CHAPTER 6

6 CONCLUSIONS – FURTHER RESEARCH

The purpose of the current thesis is to describe the most appropriate statistical models and methods in order to analyze hierarchical data structures. In the first part of the thesis (the "theoretical") we described all the possible known approaches for analyzing this type of data structures and we elaborated more on the "Multilevel Analysis" and the corresponding "Multilevel Models". We did so because this kind of approach was proved to be the most appropriate in order to analyze hierarchical structured datasets. According to the related literature, the main advantage of multilevel models is that they "respect" the hierarchical structure of the data. In other words, they allow variables from all levels of interest to be introduced in the model, they can also examine cross-level interactions between variables in different levels and, furthermore, they can examine in detail the random part of a model by examining the variation of data separately in all levels of interest. By doing so, multilevel models offer a more precise approach for the response variable of interest compared to the classical models. In the first Chapters we described in detail all the theoretical basis of these models, the formulas and notations, the estimation methods and testing methods for all the parameters of the model, both fixed and random, the algorithms and also the extensions of the simple multilevel model in more sophisticated cases. We presented cases where simple multilevel models can readily extent to more complex data structures (multivariate models, models with discrete response variable etc.). Moreover, in this part of the thesis we have chosen and described in detail a number of practical examples and applications of multilevel models in all areas of applications of multilevel modelling. These areas are educational statistics, spatial statistics, health statistics, repeated measures and survey research. By reviewing the methods and the results of these applications described by the authors, we have shown that multilevel techniques can be applicable and also very useful in many areas where hierarchical data structure exists. Also, the chosen examples were proved to be very representative and can form the basis for other applications in the same area of interest.

In the second part of the thesis (the "practical") we applied the multilevel techniques and models into real data made available from the Greek Ministry of

Education, Lifelong Learning and Religious Affairs referring to the students' score of the General Admission Grade in the National Exams in the years 2006-2009. Our results from the analysis confirmed that the use of multilevel techniques may provide more precise results and estimates for the students' performance referring to their General Admission Grade. More specifically the conclusions obtained from our analysis can be briefly summarized to the following:

- As concerns the prefectures, and utilizing the results of the descriptive statistics, Chios seems to be the prefecture with the best average performance through the years of interest (2006-2009). This result is consistent with the descriptive results given by Kosmopoulou (1998) for the years 1990 and 1991 indicating an ongoing stability of the students' performance of this particular prefecture during the years. The result is also consistent with the results of the project of the Centre of Development of Educational Policy of the General Confederation of Greek Workers (GSEE) (2009) (www.kanep-gsee.gr/index.php?download=keimeno%206-4-09.doc) concerning the indices of access in higher education. However, this conclusion should be drawn with caution since we refer only to descriptive and not confirmatory statistics.
- The use of level-2 and level-3 analysis which contains the effect of between-schools and between-prefectures variability is a significant improvement compared to models which contain only the between-students effect.
- According to the multilevel analysis, female students seem to perform significantly better than male students concerning their score in the General Admission Grade. This result seems rational, taking into account the general belief that girls perform better than boys in their school examinations.
- As concerns the scientific orientation of the studies, students examined for the Exact Sciences orientation seem to have highly better performance than students examined for the other two orientations (Human Sciences and Technical Sciences). This is also an expected result since Exact Sciences orientation is chosen by less (more "conscious") students mainly focused on entering Institutions related to health studies which demand very high entrance exams scores. As for the other two scientific orientations, students of Human Sciences orientation have a slightly higher performance than those of Technical Sciences orientation. The above results are also confirmed by the official results on the scaling of the General Admission Grade of the candidate

students for the access to the National Universities and Technical Institutions by scientific orientation, published every year by the Greek Ministry of Education, Lifelong Learning and Religious Affairs (www.ypepth.gr).

- Although for the whole of students of Human Sciences orientation the General Admission Grade is better than those of Technical Sciences orientation, for boys the performance in the Technical Sciences orientation seems to be better than in Human Sciences orientation. This conclusion also seems to be in agreement with the "common sense" that boys perform better in technological areas and girls in classical. Analogous results were drawn by Marouga (2004), although the educational system of access and the descriptions of the scientific orientations presented in the two projects are different.
- The year of examination also seems to have a significant effect on the performance of the students and their scores in the General Admission Grade. We can conclude from the analysis that 2009 is the best year for students' performance, while 2006 is by far the worst. This result is probably due to the fact that 2006 was the first year of application of the new educational system of access, so students needed several years in order to adapt to this new system. The most profound reason, in general, for the differences in the performance of students over the years is the fact that the level of difficulty of the National Exams is impossible to be equally predetermined among the years. It has been discussed by many authors, politicians, professors and sociologists (see for example the report of the Centre of Research and Documentation of the Greek Federation of State School Teachers of Secondary Education (OLME) (2004) (http://www.smarinis.gr/aei1.pdf)) that this fact is maybe one of the main disadvantages of the Greek National Exams system, since it does not offer equal opportunities for students in their attempt to access the Greek National Universities and Technical Institutions. From the statistical point of view, this factor (year of examination) produces serious problems to the interpretation of the results, since it cannot easily be controlled and therefore does dot allow the detection of the effect of more important factors.
- As far as the type of school is concerned, we can conclude from the model that the performance of students from private schools according to their General Admission Grade is much higher than the students from public schools. This is

also an expected result, however we should take into account the very small number of students in private schools compared to those of public schools.

- By examining the cross-level interactions between type of school and gender and type of school and scientific orientation we conclude that the performance of students in the two types of schools does not depend on the gender of the student. In other words, boys and girls perform "in the same pattern" both in private and public schools. On the other hand, it can be deduced by the analysis that, especially in public schools, the performance of students for the Exact Sciences orientation is even higher than the "usual pattern". With regard to this particular outcome, Marouga (2004) has also come to analogous results.

Apart from the usefulness of the results of the analysis themselves, which is straightforward since we refer to real data from the Greek educational system, we should also argue on the reflections of the practical application of this kind of Multilevel Analysis to this real situation. It is verified throughout the analysis that, from a statistical and methodological point of view, the use of Multilevel Analysis Techniques has significant advantages compared to simplest (non-multilevel models) concerning the precision of the estimates, the explanation of the variability of the model (especially in the random part), as well as the improvement in the interpretation of the hierarchical structure of the data.

So far we have pointed out the obvious advantages of the use of multilevel modeling techniques in our analysis. The statistical advantages (more precise estimates, elaboration on the random part of the model), the consistency of our results with the results of other reports and projects (not necessarily statistical), as well as the "harmony" of the results with our "common sense" and knowledge for the National Examination Results. On the other hand, we should point out some technical disadvantages. Firstly, it has been argued by many authors (see for example Goldstein, 1993) that the lack of an explanatory (continuous) variable referring to the previous achievements of the students and the use of raw unadjusted results may lead to some invalid comparisons and some misleading outcomes. For example, the results of our analysis strongly agree with the results of the previous analysis conducted by Kosmopoulou (1998) when raw data are used in both analyses, but somehow differ when an "adjuster" was used. Further research on the same subject should be focused

on the addition of more explanatory variables in all levels of interest, especially an explanatory variable as an adjustment of the outcome and, also, more higher-level variables. Furthermore, the use of SPSS program to analyze the data offers applicability, easy handling of data transformation situations, multiple choices of syntax procedures and of course high quality of the produced results, however it is rather time-demanding compared to other more specialized statistical programs (MLwiN, HLM or even SAS).

From all the above we can conclude that the use of multilevel analysis techniques is a significant improvement for the examination of hierarchical structured datasets in many areas of interest -including education- however results of this type of analysis should be treated with caution. The application presented in the thesis, despite the constraints, is the first multilevel analysis approach concerning this particular educational system of access in the National Universities and Technical Institutions and the second (after Kosmopoulou, 1998) considering the use of multilevel techniques in Greek educational datasets in general. Since it is profound that the use of such models is a significant improvement for the analysis of hierarchical data structures, further research needs to be done, especially in the education area. More specifically:

- We have already pointed out the necessity of using more explanatory variables in all the levels of interest. Especially, in the 1st level (students) a continuous explanatory variable, such as the average grade of the students in previous high-school exams, could be used as an initial adjustment of the outcome. Moreover, more higher-level variables, such as the size of the school (2nd level variable) or the demographical structure of the prefecture (3rd level variable), would be useful in order to obtain more precise estimates for both the fixed and the random part of the model. However, such information is not easily available in real datasets and, if available, requires the combination of datasets from many sources.
- Multilevel Models outcomes have been used by many authors in order to rank Institutions (schools and/or Universities) according to their students' performance. A further application of such techniques regarding the ranking of the Greek Institutions would be interesting. However, as discussed by many authors (see Goldstein, 1993) the results of ranking are very sensitive to data alterations and constraints and, therefore, should be used with great caution.

- The rapid development of IT-Systems allows the use of more sophisticated and memory-demanding algorithms for the estimation of the fixed and random parameters of the model. Comparisons between the results of various estimation techniques, especially in small datasets, may reveal significant improvements regarding the robustness of the estimates.
- Extensions of the Linear Multilevel Model have already been discussed, from a theoretical perspective, within the thesis. Applications of such techniques in Greek datasets would have great practical importance. For instance, in practice, the performance of the students in the National Exams is usually measured by a dichotomous variable ("pass"/"fail") or a polynomial variable. Analysis of a dichotomous or polynomial response variable using multilevel approaches requires the introduction of a "Generalized Linear Multilevel Model'. However, the application of such models in practice has difficulties, due to the fact that it requires advanced algorithms and memory-demanding computational techniques, not available by the classical computer software.
- Finally, it is well-known that the Greek educational system of access in the National Universities and Technical Institutions has been altered various times through the last years. The lack of a stable system, does not allow an ongoing comparison of the performance of students in the National Exams for their access in the third-degree education. Therefore, it would be of great practical importance to be able to perform techniques of multilevel analysis (Meta-Analysis techniques for instance) in order to adjust the outcomes of various educational systems of access and make the appropriate comparisons.