Multilevel Model Applied on Brazilian Educational System Assessment[1]

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Abstract

This paper shows that over-age students' proficiency is penalised, although not linearly. In some schools the students are more penalised than in others - there is significant variability between schools. On average, over-age students have lower performance but there is a statistically significant *school-effect*.

The research aims at investigating the impact of school factors, such as teachers and principal's experience, class size, promotion system, school quality indicator, reinforcement program, on the school variability reduction. A multilevel model is applied on Brazilian Educational System Assessment data (SAEB).

Keywords: educational assessment, multilevel model, school-effect, over-age student.

1. Introduction

In this paper we show that there is a statistically significant school-effect on the impact of the student age-grade gap on a student's proficiency. We use a two level model applied on Brazilian Educational Assessment System (SAEB) data. The analysis is focused on the south eastern region.

The number of students enrolled in the elementary school level in 1999 is over 36 million. Table 1 shows student distribution per kind of school administration (public – federal, state or municipal, and private).

Table 1 – Distribution of students per kind of school administration – Brazil – 1999
(unit: thousand)

Administration		Number of Students	Distribution %
Public	Federal	28.6	0.08
	State	16589.5	46.0

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	Municipal	16164.4	44.8
Private		3277.3	9.0
Total		36059.8	100.00

Source: MEC/INEP/SEEC

The enrollment rate of students aged from 7 to 14 was 83.8% in 1989 and 95.7% in 1999 (Source: IBGE, PNAD). The percentage of children aged from 7 to 9 who were out of school is 29.3% in 1981, 15.0% in 1989 and 3.8% in 1999.

Although the consistent improvement of the educational indicators over time, the over-age student rate in Brazil is still 44% at the elementary school level. Table 2 shows the rates for all the Brazilian regions in 1999.

Table 2 – Over-age student rate, Brazil - 1999

	Grade								**Total**
Region	1st	2nd	3rd	4th	5th	6th	7th	8th	
North	44,6	57,9	62,6	62,7	68,2	66,3	64,7	63,0	58,3
North east	47,2	60,4	67,1	64,6	71,8	68,5	69,4	66,8	61,9
South east	*12,6*	*19,4*	*23,5*	*27,8*	*39,4*	*39,3*	*42,4*	*43,3*	*30,6*
South	9,2	14,8	19,0	21,3	32,3	30,9	29,3	33,2	23,2
Mid-West	20,6	31,7	38,4	41,1	56,2	56,5	56,9	56,4	43,7
Brazil	32,0	40,6	44,5	42,7	52,3	49,7	50,6	49,5	44,0

Source: MEC/INEP/SEEC

There are three causes for the "age-grade gap" phenomena: joining the school system late, repetition and return to school after being away for some time. Several researchers have pointed out these causes (Teixeira de Freitas 1947, Schiefelbein, 1975, Klein and Ribeiro, 1991). Klein and Ribeiro, (1991) have concluded that, based on official statistics, it has been impossible to quantify the relative importance of each cause exactly and they present a proposal to overcome the difficulty.

Joining the school system late has been greatly reduced by special incentive programs jointly promoted by federal, state and municipal governments. Repetition and evasion from school are related because most of the students who drop-out are repeaters. Almeida Júnior (1947) resumes the discussion about automatic promotion and repetition. This author says that repetition causes evasion, resources waste and retains students at initial grades: "students get older and take the place destined to younger generations". He is against generalized automatic promotion without teachers training, curriculum planning and the definition of criteria of promotion. We are also working on the investigation of the automatic promotion impact on proficiency results.

The proficiency of over-age students is reduced, but in some schools these students are more penalized than in others. This paper aims to investigate the school factors, which explain that variability.

The paper is organized as follows: a brief specification of the multilevel model is presented in the next section. In section three we describe data characteristics and in section four the results of the two-level models applied to the data are shown. The conclusion constitutes the final section.

2. Multilevel Model

Educational data contains a hierarchical structure: students are grouped in classes, classes in schools, the schools in municipalities, and so on. Multilevel regression models incorporate this structure naturally.

Consider that "student" is the level-one unit and "school" is the level-two unit. The response variable is "student achievement", *proficiency*, and the explanatory variables are, for instance, student age-grade gap, *age-grade*, and school quality indicator, *school-quality*. The first is measured at level-one, student, and the second at level-two, school. Students are identified by index *i* and schools by index *k*. Index *k* varies from 1 to K and index i varies from 1 to n_k, so that n_k represents the number of students in school *k*.

The two-level model for the i^{th} student' s proficiency in the j^{th} school can be written as follows:

Both intercept and slope are random parameters, which means that they vary across schools.

Equation (4) follows from the substitution of (2) and (3) in (1). The first line at the right hand side

$$proficiency_{ij} = \beta_{0j} + \beta_{1j} over\_age_{ij} + e_{ij} \quad (1)$$

$$\beta_{0j} = \beta_{00} + \beta_{01} school\_quality_j + u_{0j} \quad (2)$$

$$\beta_{1j} = \beta_{10} + \beta_{11} school\_quality_j + u_{1j} \quad (3)$$

$$e_{ij} \sim N(0, \sigma_e^2)$$

$$u_{0j} \sim N(0, \sigma_{u0}^2)$$

$$u_{1j} \sim N(0, \sigma_{u1}^2)$$

$$\mathrm{cov}(e_{ij}, u_{0j}) = \mathrm{cov}(e_{ij}, u_{1j}) = 0$$

$$\mathrm{cov}(u_{0j}, u_{1j}) = \sigma_{u01}$$

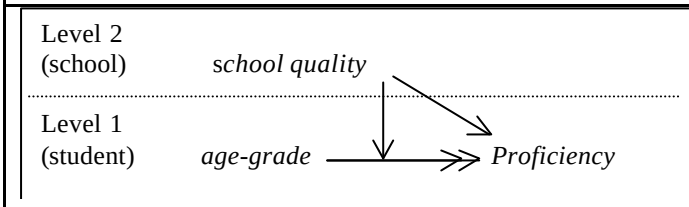
$$proficiency_{ij} = \beta_{00} + \beta_{10} over\_age_{ij} + \beta_{01} school\_quality_j + \beta_{11} school\_quality_j \times over\_age_{ij} + u_{0j} + u_{1j} over\_age_{ij} + e_{ij} \quad (4)$$

of equation (4) is the linear predictor or deterministic part of the model and the second line is the random or stochastic part. The level-one error is e_{ij}, and u_{0j} and u_{1j} are level-two errors related to intercept and slope, respectively. Level-one and two errors are supposed to be uncorrelated and all of them are Normally distributed.

The fixed and random parameters, $\beta_{00}, \beta_{10}, \beta_{01}, \beta_{11}, \sigma_e^2, \sigma_{u0}^2, \sigma_{u1}^2, \sigma_{u01}$ are unknown and estimated from the data. The variance parameter σ_e^2 represents intra-school variability, and both σ_{u0}^2 and σ_{u1}^2 represent between schools variability.

The diagram below shows the relationship between the variables in model (4).

Figure 1 – Variables relationship diagram



Extension of the model to three or more levels is straightforward. More details on multilevel models can be found in Bryk & Raudenbush (1992), Longford (1993) or Goldstein (1995)

3. Data

The analysis is conducted by applying multilevel models on the data of the SAEB (Brazilian Educational System Assessment, collected in 1999) together with some variables extracted from the 1999 school census. SAEB is a large scale survey sponsored and conducted by the National Institute of Educational Studies and Research (INEP) of the Ministry of Education. This survey has national (and state) representativity, based on a sample of 4th and 8th grade students from the elementary school level and 3rd graders from High School level.

This study focuses on 4th grade students in the south east of Brazil (the states of São Paulo, Rio de Janeiro, Espírito Santo e Minas Gerais). The subsample has 13200 students (level-one units) in 488 schools (level-two units).

The outcome variable is student proficiency in Mathematics, Science, native language (Portuguese), History and Geography.

There are explanatory variables measured at level-one and at level-two. Level-one variables are:

- "Age-grade gap" is the explanatory variable of interest (variable *age-grade*). Table 1 in the annex shows a frequency distribution for this variable and the respective average of proficiency. Age was computed using date of birth, and the gap was computed considering that the adequate age for enrolment is seven years old by June of the enrolment year.
- "Socio-economic indicator of the student's family" (scale: from 1, very poor, up to 7, very rich; variable name *SES*) is an indicator used for family classification calculated from primary variables such as parents' education and household goods (freezer, refrigerator, washing machine, car, etc);
- "Ethnic group/skin colour" is a dummy variable and the baseline is *white*;
- "Attitude towards homework assignments" is an ordinal variable coded as dummy. The baseline is *never* does homework;
- "Student likes the subject of study" is an ordinal variable called *motivation*);

Level-two variables are:

- "Principal and teachers' experience" is the number of years in the position;
- "School environment" is a score built up by using a technique called "grade of membership". The primary variables are classroom and toilets tidiness, school noise level and safety, availability of educational resources such as library and number of computers. The name of the variable is *school quality* and varies from 0 (a very good school) up to 1 (a very bad school);
- "School socio-economic" indicator is the average of the student's socio-economic indicator;
- "Repetition rate" is the percentage of students not passing to the next stage;
- "Reinforcement program" is a dummy variable meaning that there is a program at the school;
- "Automatic promotion system" is a dummy variable;
- Class size.

The next section presents the results of the multilevel model applied on this data.

4. Results

All computations were done in MlwiN 1.1 (Rasbash et al. 2000) and the estimation procedure was IGLS with weights. We assume that level-two errors are non-informative. We also assume that for over-age students, the three above mentioned causes for the age-grade gap are equally distributed among schools, and that the school system does not discriminate between late comers into the system and drop-outs who have came back.

Table 3 presents the estimated parameters and the corresponding standard deviation for the models proposed. Coefficients estimated for variables present in both models do not differ from each other by a statistically significant amount, suggesting that multicolinearity is not a problem, with the new variables added to model 1 to obtain model 2 (see graphs 1 and 2 for the 95% confidence interval "subject matter" and "attitude towards homework assignments").

********** insert here graphs 1 and 2 **********

Usually, students of lower social strata, present both lower proficiency and larger age-grade gap. To control for these effects, we have included proxy for social strata (socio-economic indicator of the student's family), in both models and also the school average, "Ethnic group/skin colour" of student and "Attitude towards homework assignments". The use of the latter variable considers that, besides a component of motivation and personal interest of the student, it captures home/school relationship.

"Age-grade gap" presents a quadratic and similar effect in both models. For model 2, the average effect is monotonically decreasing, though, across the full range. For model 1, the minimum of the average is attained when "age-grade gap" equals 4, but the difference to gap equals 5 is not significant given the standard errors of the parameter estimates. Under-age students present much lower proficiency. Dummy variables were used to model this effect.[4] Negative "age-grade gap" results in a proficiency level lower than "no gap", but combined with the quadratic effect, the dummy variables are less impressive. For example, for "gap" equals –1 the effect is only 6.82 =13.32 (linear)+1.83 (quadratic) -21.97 (dummy), less than twice the standard error for the estimate of the subject matter effect..

As expected, "attitude towards homework assignment" has a significant effect (see graph 2) and students who declared that they never do their homework fare worse than the ones who claimed to do it seldom. These students fare worse than the ones who claimed to do it usually, and always. Motivation also has a positive and significant effect.

Table 3. Estimates of the fitted models

	Model 1 Estimate (s.e.)	Model 2 Estimate (s.e.)
Fixed Parameters		
Science	117,72 (3,76)	130,37 (5,13)
Geography	135,40 (3,75)	148,29 (5,12)
History	123,02 (3,74)	135,53 (5,12)
Portuguese	115,18 (3,75)	127,70 (5,12)
Mathematics	124,60 (3,74)	137,22 (5,11)
SES	2,39 (0,41)	2,42 (0,41)
Age_grade	-13,32 (0,92)	-15,33 (0,93)
Age_grade^2	1,83 (0,22)	1,77 (0,21)
Before_age_1	-21,97 (1,80)	-22,69 (1,80)
Before_age_2	-68,48 (5,13)	-68,51 (5,09)
Brown/white	-2,12 (0,80)	-1,92 (0,80)
Black /white	-13,36 (1,33)	-13,19 (1,32)
Homework-seldom/never	3,59 (1,42)	4,46 (1,43)
Homework-usually /never	11,25 (1,43)	11,99 (1,44)
Homework-always /never	20,05 (1,26)	20,82 (1,26)
Motivation	4,39 (0,99)	4,49 (0,99)
School quality	-5,43 (4,52)	-9,07 (4,54)
School –SES	19,72 (0,96)	18,11 (1,06)
Repetition rate	-	-0,12 (0,12)
Automatic promotion	-	-5,45 (1,92)
Class size	-	-0,16 (0,08)
Age-grade **x** repetition	-	0,19 (0,03)

[4] Other studies conducted by the authors and co-leagues show that the rate of incomplete and inconsistent information among students that declared themselves to be with a negative age-grade gap is much higher than among the population studied and there is a fair chance that the age information is also not reliable.

Age-grade **x** school quality	-	5,04 (1,56)
Random Parameters		
Level 2 – School		
Intercept	7,14 (5,86)	2,42 (5,21)
Age-grade	9,32 (3,11)	3,43 (2,50)
Intercept **x** age-grade	190,22 (18,53)	174,15 (17,42)
Level 1 – Student		
Intercept	1650,58 (20,89)	1651,63 (20,91)

School quality has, as expected, a negative effect in model 2 and was included in model 1 for the sake comparison.

The inclusion of new variables and some of the interaction with age-grade gap (cf. model 1 and model 2) strongly reduces the variance of the random effect related to the intercept of the latter (from 9.32 to 3.43 – almost to one third of the original value). This reduction is due (in order of importance) to the inclusion of: a dummy variable for the existence of automatic promotion, interaction of age-grade gap and level of repetition in the school, interaction of age-grade gap and school environment and class size. Graphs 3 and 4 plot the marginal effect of age-grade gap on proficiency, and the reduction in variability (compare the red and the green curves) is obvious.

**********insert here graphs 3 and 4 **********

Although the main effect of "repetition rate" is not significant, the interaction with age-grade gap is. The positive interaction of student age-grade gap and school environment shows that worse schools penalise relatively less, perhaps because o a higher uniformity. Class size is statistically significant, and students in larger classes show lower performance.

Some of the variables listed above in section 3 presented coefficients that were not statistically significant when jointly tested with the variables in table 3. For instance, teacher and principal's experience, and the existence of reinforcement programs are among this set of variables. The effect of the principal´s experience is positive and statistically significant when model does not include a school socio-economic indicator. These variables are correlated, and more research is needed to explain the relationship between them.

5. Conclusion

The proficiency of over-age students is reduced, but in some schools these students achieve less than in others. Age-grade gap has a quadratic effect. This paper shows that some of the school factors, which explain that variability between schools, are: school environment, class size, repetition rate, promotion system and principal's experience.

6. Bibliography

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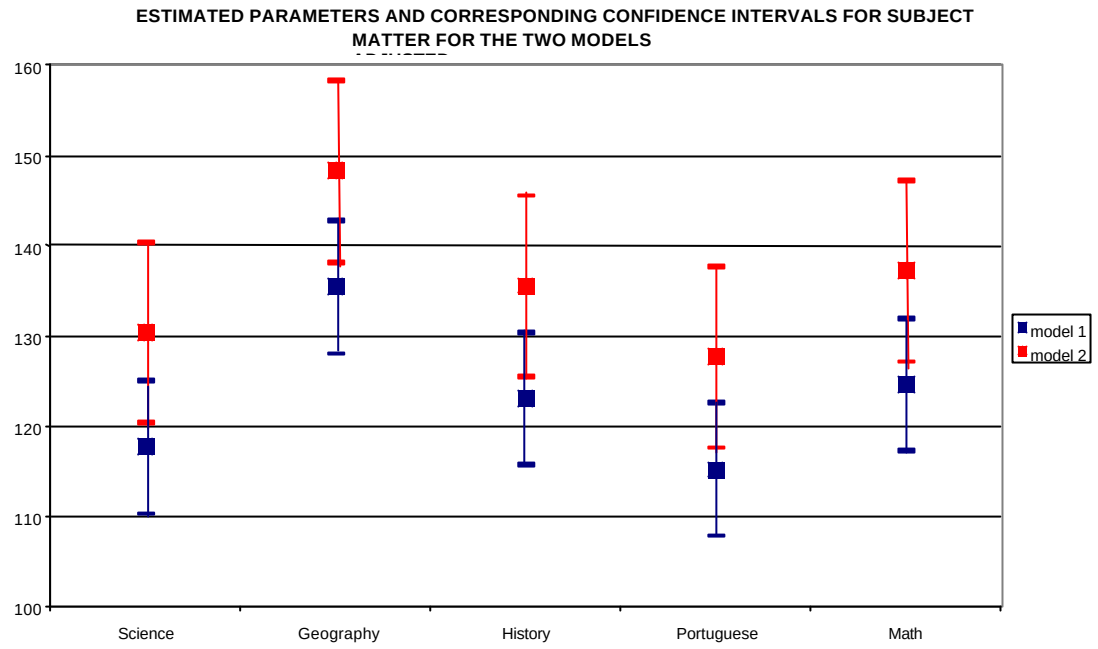
ANNEX

Table 1
Age distribution for 4th graders

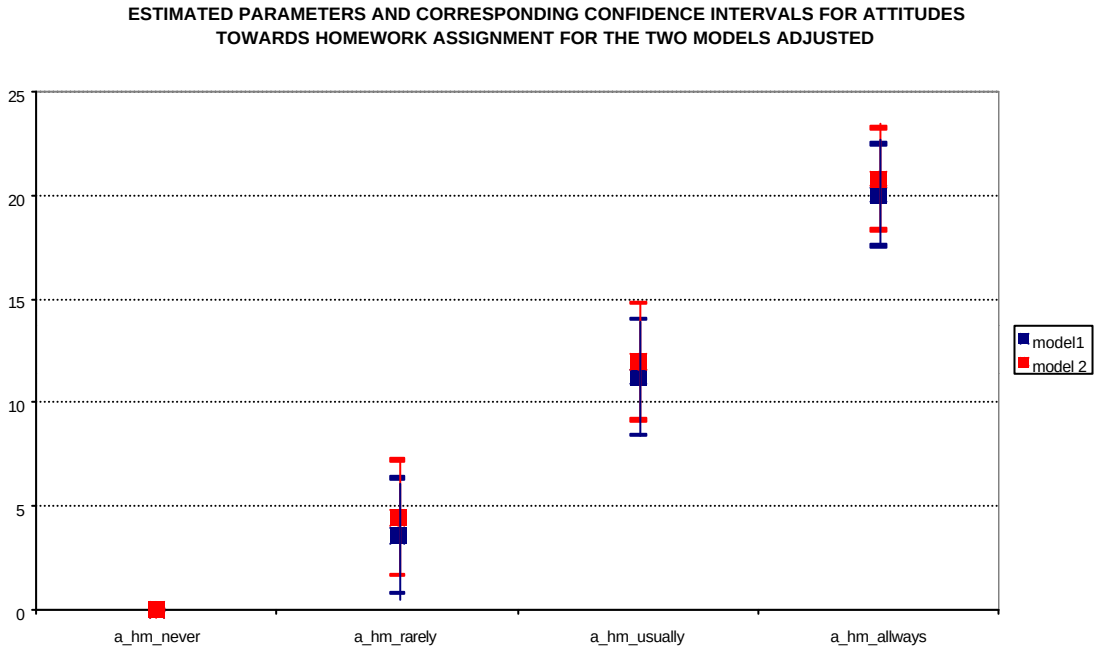
	Age	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	7	2607	.4	.4	.4
	8	5426	.8	.8	1.2
	9	71288	10.4	10.6	11.8
	10	334416	48.7	49.9	61.7
	11	122626	17.9	18.3	80.0
	12	56834	8.3	8.5	88.4
	13	30957	4.5	4.6	93.1
	14	28821	4.2	4.3	97.3
	15	17784	2.6	2.7	100.0
	Total	670759	97.8	100.0	
Missing	-999	15284	2.2		
Total		686043	100.0		

GRAPHS

Graph 1

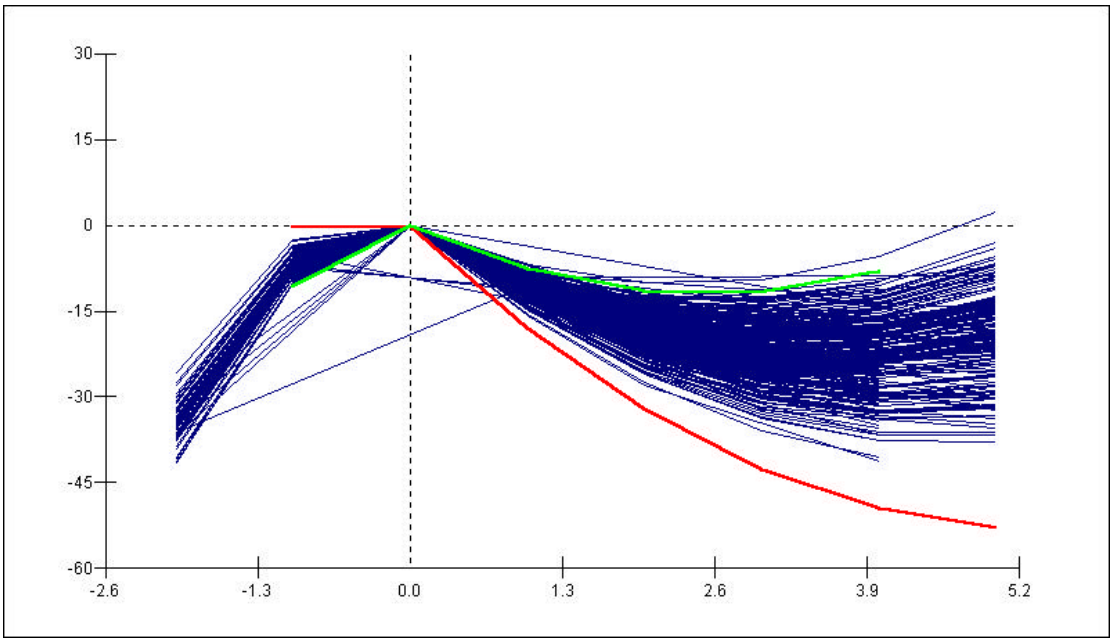


Graph 2



Graph 3

Marginal effect of age-grade gap on proficiency – model 1



Graph 4

Marginal effect of age-grade gap on proficiency – model 2