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An Alternative Educational Indicator for Classifying Secondary Schools in Portugal

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Abstract. The purpose of this paper aims at carrying out a study in the area of Statistics for classifying Portuguese Secondary Schools (both mainland and islands: “Azores” and “Madeira”),taking into account the results achievedby their students in both national examinations and internal assessment. The main according consists of identifying groups of schools with different performance levels by considering the sub-national public and private education systems’ as well as their respective geographic location. For this, we developed an alternative educational indicator for the so-called Secondary Education indicator rankings released since 2001 by the Portuguese media.

Keywords: Classification, Cluster Analysis, Educational Indicator, Hypothesis Tests, Secondary Education
PACS: 02.50.Sk,02.50.Fz, 02.50.Tt

INTRODUCTION

This work stems from the need to rank secondary schools by incorporating relevant aspects at the expense of using rankings solely based on students' ratings in the national examinations. The main purpose is to identify groups of schools with different performance levels by considering the sub-national public education system (public schools, i.e., “EscolasPúblicas” - PUB) and the private education system (Charter Schools, i.e., “Escolas com Contrato de Associação - CA” and Private Schools, i.e., “EscolasParticulares - PRI”), and their geographic locations (at the national and regional levels). Traditionally, the established rankings only considered private education provided by Private Schools. Although most students attend public schools, the weight of private schools has been increasing steadily. For this reason, we developed an alternative educational indicator in order to try to incorporate other relevant variables besides evaluation scores of the national examinations.We proposed theI_{SU},an alternative indicator for classifying secondary Schools by subject. Various procedures of Multivariate Statistics are also performed in order to recognize (identify) certain geographical areas (particularly the Northern region) and clusters of schools, in line with the defined alternative indicator. In the analysis, statistical tests are applied, namely parametric and non-parametric (after clusters definition), in the characterization and differentiation relatively to the proposed alternative indicator.

SECONDARY EDUCATION IN PORTUGAL AND DATA

Secondary education in Portugal (i.e., "EnsinoSecundário") corresponds to what in Europe is currently called "Upper Secondary Education". It is structured in different ways in order to provide general programmes (i.e., "cursosgerais"), aimed at those students wishing to progressto higher education, and other programmes aimed at those seeking to enter the labour market. Studentsmay change from one programme to another. Each of these programs lasts three years, corresponding to the 10th, 11th and 12th grades of schooling. Approval in the 11th and 12th grade depends partially on the scores in a set of national examinations.The data set used in this paper was provided by the National Examinations Jury and reports to the results obtained by the students who took the National Examinations in the school yearsfrom 2006/2007to 2010/2011, by School and by subject. The methodology adopted here considers internal students from each school that takethe 1st phase of the national examinations, at the end of the school year there are two phases of exams separated for a question offew days, but the majority of students take in the 1st phase, given the amount of subjects with the highest number of students:

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Mathematics in the 12th grade ("Matemática A"), Portuguese Language, Biology and Geology in the 11th grade, and Physics and Chemistry in the 11th grade. In this paper, we are going to present results bysubject considering a minimum of 15 internal students by school who take thenational examination.The results for the "Matemática A" are presented with more detail.A student's final classification in a subject is a weighed mean score between his final internal classification in the subject within the internal school system and his classification obtained in the national examination. External or self-proposed students can only take the national examination (but this group of students is very small). The classifications are scored between 0 and 200 points.We use the freeware statistical R software (R Development Core Team 2011, [2]) and the SPSS software in the statistical analysis.

AN ALTERNATIVE INDICATOR

The new proposed indicator aims at serving as a tool so that each school can reflects on the global performance, the student's behavior at different subjects in the National Examinations, without confining only to the results obtained at each examination.Thus, in addition to "student performance", will be deemed a "school performance" as follows:

$$\boldsymbol{I}_{SU} = 60\%\left[\mathbf{M}_{SU}(\boldsymbol{S})\right] + 25\%\left[\Delta\mathbf{M}\ (\delta_{SU})\right] + 10\%\left[\boldsymbol{R}_{SU}(\boldsymbol{r}_{SU})\right] + 5\%\left[\Delta\boldsymbol{A}\ (\delta_{SU})\right]. \quad (1)$$

Where $M_{SU}(S)$ is the average of the final exam of the subject SU in School$S$; $\Delta M(\delta_{SU})$is the valuation of the difference between the average of subject SU, the final internal ratings and the ratings average obtained in the national exams at School S;$R_{SU}(r_{SU})$ is the valuation of failure percentage in subject SU, in School S; $\nabla A(\delta_{SU})$is the valuation of the difference between the annual examinations classifications variation, by subject, in School S, relatively to the rate of change of the annual national examinationaverage, by subject, between consecutive academic years. Thus, $60\%\,[M_{SU}(S)]$represents the students' performance; $25\%[\Delta M(\delta_{SU})] + 10\%[R_{SU}(r_{SU})] + 5\%[\Delta A(\delta_{SU})]$represents the School performance, where $25\%[\Delta M(\delta_{SU})] + 10\%[R_{SU}(r_{SU})]$ is the score's coherence obtained in School and $5\%[\Delta A(\delta_{SU})]$ is the School's annual progression. Relatively toδ_{SU}, is defined a functionΔM (2).

$$\Delta\mathbf{M}\ (\delta_{SU}) = \begin{cases} 0 & \textit{if} \quad \delta_{SU} \in [-100,-45] \\ 6\delta_{SU} + 270 & \textit{if} \quad \delta_{SU} \in]-45,-15] \\ 200 & \textit{if} \quad \delta_{SU} \in]-15,15] \\ \dfrac{-180\delta_{SU} + 10080}{41} & \textit{if} \quad \delta_{SU} \in]15,56[\\ 0 & \textit{if} \quad \delta_{SU} \in [56,200] \end{cases} \quad (2)$$

$$\Delta\boldsymbol{A}(\delta_{SU}) = \begin{cases} 0 & \textit{if} \quad \delta_{SU} \in [-400,-20] \\ 5\delta_{SU} + 100 & \textit{if} \quad \delta_{SU} \in]-20,20[\\ 200 & \textit{if} \quad \delta_{SU} \in [20,400] \end{cases} \quad (3)$$

Relatively to r_{SU}, was established a new function R_{SU}: $R_{SU}(r_{SU}) = -2r_{SU} + 200$,if$r_{SU} \in [0,100]$, 200 points are attached to schools that present a null failure percentage (a related, continuous, and descending function). For δ_{SU}, we defined the function ΔA (3). The $I_{SU}$was built for the subjects Mathematics, Portuguese Language, Biology and Geology, and Physics and Chemistry for the 4 school years and for each of the secondary schools (with more than 15 internal students who the took national examinations). In Figure1 is represented the mean I_{SU} at the national level, by subject and School type in each school year.

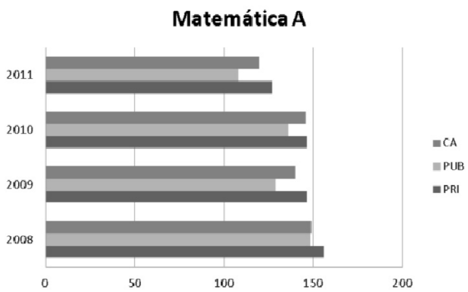

FIGURE 1. I_{SU} average at national level for the Mathematics subject, by School type in each school year.

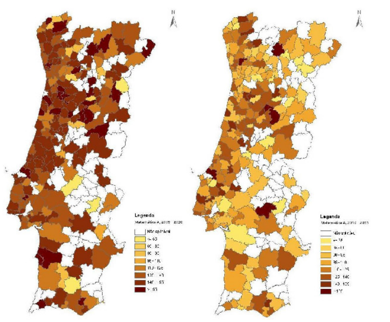

FIGURE 2. Spatial distribution mean by municipality (Mainland Portugal) for the Mathematics subject in school years 2009/2010 and 2010/2011.

The I_{SU}average in PRI Schools is always higher, not only for the Mathematics, but for all subjects. We should stress that the I_{SU}average for the Mathematics subject tends to diminish throughout the academic years under analysis. Regarding the Portuguese Language subject, there's an I_{SU}average increase from school year 2007/2008 to 2008/2009, followed by a descending evolution. TheI_{SU} average for Biology and Geology, and Physics and Chemistry subjects behaves similarly throughout the academic years under study, that is, the average decreases from school year 2007/2008 to 2008/2009, followed by an increaseuntil school year 2010/2011. According to the I_{SU}alternative indicator, we made its representation (municipality averages by classes) in a geographical aggregation maps by municipality for each school year. There is a total of 308 municipalities: 278 in Mainland Portugal, 11 in the Madeira Archipelago, and 19 inthe Azores Archipelago.Figure 2 presents the I_{SU}mean by municipality for Mathematics, for the 2 school years (2009/2010 and 2010/2011) in Mainland Portugal. In school year 2007/2008, 58 municipalities (26%) presented a meanI_{SU}higher than 155 points, for in that year the National Examination for Mathematicsrevealeda degree of difficulty lower than expected; only 2% of the municipalities obtaineda I_{SU}meanlower than 95 points.In school year 2008/2009, there are 4 municipalities (2%) with a meanI_{SU}lower than 65 points. About 14% of municipalities present a mean I_{SU}lower than 95 points.In contrast to previous school year the academic year 2009/2010 revealed a considerable increase in the number of municipalities, totaling 28 (13%), with a I_{SU}meanhigher than 155 points. About 9% of municipalities present a I_{SU}mean lower than 95 points.In 20010/2011, the I_{SU}mean was of about 107 points. In contrast with previous school years, there is a significant increase of municipalities, totaling 20 (9%), with a meanI_{SU}lower than 65 points.Generally, by proceeding to a global analysis of the results variation obtained in the maps throughout the academic years, we concluded that the municipalities with the best results are located in the coastal area of Northern Tagus River, with a special highlightforthe Central region: here, good performances are present in several municipalities of the country's interior regions. These municipalities feature higher living standards and education levels and theirSchools achieve a comparatively better performance. Globally, the municipalities of the Northern Interior, Alentejo, and the Madeira and Azores Archipelagos, safeguarding isolated exceptions, are thosethat continue topresent lower results.

CLUSTER ANALYSIS AND HYPOTHESIS TESTS

In the extent of this work, the region of the country with larger proximity and interest for authors is Northern Portugal where we are inserted(we belong to the University of Minho, located in this region). This region features 79 schools, however we have only considered schools with more than 15internal students that took the national examination by subject in each school year. Cluster Analysis is a way of grouping a set of objects in order to classify them in a small number of classes. An agglomerative hierarchical method was applied to the data set, whose primary purpose is to assemble objects (schools) based on their characteristics ([3], [4], and [5]) with different criteria for aggregation. The dissimilarity measure adopted was the Euclidian distance, because it is the most usual and appropriate for the data (quantitative and continuous).The dissimilarity matrix was subjected to Ward's, singlelinkage and complete linkage clustering procedures. Because the three methods produce similarresults, we only discussed the results of Ward's method.

TABLE 1. Descriptivestatistics of clusters (Mathematics, 2009/2010).

Cluster	Nr of schools	Minimum	Maximum	Mean	Standard Deviation
1	25	142.05	154.98	148.71	3.86
2	13	93.16	121.60	110.76	8.46
3	15	124.60	135.99	130.74	4.22
4	14	157.76	170.79	162.72	4.52
5	5	78.24	87.37	83.86	3.62

TABLE 2. Descriptive statistics of clusters(Mathematics,2010/2011).

Cluster	Nr of schools	Minimum	Maximum	Mean	Standard Deviation
1	19	88.75	109.74	100.44	6.14
2	15	113.62	127.73	121.05	4.47
3	24	46.90	84.53	70.32	10.60
4	14	131.19	164.32	145.10	10.55

For school year 2007/2008 (and for the Mathematicssubject), we considered 4 clusters. The analysis has a cophenetic correlation coefficient of 0.92 (i.e., the correlation between the actual dissimilarities as recorded in the original dissimilarity matrix, and the dissimilarities that can be found of the dendrogram).Cluster 1 is formed by the majority of Schools (38 schools) whose I_{SU}values range from 147, 54 to 157, 04 points; the smaller Cluster 2 comprises 6 Schools with a lower I_{SU} mean. Cluster 3 comprises the "best" Schools, with a higher I_{SU} mean. Cluster 4 is formed by 12 Schools with I_{SU} values that range from 126, 25 to 143, 88 points. A Kruskal-Wallis test was performed ([1], [3] and [6]) in order to analyse if the alternative I_{SU} indicator discriminates the clusters, that is, in order to study the I_{SU} influence on the schools performance in the clusters. When the null hypothesis on identical behaviour of the different clusters was rejected, multiple comparisons tests were carried out by performing the non-parametric Tukey test with ranked sums (because the requirements of ANOVA are not verified). The idea was to determine which pairs of clusters tended to differ ([6]). It was considered a significance level of 5%. It is worth stressing that the results of some of these tests will not be reported here.For school year 2007/2008 (Mathematics), the Kruskal-Wallis tests results (test statistic=59.425 and p-value<0.001) indicate that there are significant differences in the clusters regarding the alternative indicator. In view of this conclusion, multiple comparisons tests were performed, and we concluded that all clusters differ on the I_{SU} level (all 12 p-value were < 0.001).The same analysis was made for school years 2008/2009, 2009/2010, and 2010/2011. By way of cluster analyses, we obtained 5 clusters in 2008/2009, 5 clusters in 2009/2010, and 4 clusters in 2010/2011. For the all school years, the Kruskal-Wallis tests results indicate that school clusters depend on its alternative indicator. Given the results of non-parametric Tukey tests, we found out that all clusters behave differently from each other.Tables 1 and 2 present the descriptive statistics for the clusters obtained for school years 2009/2010 and 2010/2011.

CONCLUSIONS

According to the I_{SU} there is a relative uniformity in students' behavior in Mathematics, Biology and Geology, andPhysics and Chemistrysubjects. The municipalities presenting the best results are located in coastal Northern Tagus River, with a special highlight for the Central region, for here the bestperformances are present in several interior municipalities.The results at Portuguese Language do not present the previous pattern; the best results stem from municipalities located in the Tagus River Valley, NorthwestTrás-os-Montes, Coastal Beira, and Beira Alta (a North/South andCoastal/Interior asymmetry).Globally, Northern Interior, Alentejo, the Madeira and Azores Archipelagos municipalities are those that continue to present the worst results at all subjects under analysis.The 10 "best" Schools classified by subject are located in Lisbon, Coimbra,andCascais municipalities. The 10 "worst" Schools classified by subject are located in the country's Interior and inthe Madeira Archipelago (Public Schools).In the academic years under study, in Schools Ranking, according tothe I_{SU} we can conclude that, regarding Public Schools and Charter Schools, not a single one can maintain and/or repeat its position in the 10 "best" Schools for the subjects under consideration. We should stress that the majority of Schools presented in the 10 "worst" list are Public Schools, located inthe country's Interior and inthe Madeira Archipelago.Analysis applied to the subjects under study has grouped the Schools in four or five clusters. The non-parametric Kruskal-Wallis test and non-parametric Tukey test ([6]) allowed detecting the existing differences in the clusters distributions.We hope this paper can contribute for the discussion and understanding of thesubject regarding the Secondary Schools ranking and all its related issues. Consequently, we hope that the I_{SU} can be used as a support tool for drawing up and analysing the next rankings bysubject, and forthe reformulationof the existingEducational Effectiveness Indicator ("Indicador da EficáciaEducativa", or EFI)inLegislative Order nr 13-A/2012.

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