Assessment of School Effectiveness in Greece using Multilevel Models

Kosmopoulou, Anna and Panaretos, John

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Anna Kosmopoulou and John Panaretos
Department of Statistics
Athens University of Economics and Business
76, Patision St., 104 34 Athens, Greece
E-mail for correspondence: jpan@aueb.gr

Abstract

In recent years, a lot of attention has been given to the so-called 'performance indicators', which are primarily used for institutional comparisons. Education and health are the areas in which these indicators are widely applied, serving the needs of modern societies for highly qualified rendering of services.

In the present paper we focus attention in the area of education. Our main target is to assess the effectiveness of Greek schools and explore those factors that affect students' performance in the Greek National Entrance Exams for Universities. Multilevel models are employed for this kind of analysis and more specifically, a three level model assigning students at level-1, schools at level-2 and prefectures at level-3.

Keywords and phrases: MULTILEVEL MODELING; HIERARCHICAL DATA; PERFORMANCE INDICATORS; SCHOOL EFFECTIVENESS;

1. INTRODUCTION

The need of quantitative comparisons between institutions gave rise to the development of performance indicators. As Goldstein and Spiegelhalter (1996) argued, '... a performance indicator is a summary statistical measurement on an institution, or system, which is intended to be related to the 'quality' of its functioning'. Education, health and social services are the areas where these indicators are widely used in the last decade. We are primarily interested in the performance indicators in the area of education.

In this paper we concentrate on outcome indicators in the area of education. More specifically, the aim is to assess the effectiveness of Greek Lyceums, to detect potential differences in the performance of Lyceums according to the type of Lyceums (public, private), the gender of the students and the scientific orientation that students have chosen. The data examined refer to examination results for two adjacent years, 1990 and 1991. Thus, we want to explore those factors that affect students' achievement in the National Entrance Exams for the Greek Universities and the Technical Institutions.

A basic characteristic of the data, that will be analyzed, is their hierarchical structure. A hierarchy consists of units grouped at different levels (Goldstein, (1995)). In the area of education the most trivial example of hierarchical data consist of the grouping of students in classrooms and of classrooms in schools. In the data we analyze in this paper the following structure holds: there are prefectures, schools nested in prefectures and students nested in schools. Consequently, there is the need for taking into account the fact that the units of one level are subject to the influences of their grouping in the units of higher levels. For this reason, when one wants to analyze a set of data with hierarchical structure one cannot just ignore this hierarchy and use traditional statistical analysis techniques. The analysis that is required, in such cases, is the multilevel modeling. Furthermore, another subject that needs to be treated cautiously is the need of making adjustments for the existing achievements of the students. In the opposite case, the results produced by an unadjusted analysis would be insufficient and misleading for the inferences about school differences.

2. DATA DESCRIPTION

The data consist of prefectures, schools nested in prefectures and students nested in schools. The hierarchical structure of the data is apparent as well as the necessity for taking into account the fact that the students are subject to the influences of their grouping in schools. This is the reason why multilevel modeling is required for the analysis of this kind of data. On the other hand, there is the need of making adjustments for the existing achievements of the students. Otherwise, the results produced by an unadjusted analysis would be insufficient and misleading as for the inferences about school differences (Goldstein and Thomas (1996)).

We are going to use the results of the examinations taken for the entrance exams as response variable. Also, the results of the examinations taken at the end of the 3^{rd} grade (last year) of Lyceum are going to be used as indicators of the existing achievements of the students. Except from this explanatory variable it is also possible to examine differences between boys and girls, between public and private schools and differences in the performance of students belonging to different scientific orientations. It would also be interesting to include the socioeconomic status of the students as explanatory variable and furthermore to observe the progress of the students in Universities and Technological Educational Institutions according to their achievements in the Lyceum.

The variables that are going to be used in the analysis concisely are the following: the mean score of students in the National Entrance Exams, the 3^{rd}-Lyceum grade score, the type of school (public or private), the gender of students, the scientific orientation (desmi) they have chosen and the year in which the students took the National Entrance Exam. Let us now give a complete account of each variable.

Response Variable

The response variable is the mean score of students in the National Entrance Exams. Students take four subjects in these Exams and these subjects are different in each scientific orientation. More specifically, the subjects in each scientific orientation are the following:

1st orientation	**2nd orientation**	**3rd orientation**	**4th orientation**
Mathematics	Biology	Ancient Greek	Mathematics
Physics	Physics	Latin	Sociology
Chemistry	Chemistry	History	History
Composition	Composition	Composition	Composition

Thus, for each student the mean score of the subjects has been calculated and used as the response variable. Also, these scores have been transformed to normality using normal scores, where this is a method of rescoring by assigning expected values from the standard Normal distribution according to the ranks of the original scores.

Explanatory variables

1. The only continuous explanatory variable that is going to be used in the analysis is the 3rd-grade Lyceum score. This is the mean score of students in the 3rd grade (last year) of Lyceum. The scores have been standardized in order to follow the standard Normal distribution.

2. The type of school is going to be used also as explanatory variable. There are two kinds of schools that are to be compared in the analysis. The public Lyceums and the private ones. The variable indicating the kind of school is a dummy variable coded 1 for public Lyceums and 0 for private Lyceums.

3. It is also interesting to compare the performance of students according to their gender. Thus, a dummy variable has been included in the analysis, coded 1 for girls and 0 for boys.

4. Furthermore, three dummy variables indicating the scientific orientation that students have chosen have been included. The first one is coded 1 for the 1st orientation and 0 for the others. The second, is coded 1 for the 2nd orientation and 0 for the others. The third, is coded 1 for the 3rd orientation and 0 for the others, while the 4th orientation is the base category. Thus, a comparison between the four orientations can be made.

5. Finally, a dummy variable indicating the year in which students took the Exams is included. This variable is coded 1 for those who took the Exams in 1990 and 0 for those who took the Exams in 1991. It is important to mention at this point that in the analysis only students who took for the first time the National Entrance Exams are included.

4. DESCRIPTIVE STATISTICS

Let us now give some descriptive statistics for our data, separately for each year of Exams. First, the data of the National Entrance Exam taken in 1990 will be analyzed. The number of the level-3 units, that is the prefectures, is 51, the number of level-2 units, that is the schools, is 961 and the number of the level-1 units, that is the students participated in the exam, is 52,041. The total mean score of the students in National Entrance Exams is given in table 4.3.1. The grading Scale in the Greek Educational system is from 0 to 20. (18.1-20 excellent, 16.1-18 very good, 13.1-16 good, 10-13 almost good, 5.1-9.9 insufficient, 0-5 bad).

Table 4.3.1 Descriptive statistics for the 1990 Greek National Entrance Exams score

Variable	Mean	Std Dev	Minimum	Maximum	N of cases
National Entrance Exams Score	10.17	4.81	0	19.72	52,041

Among the prefectures, the one with the highest mean score is Chios (prefecture 4) with mean National Entrance Exams score 11.58 and with 247 participating students. The prefecture with the second highest mean score is Corinthia (prefecture 7) with mean score 11.33 and 732 students. The prefecture with the lowest mean score is Evros (prefecture 47) with mean score 8.62 and 451 students. However, it is also interesting to set out the performance of students in these Exams according to: (a) the type of school, (b) the scientific orientation and (c) the gender of students. These data are reported in tables 4.3.2, 4.3.3 and 4.3.4 respectively.

Table 4.3.2 Descriptive statistics for the 1990 Greek National Entrance Exams score according to the type of school

Variable	Type	Mean	Std Dev	Minimum	Maximum	N of cases
National Entrance	Public	10.16	4.80	0	19.72	51,358
Exams Score	Private	11.07	5.00	0.13	19.47	683

As we can observe from the above table, private schools have a higher mean score than the public ones, but the highest mean score for that year was attained by a student in a public school. Besides, we have to take into consideration the small number of students attending private schools.

Table 4.3.3 Descriptive statistics for the 1990 Greek National Entrance Exams score according to the scientific orientation

Variable	Orientation	Mean	Std Dev	Minimum	Maximum	No of cases
National	1st orient.	9.81	4.62	0.06	19.63	11,561
Entrance	2nd orient.	12.05	4.74	0.03	19.66	4,552
Exams	3rd orient.	12.65	4.46	0	19.72	12,640
Score	4th orient.	8.63	4.40	0.03	19.66	23,288

Table 4.3.4 Descriptive statistics for the 1990 Greek National Entrance Exams score according to the gender of the students

Variable	Orientation	Mean	Std Dev	Minimum	Maximum	No of cases
National Entrance	Boys	9.66	4.87	0	19.63	21,887
Exams Score	Girls	10.54	4.73	0	19.72	30,154

The data of the Exams taken in 1991 are also analyzed. The number of the level-3 units, that is the prefectures, is 51, the number of level-2 units, that is the schools, is 978 and the number of the level-1 units, that is the students, is 54,200. The total mean score of the students in the 1991 National Entrance Exams is given in the table 4.3.5.

Table 4.3.5 Descriptive statistics for the 1991 Greek National Entrance Exams score

Variable	Mean	Std Dev	Minimum	Maximum	No of cases
National Entrance Exams Score	9.58	4.92	0	19.59	54,200

It is important to point out the lowering of the mean score for the Exams taken in 1991 as compared to that of 1990. Among the prefectures, the one with the highest mean score is again Chios (prefecture 4) with mean National Entrance Exams score 11.01 and with 289 students. The prefecture with the second highest mean score is Trikala (prefecture 31) with mean score 10.39 and 814 students. The prefecture with the lowest mean score is Evritania (prefecture 27) with mean score 7.44 and 77 students. Besides, the performance of students in these Exams according to: (a) the type of school, (b) the scientific orientation and (c) the gender of students is set out, too. These data are reported in tables 4.3.6, 4.3.7 and 4.3.8 respectively.

Table 4.3.6 Descriptive statistics for the 1991 Greek National Entrance Exams score according to the type of school

Variable	Type	Mean	Std Dev	Minimum	Maximum	No of cases

National Entrance Exams Score	Public	9.58	4.92	0	19.59	53,386
	Private	9.87	5.35	0.06	19.44	814

As in the previous year, the private schools do better than the public ones, but now the difference is much smaller.

Table 4.3.7 Descriptive statistics for the 1991 Greek National Entrance Exams score according to the scientific orientation

Variable	Orientation	Mean	Std Dev	Minimum	Maximum	No of cases
National Entrance Exams Score	1st orient.	8.95	3.89	0.06	19.03	12,292
	2nd orient.	11.60	4.40	0	19.41	4,551
	3rd orient.	13.39	4.32	0.06	19.59	12,874
	4th orient.	7.52	4.45	0	19.53	24,483

The students of the 3rd scientific orientation do better than the students of the other orientations, while the differences in mean scores between the four orientations are large.

Table 4.3.8 Descriptive statistics for the 1991 Greek National Entrance Exams score according to the gender of the students

Variable	Orientation	Mean	Std Dev	Minimum	Maximum	No of cases
National Entrance Exams Score	Boys	8.84	4.74	0	19.56	22,700
	Girls	10.12	4.99	0	19.59	31,500

In the Exams taken in 1991 girls do better than boys, just as in the previous year, but this time with larger difference.

4. MODELS FOR ASSESSING SCHOOL EFFECTIVENESS

A simple model that is used for the assessment of school effectiveness is the following one:

$$Y_{ij} = \beta_0 + \beta_1 X_{ij} + u_{0j} + e_{0ij}$$

The above model is called *variance components model* and the only random parameters are the intercept variances at each level. In these models, the variance of the response about the fixed component is

$$\mathrm{var}(Y_{ij} | \beta_0, \beta_1, X_{ij}) = \mathrm{var}(u_0 + e_{0ij}) = \sigma^2_{u0} + \sigma^2_{e0}$$

where σ^2_{u0} and σ^2_{e0} are the level-2 and the level-1 variance respectively. Thus, in the variance components models, the variance of the response about the fixed component is the sum of level-1 and level-2 variance. A measure of the extend of clustering of students within schools is the intra-school correlation and is defined as

$$\rho = \frac{\sigma^2_{u0}}{\sigma^2_{u0} + \sigma^2_{e0}}.$$

In other words, this correlation measures the proportion of variance that is between schools (Goldstein, 1995). A variance component model is a 1-level model in its simpler form. In order to include further fixed explanatory variables in the previous model we extend it and we have

$$y_{ij} = X_{ij}\beta + \sum_{h=0}^{1} u_{hj} z_{hij} + e_{0ij} z_{0ij}$$

where **X** is the design matrix for the fixed explanatory variables, X_{ij} is the ij*th* row of X and z_{hij} are the explanatory variables for the random part of the model. In the above equation Z={Z_0 Z_1}, where Z_0 is a vector of ones and

$Z_1=\{x_{1ij}\}$. Any of the explanatory variables can be measured at any of the levels.

A preliminary series of analyses has been carried out, using the statistical package MLwiN (Goldstein et al (1998)), in order to determine a parsimonious relationship between the mean score of students in the National Entrance Exams and the mean score of students in the 3rd grade of Lyceum. The model to which we have ended up is the following one:

$$y_{ijk} \sim \mathrm{N}(XB,\ \Omega)$$

$$y_{ijk} = \beta_{0ijk}x_0 + \beta_{1jk}x_{1ijk} + \beta_2 x_{2jk} + \beta_{3i}x_{3ijk} + \beta_4 x_{4ijk} +$$

$$\beta_5 x_{5ijk} + \beta_6 x_{6ijk} + \beta_{7j}x_{7k}$$

$$\beta_{0ijk} = \beta_0 + v_{0k} + u_{0jk} + e_{0ijk}$$

$$\beta_{1jk} = \beta_1 + v_{1k} + u_{1jk}$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim \mathrm{N}(0,\ \Omega_v)\ :\ \Omega_v = \begin{bmatrix} \sigma^2_{v0} & \\ \sigma_{v10} & \sigma^2_{v1} \end{bmatrix}$$

$$\begin{bmatrix} u_{0jk} \\ u_{1jk} \\ u_{7jk} \end{bmatrix} \sim \mathrm{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} \sigma^2_{u0} & & \\ \sigma_{u10} & \sigma^2_{u1} & \\ \sigma_{u70} & \sigma_{u71} & 0 \end{bmatrix}$$

$$\begin{bmatrix} e_{0ijk} \\ e_{3ijk} \end{bmatrix} \sim \mathrm{N}(0,\ \Omega_e)\ :\ \Omega_e = \begin{bmatrix} \sigma^2_{e0} & \\ \sigma_{e30} & 0 \end{bmatrix}$$

$$-2^*log(like) = 174379.100$$

where y_{ijk} is the mean score of students in the National Entrance Exams, x_0 is the constant term, x_{1ijk} is the 3rd-grade score, x_{2jk} is the type of school, x_{3ijk} is the gender of the students, x_{4ijk}, x_{5ijk} and x_{6ijk} are the dummy variables indicating the first, the second and the third scientific orientation respectively.

Finally, x_{7k} is the year in which the students took the Exam. The parameter estimates for the model is given by the table below:

Parameter	**Estimate (s.e.)**
Fixed:	
Constant	-0.768
3^{rd}-grade score	0.784 (0.005)
Type of school	0.543 (0.053)
Gender of student	-0.214 (0.004)
Scientific Orientation 1	-0.036 (0.005)
Scientific Orientation 2	0.057 (0.006)
Scientific Orientation 3	0.446 (0.004)
Year of the Exams	0.124 (0.031)
Random:	
σ^2_{v0} (between prefectures)	0.017 (0.004)
σ_{v10}	-0.002 (0.001)
σ^2_{v1}	0.001 (0.000)
σ^2_{u0} (between schools)	0.123 (0.006)
σ_{u10}	-0.008 (0.001)
σ^2_{u1}	0.006 (0.000)
σ_{u70}	-0.012 (0.004)
σ_{u71}	0.003 (0.002)
σ^2_{u7}	0
σ^2_{e0} (between students)	0.321 (0.002)
σ_{e30}	-0.031 (0.001)
σ^2_{e3}	0

-2*log(likelihood)	174379.100

The total level-3 variance is a quadratic function of the 3rd-grade score and level-2 variance is a function of two explanatory variables; the 3rd-grade score and the year in which the students took the Exam:

Total level-3 variance

$$\text{var}(v_{0k}x_0 + v_{1k}x_{1ijk}) = \sigma^2_{v0}x^2_0 + 2\sigma_{v01}x_0x_{1ijk} + \sigma^2_{v1}x^2_{1ijk}$$

Total level-2 variance

$$\text{var}(u_{0jk}x_0 + u_{1jk}x_{1ijk} + u_{7jk}x_{7k}) = \sigma^2_{u0}x^2_0 + 2\sigma_{u01}x_0x_{1ijk} + \sigma^2_{u1}x^2_{1ijk}$$
$$+2\sigma_{u07}x_0x_{7k} + 2\sigma_{u17}x_{1ijk}x_{7k}$$

Moreover, in this model the level-1 variance is also a quadratic function of an explanatory variable; the gender of the student. Thus, the level-1 variance is given by

Total level-1 variance

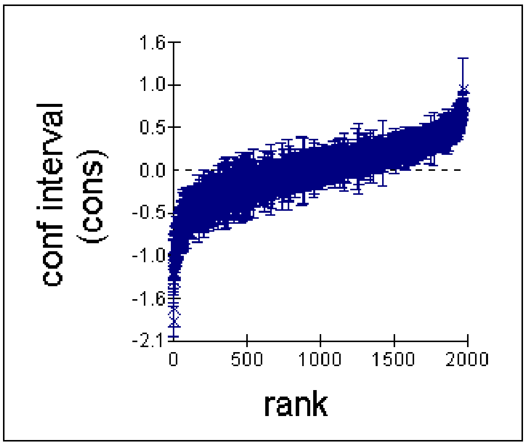
$$\text{var}(e_{0ijk}x_0 + e_{3ijk}x_{3ijk}) = \sigma^2_{e0}x^2_0 + 2\sigma_{e03}x_0x_{3ijk}$$

because we have constrained the variance of the gender coefficient to be zero. Consequently, for girls (x_{3ijk}=1) the level-1 variance is $\sigma^2_{e0} + 2\sigma_{e03}$ and for boys (x_{3ijk}=0) the level-1 variance is σ^2_{e0}.

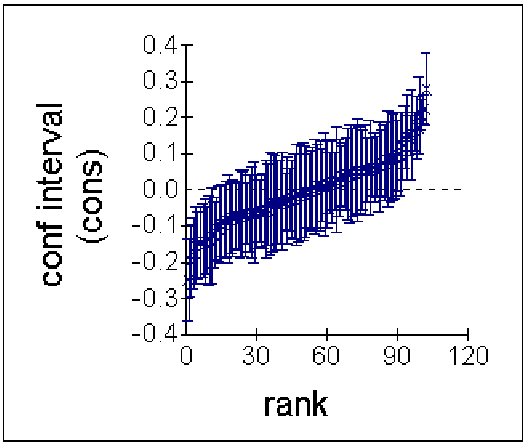
5. RESULTS

The level-2 and level-3 residuals have been estimated for each school and each prefecture, respectively. The primary aim in studies of school effectiveness is to try to identify schools, or prefectures, with residuals which are substantially different. In order to do so, first, we order the residuals from smallest to largest and then we construct an interval about each residual so that the criterion for judging statistical significance at the (1-α)% level for any pair of residuals is whether their confidence intervals overlap. In the two figures presented below the confidence intervals for the level-2 residuals and for the level-3 residuals are presented. Two schools or two prefectures, respectively, are judged to have significantly different residuals, at the 5% level, if and only if their error bars do not overlap.

Level-2 Residuals



Level-3 Residuals



As we observe from the figures above there is substantial difference between some schools and between some prefectures also. As far as the prefectures are concerned, the one with the highest mean score, for both years, is the prefecture of Corinthia of the 1990 Greek National Entrance Exam. The second best prefecture is Attica again of the 1990 Exam. On the other hand, prefecture 47 of the 1991 Exam has the lowest mean score for both years. We stress again that: (a) two prefectures are judged to have significantly different residuals, at the 5% level, if and only if their error bars do not overlap and (b) the comparisons can be made only between two prefectures each time.

6. DISCUSSION

The purpose of this paper has been to assess school effectiveness in Greece using multilevel models and to make adjustments for the previous achievements of the students. Some interesting differences, with respect to gender, to the type of institution and to the scientific orientation that students have chosen, have been observed.

To be more precise, first of all, if we do not make adjustment for the 3rd-grade Lyceum score we conclude that girls do much better than boys in the National Entrance Exam in Greece and that the students of the 1st, 2nd and 3rd scientific orientation do better than those in the 4th one. The difference between the 2nd and, especially, the 3rd scientific orientation with the 4th orientation is very large. On the other hand, if we make adjustment for the background of the students, that is the 3rd-grade score, then the results would be very different. It has been observed that the 3rd grade Lyceum score is a very significant explanatory variable, since the estimate of the standard error of the parameter is less than a third of the parameter estimate (0.784(0.005)). In this case, we concluded that boys do better than girls. This means that boys make more progress than girls in the National Entrance Exam with respect to their 3rd-grade Lyceum score. It was also concluded that public schools do much better than private ones, while the scientific orientation differences are not so pronounced and that students who choose the 4th scientific orientation do better than ones who choose the first one. Finally, it was found that the students who took the Exam in 1990 did better than those who took the Exam in 1991.

In order to identify schools or prefectures with residuals which are substantially different we ordered the residuals from smallest to largest and confidence intervals about each residual were constructed. Through this procedure we concluded that the prefecture with the highest mean score, for both years, was the prefecture of Corinthia for the year 1990, the second best prefecture was Attica for the year 1990 while the prefecture of Evros for the year 1991 had the lowest mean score for both years.

Nevertheless, we have to keep in mind that there are limitations in making comparisons between institutions and that when we apply a statistical model we have to treat the results as suggestive rather than definitive (Goldstein, Spiegelhalter (1996)). When comparative information about institutions are to be analyzed, it must be handled sensitively and with regard to all its problems and limitations.

REFERENCES

Goldstein, H., Rasbash, J., Plewis, I., Draper, D., Browne, W., Yang, M., Woodhouse, G., Healy, M. (1998). A User's Guide to MLwiN. Multilevel Models Project: Institute of Education, University of London.

Goldstein, H. (1995). Multilevel Statistical Models. (2nd edition). London, Edward Arnold; New York, Halstead Press.

Goldstein, H. and Speigelhalter, D. J. (1996). League Tables and their Limitations: Statistical Issues in Comparisons of Institutional Performance, **Journal of the Royal Statistical Society**, Series A, 159, 385-443.

Goldstein, H. and Thomas, S. (1996). Using Examination Results as Indicators of School and College Performance, **Journal of the Royal Statistical Society**, Series A, 159, 149-163.

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