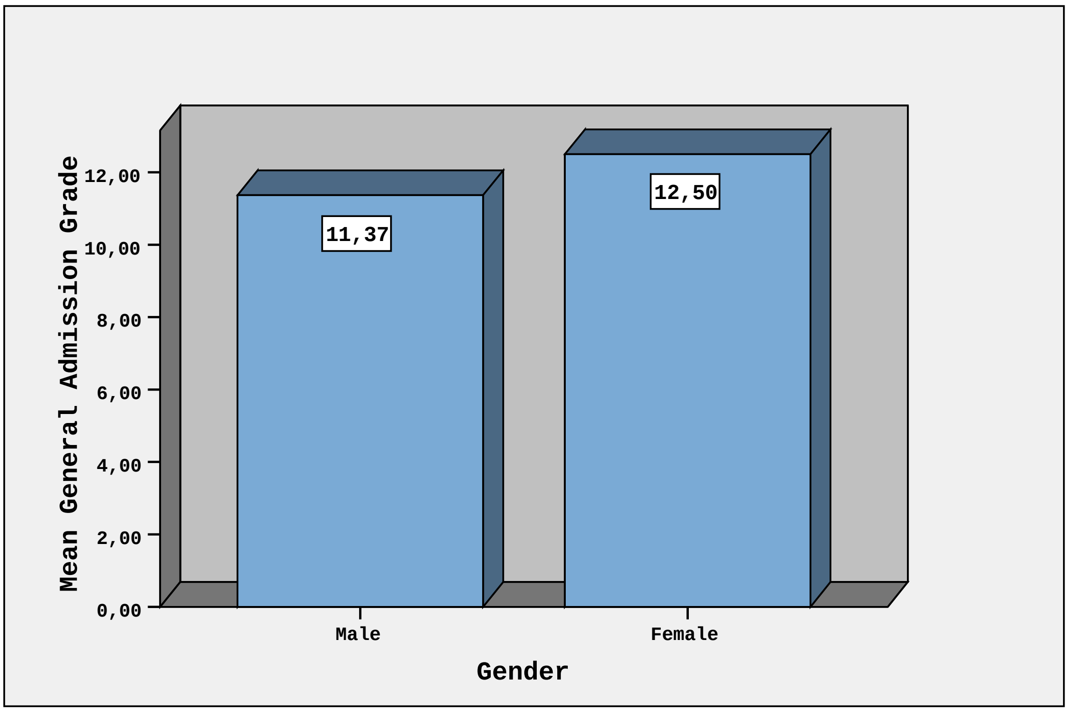
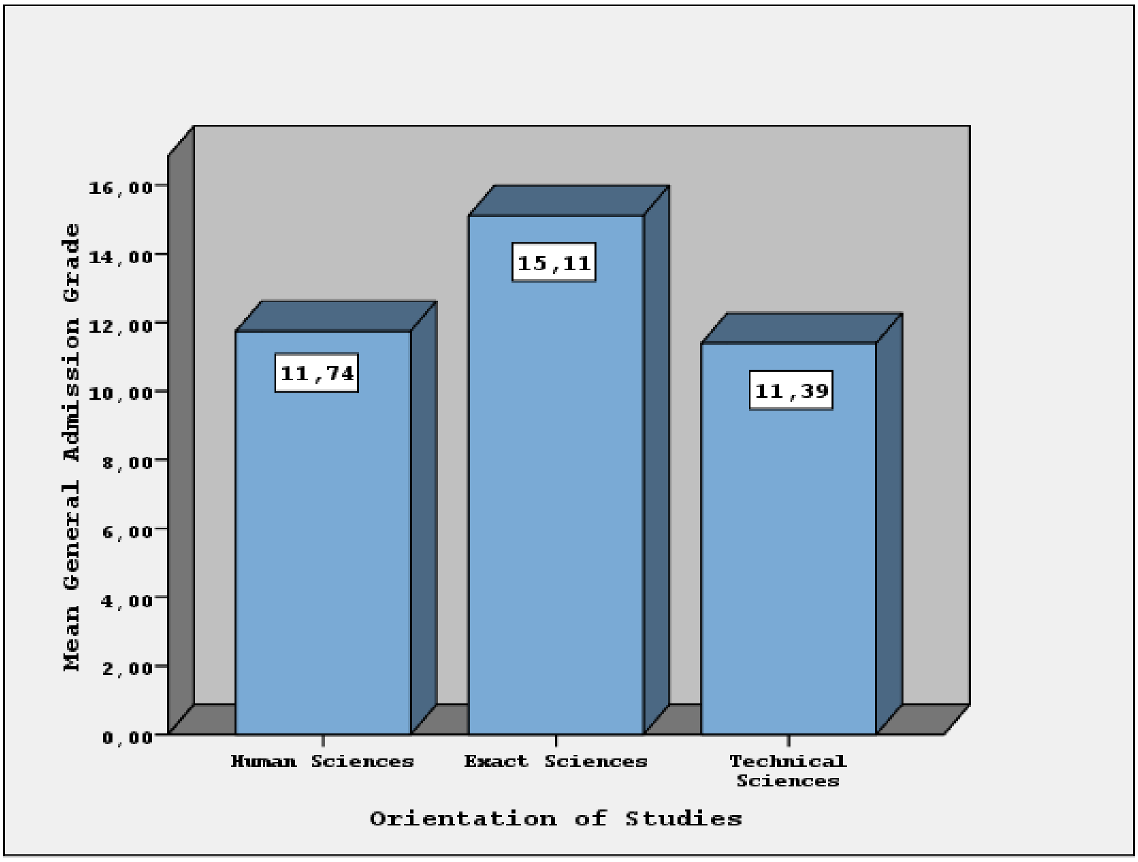


Table 5.3 and the corresponding figure (Figure 5.2) show that female students perform much better than male students, since the mean score for General Admission Grade for girls is 12.5 versus only 11.37 for boys. However, we will elaborate more on this result in the following Chapter of multilevel analysis, since this difference might be also related to the differences in scientific orientations chosen by girls and boys.

Table 5.4: Descriptive Statistics for the General Admission Grade according to the Scientific Orientation of Studies

Variable	Orientation of Studies	Mean	Std. Dev.	Minimum	Maximum	N of cases
General Admission Grade	Human Sciences	11.74	4.61	.03	19.93	121258
	Exact Sciences	15.11	3.92	.07	19.92	38117
	Technical Sciences	11.39	4.57	.02	19.95	150686
	Total	**11.99**	**4.66**	**.02**	**19.95**	**310061**

Figure 5.3: Figure for the Mean General Admission Grade according to the Scientific Orientation of Studies



From the above table (Table 5.4 and the corresponding figure (Figure 5.3) we can easily detect that the performance of the students who have chosen the “Exact Sciences” scientific orientation is much higher than those who have chosen the two other orientations (“Human Sciences” and “Technical Sciences”). The mean General Admission Grade for the Exact Sciences scientific orientation is 15.11 versus 11.74 and 11.39 for the Human Sciences and Technical Sciences orientation respectively. However, the highest score (19.95) was accomplished by a student of the Technical Sciences scientific orientation. In order to give a first explanation for the superiority of the students of Exact Sciences orientation, as regards their General Admission Grade performance, we should mention the relative small number of students who choose this scientific orientation, as well as the fact that this orientation is chosen by students focused mainly on health studies which demand very high entrance exams scores from the students.

Table 5.5: Descriptive Statistics for the General Admission Grade according to the Type of School

Variable	Type of School	Mean	Std. Dev.	Minimum	Maximum	N of cases
General	Public	11.82	4.64	.03	19.95	289287
Admission	Private	14.33	4.37	.02	19.90	20774
Grade	**Total**	**11.99**	**4.66**	**.02**	**19.95**	**310061**

Figure 5.4: Figure for the Mean General Admission Grade according to the Type of School

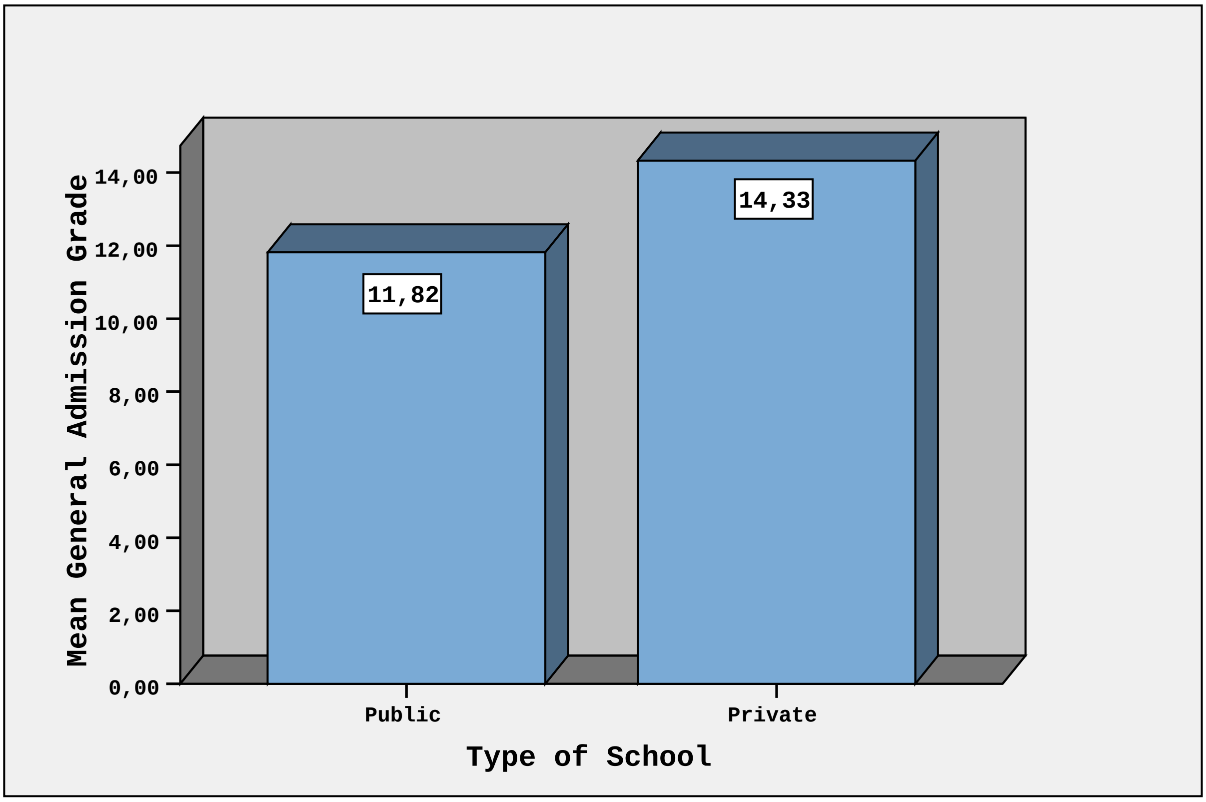


Table 5.5 and the corresponding figure (Figure 5.4) show the descriptive results for the General Admission Grade according to a 2nd Level explanatory variable (type of student). We can see from the results an obvious higher performance for students in private schools compared to students from public schools (mean scores are 14.33 versus 11.82 respectively). However, the highest score for General Admission Grade (19.95) was accomplished by a student in a public school. Again, we have to take into consideration the relatively very small number of students attending private schools. In the following Chapter of multilevel analysis we will also examine the possible cross-level interaction between the type of school and some 1st level variables (gender and scientific orientation).

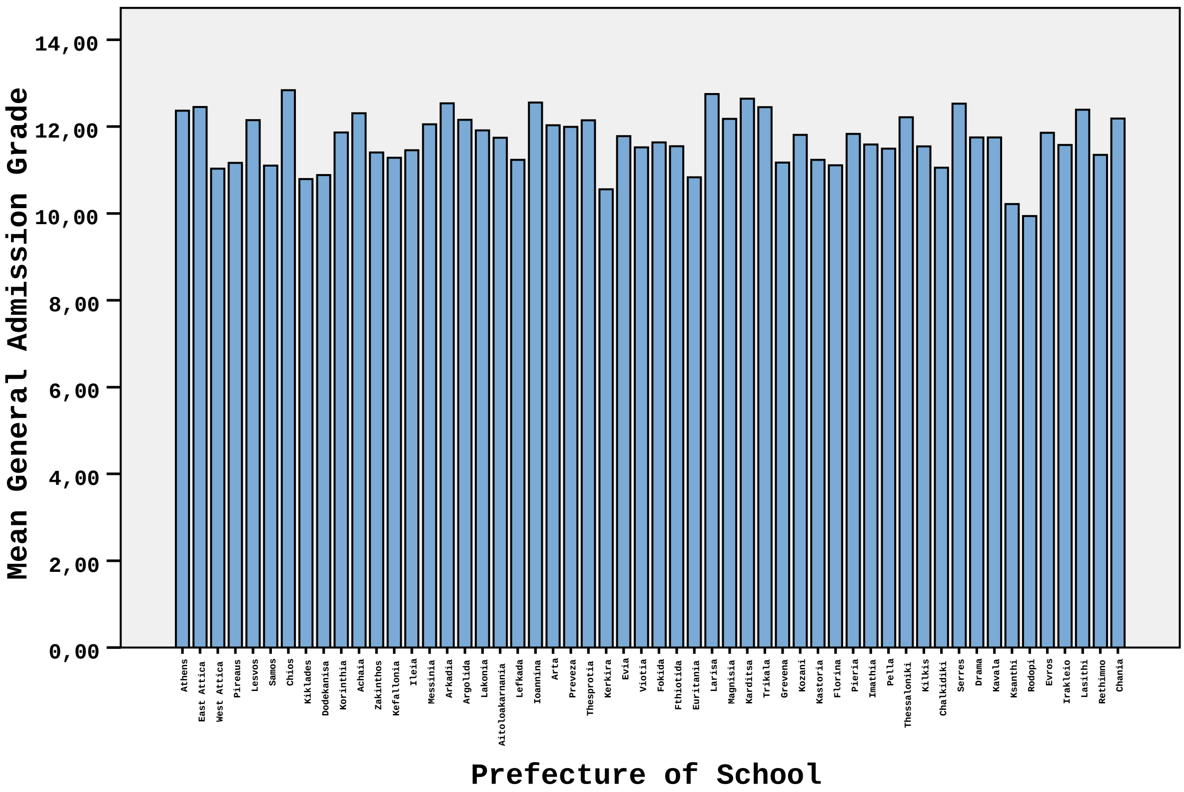
The following table (Table 5.6) and the corresponding figure (Figure 5.5) present the descriptive statistics for the General Admission Grade for all 54 prefectures in the analysis. As shown in the table, the prefecture with the best mean performance within the period of analysis is Chios (mean score for Admission Grade for the 1416 students of Chios is 12.84). The prefecture with the second highest mean score is Larisa with mean score 12.75 in a total of 8878 students. The highest score of Admission Grade for all these years (19.95) was accomplished by a student in Magnisia in the year 2009. On the contrast, the prefecture with the lowest mean score is Rodopi with mean score only 9.94 in a total of 2234 students.

Table 5.6: Descriptive Statistics for the General Admission Grade according to the Prefecture of School

Prefecture of School	Mean	Std. Dev.	Minimum	Maximum	N of cases
Athens	12.37	4.53	.03	19.90	77836
East Attica	12.45	4.62	.07	19.90	14120
West Attica	11.03	4.58	1.18	19.81	3710
Pireaus	11.17	4.54	.14	19.76	14999
Lesvos	12.15	4.63	1.37	19.85	2464
Samos	11.10	4.55	2.62	19.52	1027
Chios	12.84	4.44	.05	19.80	1416
Kiklades	10.79	4.55	.48	19.78	2651
Dodekanisa	10.89	4.82	.70	19.75	5233
Korinthia	11.87	4.78	.04	19.75	3940
Achaia	12.31	4.62	.03	19.83	9512
Zakinthos	11.40	4.93	1.82	19.65	1101
Kefallonia	11.28	4.79	.48	19.67	1124
Ileia	11.46	4.77	.53	19.78	3903
Messinia	12.05	4.74	1.07	19.81	4425
Arkadia	12.54	4.65	1.48	19.83	2582
Argolida	12.16	4.76	1.73	19.77	3044
Lakonia	11.91	4.85	1.45	19.90	2342
Aitoloakarnania	11.74	4.76	.63	19.75	6728
Lefkada	11.23	4.98	1.47	19.62	742
Ioannina	12.55	4.60	1.13	19.73	4644
Arta	12.03	4.70	1.33	19.77	1974
Preveza	12.00	4.64	1.76	19.88	1786
Thesprotia	12.15	4.58	.04	19.75	1186
Kerkira	10.56	4.63	.15	19.88	3098
Evia	11.78	4.69	.88	19.81	5909
Viotia	11.52	4.80	.03	19.85	3213
Fokida	11.64	4.79	1.18	19.91	940
Fthiotida	11.55	4.87	1.48	19.66	4687
Euritania	10.83	4.69	1.32	19.63	428
Larisa	12.75	4.60	.30	19.78	8878
Magnisia	12.18	4.78	.70	19.95	5978
Karditsa	12.64	4.66	.82	19.77	3421

Trikala	12.45	4.67	.68	19.92	4267
Grevena	11.17	4.78	1.01	19.63	782
Kozani	11.81	4.63	.83	19.77	5701
Kastoria	11.23	4.89	1.30	19.70	1876
Florina	11.11	4.87	1.12	19.60	1712
Pieria	11.83	4.89	.95	19.88	3814
Imathia	11.59	4.60	1.30	19.73	4212
Pella	11.49	4.64	.18	19.67	4152
Thessaloniki	12.21	4.53	.02	19.85	33122
Kilkis	11.54	4.60	.48	19.73	1887
Chalkidiki	11.06	4.62	.62	19.62	2257
Serres	12.53	4.52	.03	19.78	4592
Drama	11.75	4.67	.69	19.80	2862
Kavala	11.75	4.62	1.72	19.78	3870
Ksanthi	10.22	5.20	.40	19.73	2711
Rodopi	9.94	5.61	.28	19.93	2234
Evros	11.86	4.69	.97	19.76	3523
Irakleio	11.58	4.62	.50	19.87	8952
Lasithi	12.39	4.39	1.27	19.71	1910
Rethimno	11.35	4.59	1.37	19.65	2195
Chania	12.19	4.56	1.60	19.87	4389
Total	**11.99**	**4.66**	**.02**	**19.95**	**310061**

Figure 5.5: Figure for the Mean General Admission Grade according to the Prefecture of School



5.4 Multilevel Data Analysis

In the previous Chapter we have presented some descriptive results for our response variable which is the General Admission Grade according to the explanatory variables of interest (gender of student, scientific orientation of studies, year of examination and type of school). Although a brief idea of the differences in the performance of the students according to these factors was taken, we will now try to introduce statistical models in order to estimate and evaluate the effect of each factor on the score of the student. The hierarchical structure of our data is profound. Students are nested within schools and schools are nested within prefectures. Therefore, in our analysis we will try to perform Multilevel Statistical Models described in previous Chapters, in order to take advantage of this structure and present more accurate estimates. Of course, the statistical significance of the use of higher level models was tested.

The selection method of the models will be the forward method, meaning that we will start from the simple null model and we will add successively factors and test whether the more advanced model is a significant improvement of the previous one. To estimate the significance of the improvement we will carry out a likelihood-ratio test by comparing the deviances of the two models and test the difference in deviances referring to tables of the chi-square distribution. For the estimation of the parameters of the model we will use the REML (Restricted Maximum Likelihood) method. As a practical test for the significance of a parameter we will simply check if the parameter estimate is more than three times the estimate of its standard error.

Model 1

At the first stage of the analysis we simply fit the null 2-level model with the General Admission Grade as the response variable and no explanatory variables (except of course from the constant parameter). This first model (Model 1) is simply used as the basis of the analysis and the parameter values are displayed in table 5.7. The table only contains the constant estimate, the estimates for the level-1 variance (between students) and the level-2 variance (between schools), as well as the standard errors of the estimates. It also contains the deviance (-2*log(likelihood)) of the model in order to perform the appropriate likelihood-ratio tests.

Before any further discussion we should check whether this null 2-level (Model 1) is a significant improvement of the null 1-level model which can be produced if we omit the level-2 variance σ_{u0}^2 (between schools). The deviance of the model that does not contain the level-2 variance is 1834534 and is compared to the deviance of Model 1 which is 1802536. The difference is referred to tables of the chi-square distribution with one degree of freedom and is found to be highly statistically significant. Therefore, this is the first evidence that the use of a 2-level model containing also a between-schools variance estimate is a significant improvement of the simple 1-level model which only analyzes the between-students differences. In other words, we have proven that by taking into account the hierarchical structure of the data (students nested in schools) we can conclude to more accurate results.

The null 2-level model can also be used in order to estimate the so-called 'intra-class correlation' which is given by the formula $\rho = \frac{\sigma_{u0}^2}{(\sigma_{u0}^2 + \sigma_{e0}^2)}$ and estimates the proportion of the total variance which is between-schools. In our case the intra-class correlation is $\rho = \frac{3.419}{(3.419 + 19.311)} = 0.15$ meaning that almost 15% of the total variance is attributable to school traits. This proportion is relatively high, giving another evidence that the effect of 2-level units (schools) on the total performance of students should be examined.

Table 5.7: Parameter estimates for Model 1

Parameter	Estimate	Std. Error
Fixed:		
Constant	11.335	0.051
Random:		
σ_{u0}^2 (between schools)	3.419	0.142
σ_{e0}^2 (between students)	19.311	0.049
-2*log(likelihood)	1802536	

Model 2

The first explanatory variable we add in the model is a 1st level variable, the gender of the student. This is a dummy variable coded 1 for male students and 0 for female, so female will be the base category. The estimates of the parameters for this new model (Model 2) are given in the following table (Table 5.8). The difference of the deviances of this model (Model 2) and the null model (Model 1) is 1802536-1797168 and is apparently significant referring to the tables of the chi-square distribution with one degree of freedom. So Model 2 is a significant improvement from the previous one. The parameter estimate for the male category is also significant since the estimate of the standard error of the parameter is less than a third of the parameter estimate. Also the value of the estimate is negative (-1.165) implying that the score of the male students in the General Admission Grade is significally lower than the score of the female students, so, as it was expected, the gender difference is in favor of girls. As far as the random parameters are concerned, we observe that both the level-1 (between students) and the level-2 (between schools) variances are slightly decreased with the inclusion of the gender in the model.

Table 5.8: Parameter estimates for Model 2

Parameter	Estimate	Std. Error
Fixed:		
Constant	11.869	0.051
Gender (Male)	-1.165	0.016
Random:		
σ^2_{u0} (between schools)	3.363	0.139
σ^2_{e0} (between students)	18.979	0.049
-2*log(likelihood)	1797168	

Model 3

The new explanatory variable we introduce in the model is another 1st level variable, namely the scientific orientation of the studies of the student. This factor has three categories and the Technical Sciences orientation is the base category. Therefore, two parameters are estimated in the new model (Model 3), one for the Human Sciences and one for the Exact Sciences orientation, and the new estimates are presented in table 5.9. By comparing the deviances of the new model (1779371) and the previous one (1797168) we conclude that the difference of the deviances is highly significant referring to the tables of the chi-square distribution with two degrees of freedom, so we keep Model 3 as a better approach. Also all the parameter estimates of the model are statistically significant since the estimates are more than three times of the estimates of the standard errors. As we observe from the parameters, students examined for Human Sciences scientific orientation have slightly better performance than students examined for Technical Sciences orientation. However, students of Exact Sciences orientation seem to have much higher score in the General Admission Grade compared to students of Technical Sciences orientation, since the parameter estimate for this category is relatively high (3.254). Also, by adding the new variable, the values of the parameter estimates for the constant and male category have slightly decreased, as well as the level-1 (between students) and the level-2 (between schools) variances.

Table 5.9: Parameter estimates for Model 3

Parameter	Estimate	Std. Error
Fixed:		
Constant	11.392	0.050
Gender (Male)	-1.019	0.017
Scientific Orientation (Human Sciences)	0.159	0.018
Scientific Orientation (Exact Sciences)	3.254	0.025
Random:		
σ_{u0}^2 (between schools)	3.023	0.126
σ_{e0}^2 (between students)	17.923	0.046
-2*log(likelihood)	1779371	

Model 4

In the new model (Model 4) we describe in the following table (Table 5.10) we have not added a new explanatory variable. Instead, we add the interaction between the gender of the student and the scientific orientation of their studies, in order to detect possible differences in the performance of males and females according to their scientific orientation. Since the first variable (gender) has two categories and the other (scientific orientation of studies) has three, only two parameters need to be estimated, one for male with Human Sciences orientation and one for male with Exact Sciences orientation. The deviance of the new model is 1778050 and by comparing it to the deviance of the previous model (1779371) the difference is significant referring to the tables of the chi-square distribution with two degrees of freedom. So we can consider Model 4 as a significant improvement for our analysis. Also all parameter estimates of the model are significant since the estimates of the parameters are more than three times of the estimates of their standard errors.

By examining the two new parameters for the interaction term we can detect an important result which alterates our previous conclusions. The parameter estimate for male students of Human Sciences orientation is negative (-0.864). Therefore, although for the total of students examined for Human Sciences orientation the performance is better than those examined for Technical Sciences orientation, for boys the score in the General Admission Grade seem to be worse if they have chosen Human Sciences scientific orientation instead of Technical Sciences. In other words male students seem to have better performance for the Technical Sciences orientation than for Human Sciences, while all students, independently of gender, perform better in the Exact Sciences scientific orientation than in the other two. As far as the random parts of the model are concerned, we observe a further slight decrease of both the variance estimates with the inclusion of the interaction term in the model

Table 5.10: Parameter estimates for Model 4

Parameter	Estimate	Std. Error
Fixed:		
Constant	11.310	0.050
Gender (Male)	-0.868	0.023
Scientific Orientation (Human Sciences)	0.424	0.023
Scientific Orientation (Exact Sciences)	2.896	0.033
Gender*Scientific Orientation (Male/Human Sciences)	-0.864	0.037
Gender*Scientific Orientation (Male/Exact Sciences)	0.993	0.050
Random:		
σ_{u0}^2 (between schools)	2.934	0.122
σ_{e0}^2 (between students)	17.849	0.045
-2*log(likelihood)	1778050	

Model 5

The explanatory variable we add in the new model (Model 5) is the year of examination of the student. We have already noted that, in order to avoid duplications and repeated measures for the students, each student is unique and measured only in the first year of their examination. The new variable is another 1st level variable with four categories and the base category is the year 2009. The estimations for the three new parameters, as well as all the other new estimations for the parameters introduced in previous steps are presented in table 5.11. The deviance of the new model is 1775015 and if we compare it to the deviance of the previous model (1778050) we conclude that the difference is highly significant referring to the tables of the chi-square distribution with three degrees of freedom. Therefore, Model 5 is a significant improvement compared to the previous model. Also, once again, all the parameter estimates of the model are highly statistically significant since the estimates are more than three times of the estimates of their standard errors. We can observe from the table that all the new parameter estimates for the three years are negative (-1.078, -0.247 and -0.328 for years 2006, 2007 and 2008 respectively) and therefore the performance of the students according to their score in the General Admission Grade is higher in 2009 than in all other years of examination. The worst year of all seems to be 2006, since the parameter estimate is relatively high (-1.078). This result seems rational considering the fact that 2006 was the first year of application of the particular educational system, so students were probably not yet adapted to this new system. The parameter estimates for all other fixed parts of the model have not altered dramatically, and so have not alterated the conclusions made in previous steps. For the random parts of the model we should mention another slight decrease in the level-1 (between students) and the level-2 (between schools) estimates of variances after adding the new explanatory variable in Model 5.

Table 5.11: Parameter estimates for Model 5

Parameter	Estimate	Std. Error
Fixed:		
Constant	11.792	0.052
Gender (Male)	-0.877	0.023
Scientific Orientation (Human Sciences)	0.379	0.023

Scientific Orientation (Exact Sciences)	2.869	0.033
Gender*Scientific Orientation (Male/Human Sciences)	-0.864	0.036
Gender*Scientific Orientation (Male/Exact Sciences)	1.001	0.050
Year of Examination (2006)	-1.078	0.021
Year of Examination (2007)	-0.247	0.022
Year of Examination (2008)	-0.328	0.022
Random:		
σ_{u0}^2 (between schools)	2.895	0.121
σ_{e0}^2 (between students)	17.674	0.045
-2*log(likelihood)	1775015	

Model 6

So far, in all the previous steps we have introduced 1st level explanatory variables referring only to the student units (gender of student, scientific orientation of studies and year of examination), as well as the interaction term between some of them (gender*scientific orientation). However, we have seen by the null model and the calculation of the intra-class correlation that almost 15% of the total variation is attributable to school units. So, in the new model (Model 6) we will add a level-2 explanatory variable, the type of the school. This is a dummy variable coded 1 for public and 0 for private schools, so private schools will be the base category. The estimates of the parameters for this new model (Model 6) are given in table 5.12. The difference of the deviances of the new model (Model 6) and the previous one is 1775015-1774905 and is highly significant referring to the tables of the chi-square distribution with one degree of freedom. So, we can keep Model 6 and the inclusion of the new level-2 variable as a significant improvement from the previous model. Also, all the parameter estimates for the fixed and the random parts of the model are significant since the estimates of the standard error of the parameters are less than a third of the parameter estimates. We can observe that the value of the estimate of the new variable for the category "public" is negative (-1.844). From this we can conclude that the score of the students of public schools in their General Admission Grade is significally lower than the score of the students from private schools, so, as it was expected, the type of school difference is in favor of private schools. All the other parameter estimates for the fixed part of the model have no important alterations and therefore, all conclusions made in previous steps hold. As for the random parameters of the model, we observe that, as was expected, the estimate of the level-2 (between schools) variance has decreased after adding a new 2^{nd} level explanatory variable in the model, while the estimate for the level-1 variance has remained almost the same.

Table 5.12: Parameter estimates for Model 6

Parameter	Estimate	Std. Error
Fixed:		
Constant	13.500	0.165
Gender (Male)	-0.878	0.023
Scientific Orientation (Human Sciences)	0.380	0.023
Scientific Orientation (Exact Sciences)	2.868	0.033
Gender*Scientific Orientation (Male/Human Sciences)	-0.865	0.036
Gender*Scientific Orientation (Male/Exact Sciences)	1.000	0.050
Year of Examination (2006)	-1.078	0.021
Year of Examination (2007)	-0.247	0.022
Year of Examination (2008)	-0.328	0.022
Type of School (Public)	-1.844	0.170
Random:		
σ_{u0}^2 (between schools)	2.634	0.111
σ_{e0}^2 (between students)	17.675	0.045
-2*log(likelihood)	1774905	

Model 7

One of the main advantages of a multilevel model is that it gives the opportunity to combine explanatory variables taken from different levels in order to examine more precisely the response variable, simply by specifying a cross-level interaction, that is the interaction between two variables from different levels. In the new model (Model 7) we introduce the interaction term between the type of school and the gender of the students, in order to detect possible differences in the performance of males and females according to the type of school they study. Since both variables have two categories, only one new parameter needs to be estimated and that is for male students in public schools. The new estimate, as well as all the alterations in the previous estimates, are presented in the following table (Table 5.13). The deviance of the new model is 1774898 and by comparing it to the deviance of the previous model (1774905) the difference is significant referring to the tables of the chi-square distribution with one degree of freedom, so we can keep Model 7 as an improvement from the previous model. Also, once again all parameter estimates of the model are significant since the estimates of the parameters are more than three times of the estimates of their standard errors and, moreover, the values of the estimates for both the fixed and the random part have not altered by the previous model. Only the estimates for the gender and the type of school factors have slightly altered which is logical since the new parameter estimate is the interaction term of these two variables. However these new parameter estimates as well as the estimate for the new interaction term have not changed our previous conclusions. In other words, as was mentioned before, the performance referring to the score in the General Admission Grade for male students and for public schools are relatively worse than female students and private schools.

Table 5.13: Parameter estimates for Model 7

Parameter	Estimate	Std. Error
Fixed:		
Constant	13.406	0.168
Gender (Male)	-0.689	0.062
Scientific Orientation (Human Sciences)	0.378	0.023
Scientific Orientation (Exact Sciences)	2.871	0.033

Gender*Scientific Orientation (Male/Human Sciences)	-0.863	0.036
Gender*Scientific Orientation (Male/Exact Sciences)	0.991	0.050
Year of Examination (2006)	-1.078	0.021
Year of Examination (2007)	-0.247	0.022
Year of Examination (2008)	-0.328	0.022
Type of School (Public)	-1.743	0.173
Type of School*Gender (Public/Male)	-0.202	0.062
Random:		
σ^2_{u0} (between schools)	2.636	0.111
σ^2_{e0} (between students)	17.674	0.045
-2*log(likelihood)	1774898	

Model 8

The new term we introduce to the new model (Model 8) is another cross-level interaction term, the interaction between the type of school and the scientific orientation of the studies. By adding this term we try to detect if the performance of students of different scientific orientations is related to the type of school the study. Since the first variable (type of school) has two categories and the second (scientific orientation) has three, only two new parameters will be estimated, one for students from public schools with Human Sciences orientation and one for students from public schools with Exact Sciences orientation. The new estimates, as well as the estimates of all the other parameters discussed previously are presented in table 5.14. The difference of the deviances of the new model (Model 8) and the previous one is 1774898-1774550 and is highly significant referring to the tables of the chi-square distribution with two degrees of freedom. So the new model (Model 8) is a significant improvement compared to the previous model. However, it is important to observe that the parameter estimates for the interaction terms “public school*male student” and “public school* Human Sciences orientation” are not significant since the estimates of the standard error of the parameters are more than a third of the parameter estimates for the particular terms. In other word, contrary to what we concluded in the previous step, we can now say that there is no significant interaction between the type of school and the gender of student or, in other word, both male and female students perform in the same "pattern" in public and private schools. Thinking in the same way, we can say that students of Human Sciences orientation and students of Technical Sciences orientation also perform in the same "pattern" in public and private schools. On the other hand, we should seriously pay attention to the high decrease of the parameter estimate for Exact Sciences scientific orientation compared to the previous model (1.533 vs. 2.871) and at the same time to the relatively high estimate for the new interaction term "public school* Exact Sciences orientation". If we combine these two observations, we can conclude that the performance of students examined for Exact Sciences orientation is generally higher than the other two orientations (a conclusion that we have already mentioned in previous steps), but especially in public schools, the performance of students of Exact Sciences orientation is relatively even higher. For all the other parameters for both mixed and random parts of the new model, the effect of the inclusion of the new interaction term is not so important.

Table 5.14: Parameter estimates for Model 8

Parameter	Estimate	Std. Error
Fixed:		
Constant	13.653	0.173
Gender (Male)	-0.715	0.065
Scientific Orientation (Human Sciences)	0.390	0.074
Scientific Orientation (Exact Sciences)	1.533	0.083
Gender*Scientific Orientation (Male/Human Sciences)	-0.864	0.036
Gender*Scientific Orientation (Male/Exact Sciences)	1.028	0.050
Year of Examination (2006)	-1.077	0.021
Year of Examination (2007)	-0.245	0.022
Year of Examination (2008)	-0.328	0.022
Type of School (Public)	-2.009	0.179
Type of School*Gender (Public/Male)	-0.174	0.066
Type of School*Scientific	-0.007	0.075

Orientation (Public/Human Sciences)		
Type of School*Scientific Orientation (Public/Exact Sciences)	1.471	0.084
Random:		
σ_{u0}^2 (between schools)	2.661	0.112
σ_{e0}^2 (between students)	17.653	0.045
-2*log(likelihood)	1774550	

Model 9

In the new model (Model 9), which is also the final model of the multilevel analysis, we do not introduce another explanatory variable. Instead, we add a parameter in the random part of the model which is the variance term between prefectures (σ_{v0}^2). In other words our model now becomes a 3-level model with students (1st level) nested within schools (2nd level) nested within prefectures (3rd level). The new estimate of the level-3 variance term, as well as the estimates of all the other parameters, are presented in table 5.15. First, we need to perform a likelihood-ratio test in order to check whether the inclusion of a third level random term is a significant improvement to the previous 2-level model. The deviance of the new model is 1774456 and by comparing it to the deviance of the previous model (1774550) the difference is highly significant referring to the tables of the chi-square distribution with one degree of freedom. So, Model 9 is a significant improvement of the previous model. Therefore, we can conclude that the use of a 3-level model containing also a between-prefecture variance estimate is a significant improvement of the 2-level model which only contains a between-schools and between-students random part. In other words, we have proven that taking into account the full hierarchical structure of the data (students nested in schools nested in prefectures) we can conclude to more accurate results. However, by comparing the parameter estimates of the fixed part of the new model to the respective parameters of the previous model we observe minor differences, with only exception the decrease of the estimate of the type of school (-1.747 vs. -2.009 in the previous model). As it is obvious, the part of the model which has been affected more by the inclusion of the third level variance is the random part. More specifically the parameter estimate for the level-2 variance (between schools) has decreased from 2.661 to 2.364, while the estimate for the level-1 variance (between students) has remained unaffected.

Table 5.15: Parameter estimates for Model 9

Parameter	Estimate	Std. Error
Fixed:		
Constant	13.177	0.193
Gender (Male)	-0.717	0.065
Scientific Orientation (Human Sciences)	0.388	0.074
Scientific Orientation (Exact Sciences)	1.536	0.083
Gender*Scientific Orientation (Male/Human Sciences)	-0.865	0.036
Gender*Scientific Orientation (Male/Exact Sciences)	1.029	0.050
Year of Examination (2006)	-1.078	0.021
Year of Examination (2007)	-0.244	0.022
Year of Examination (2008)	-0.328	0.022
Type of School (Public)	-1.747	0.174
Type of School*Gender (Public/Male)	-0.172	0.066
Type of School*Scientific Orientation (Public/Human Sciences)	-0.005	0.075
Type of School*Scientific Orientation (Public/Exact Sciences)	1.469	0.083
Random:		
σ_{v0}^2 (between prefectures)	0.308	0.091
σ_{u0}^2 (between schools)	2.364	0.102
σ_{e0}^2 (between students)	17.653	0.045

-2*log(likelihood)	1774456

5.5 Conclusions of the Chapter

Apart from the usefulness of the results themselves, since we refer to real data from the Greek educational system, the main conclusion that can be drawn of the analysis in this Chapter, is that the use of Multilevel Analysis Techniques, and more specifically of a 3-level model, has significant advantages compared to simplest models, both concerning the precision of the estimates, as well as the interpretation of the hierarchical structure of the data.