Science competencies across PISA OECD countries: comparing exceptionally high and low performers

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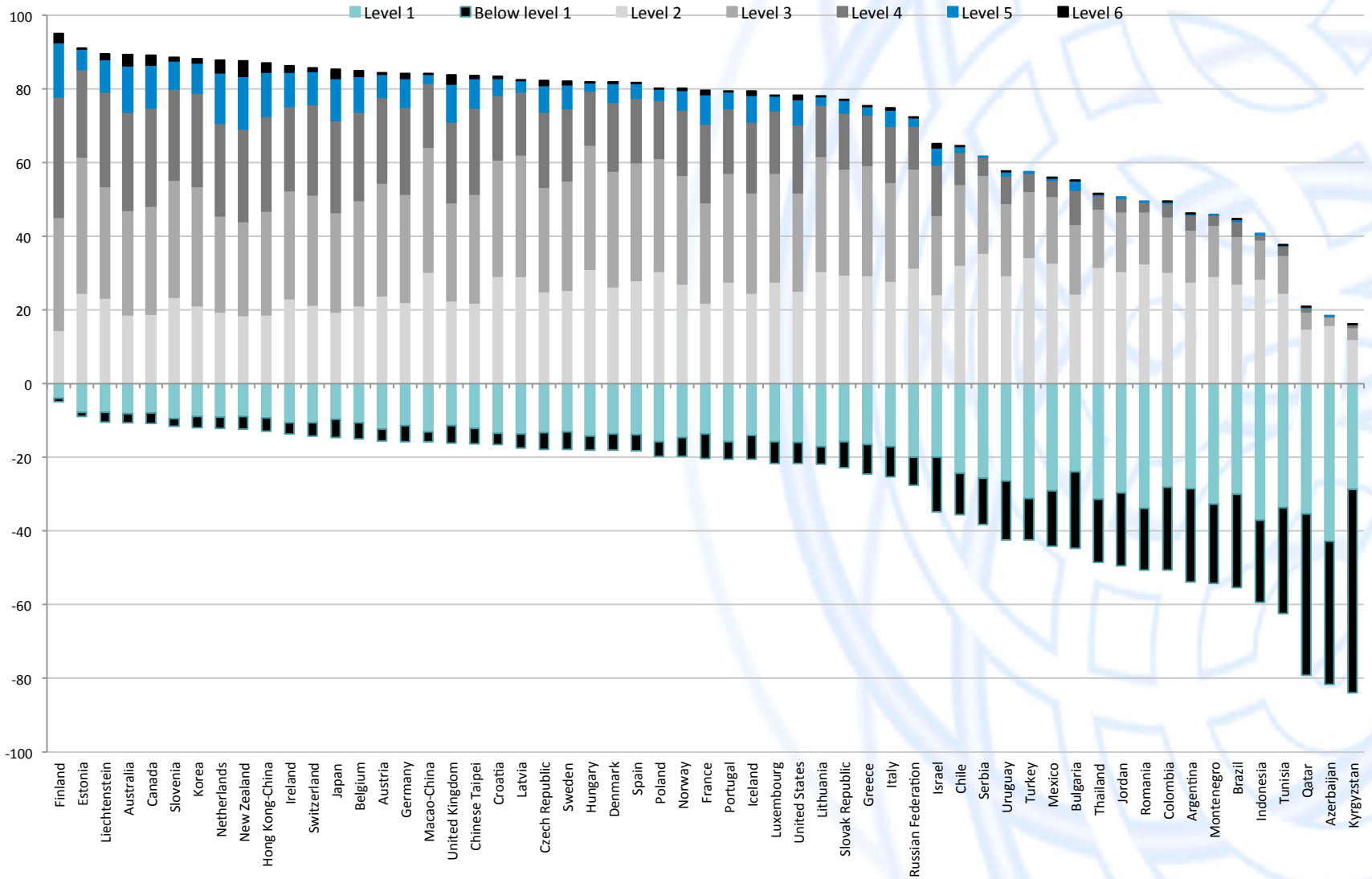
PISA 2006 proficiency levels

In PISA 2006 student science performance is classified according to six proficiency levels, with levels 5 and 6 at the top and level 1 and below at the bottom.

Students at the top levels are able to identify, to explain and to apply their scientific knowledge in a range of different and complex situations.

Students at the bottom levels (1 and below 1) show a lack of basic scientific competencies.

Percentage of students at each proficiency level of the science proficiency scale



Aim of the study

The objective of this paper is to identify, for the OECD PISA 2006 countries, **distinct subgroups of students** who share characteristics that are mostly associated with the proficiency gap

Which variables should be taken into consideration?

- According to PISA 2006 assessment framework (OECD, 2006), a large number of variables could influence students' performance in science.

- These variables are related to:
  - the context of the education system at a national level
  - the school context
  - the individual students context

Variables

- The **dependent variable** of the analysis was a dichotomous variable the values of which represent the two different groups of students: **High performers** and **Low performers**
- The **predictor variables** were OECD indicators and items and indices from PISA contextual questionnaires and were subdivided into three levels:
  - Country
  - School
  - Student

Country-level variables

Variables and Indices	Examples
OECD educational indicators (OECD, 2008) related to **financial investment in education** (data refer to 2005)	expenditure on educational institutions per student; proportion of national wealth spent on education; relative proportions of public and private investment in education; total public expenditure in education; tuition fees charged by institutions and public subsidies to students; services and resources in which education funding are spent; how efficiently the resources are used in education.
OECD educational indicators (OECD, 2008) related to the **learning environment and organization of schools** (data refer to 2005)	time that students spend in the classroom; ratio of students to teacher staff and average class size; teacher salaries; time that teachers spend teaching; impact of evaluation and assessments within education systems; level of decision making in education systems.
Variables from **PISA 2006 Student Questionnaire aggregated** (mean) at the country level	Index of Economic, Social and Cultural Status - ESCS created on the basis of the following variables: -home possession index (wealth possessions; cultural possessions; educational resources; number of books at home) -highest occupational status of parents -highest educational level of parents

School-level Variables

Variables and Indices	Examples
Variables and indices from the PISA 2006 **School Questionnaire**	School size; Class size; Availability of computers; Student-teacher ratio; Index of school selectivity; Index of school responsibility for resource allocation; Proportion of fully certified teachers; Proportion of teachers with an ISCED 5A qualification; Index of school responsibility for curriculum and assessment; Index of teacher shortage; Index of quality of educational resources; Index of school activities to promote students' learning of science; School activities for learning environmental topics; Parental pressure on academic standards.
Variables from PISA 2006 **Student** Questionnaire **aggregated** (mean) at the school level	Index of Economic, Social and Cultural Status - ESCS created on the basis of the following variables: -home possession index (wealth possessions; cultural possessions; educational resources; number of books at home) -highest occupational status of parents -highest educational level of parents

Student-level Variables

Variables and Indices

from the PISA 2006 **Student Questionnaire**

- Index of Economic, Social and Cultural Status – ESCS
- Index of interest in science learning
- Index of enjoyment of science
- Index of instrumental motivation to learn science
- Index of future-oriented science motivation
- Index of science self-efficacy
- Index of science self-concept
- Index of general value of science
- Index of personal value of science
- Index of science-related activities
- Index of awareness of environmental issues
- Index of perception of environmental issues
- Index of environmental optimism
- Index of responsibility for sustainable development
- Index of school preparation for science career
- Index of student information on science careers
- Index of science teaching – interaction
- Index of science teaching - hands-on activities
- Index of science teaching - student investigations
- Index of science teaching - focus on models or applications

Sample

- This study was based on the sample of students with scores classified below level 2 and above level 4 in PISA 2006 countries that are also OECD countries.
- The answers at the school questionnaire of the sampled students' principals
- The final sample refers to 58.596 students weighed using the final student weight.

Methodology

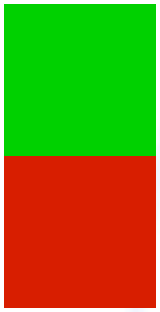
- The analysis was based on classification and regression trees (CART) (Williams, Lee, Fisher, & Dickerman, 1999).
- This method is fully non parametric and suited to detecting and interpreting complex interactions in large data sets, among a large number of variables of different types (Nominal, Ordinal, Interval).

How CART works

- The CART algorithm proceeds by performing successive binary divisions of the subjects on the basis of a statistical criterion
- Starting from the full sample each independent variable is evaluated on the basis of the extent to which it is able to reduce the impurity of the sample by dividing the subjects into two groups
- In the case under examination the best independent variable would be the one which is able to divide the sample into two pure groups:
  - one with only students at the highest level of performance
  - the other with only students at the lowest level of performance

How Cart works: a simple example

CART looks for predictor variable that produces the highest reduction in the impurity of the parent node.



High performers
N=50

Very Low performers
N=50

EYE COLOR

BLUE

N=50

N=0

OTHER COLOR

N=0

N=50

Methodology

The CART analysis was conducted using a hierarchical approach (Hox, 2002; Fabbris, 1997) in three stages:

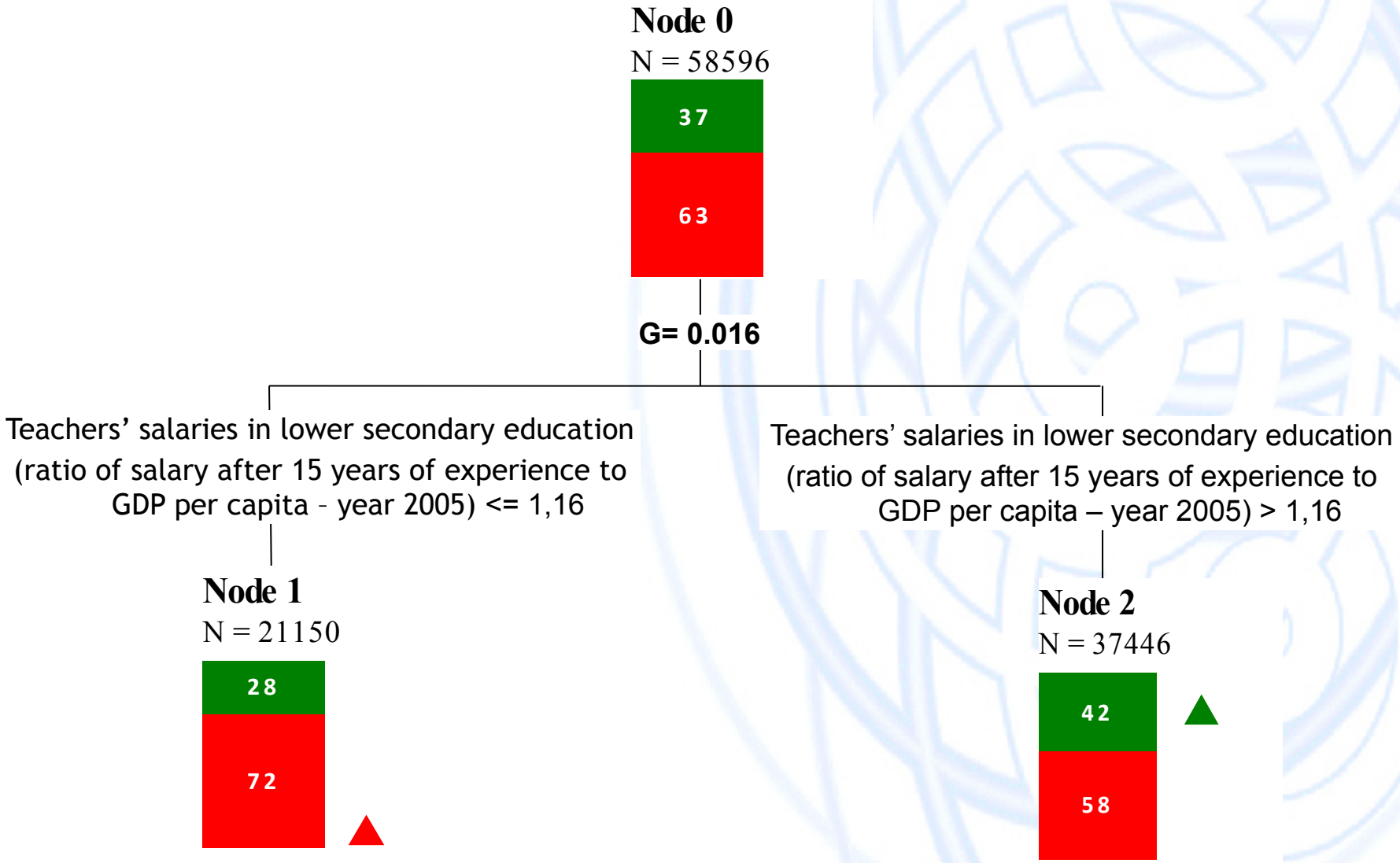
1. with **only country level** variables included in the model;
2. with **school level** variables nested under the country model identified at stage 1;
3. with **student variables** nested under the country and school model identified at stage 2.

The developed model

- The classification model was developed on a random subset of the data (training sample) and then the results were validated on a separate random sample (test sample).
- The accuracy of the model was estimated using cross validation techniques (Breinman, 1984).
- Additionally, in order to validate the model by means of more traditional techniques, once the CART model was created, a multilevel logistic regression model was computed to replicate the findings.

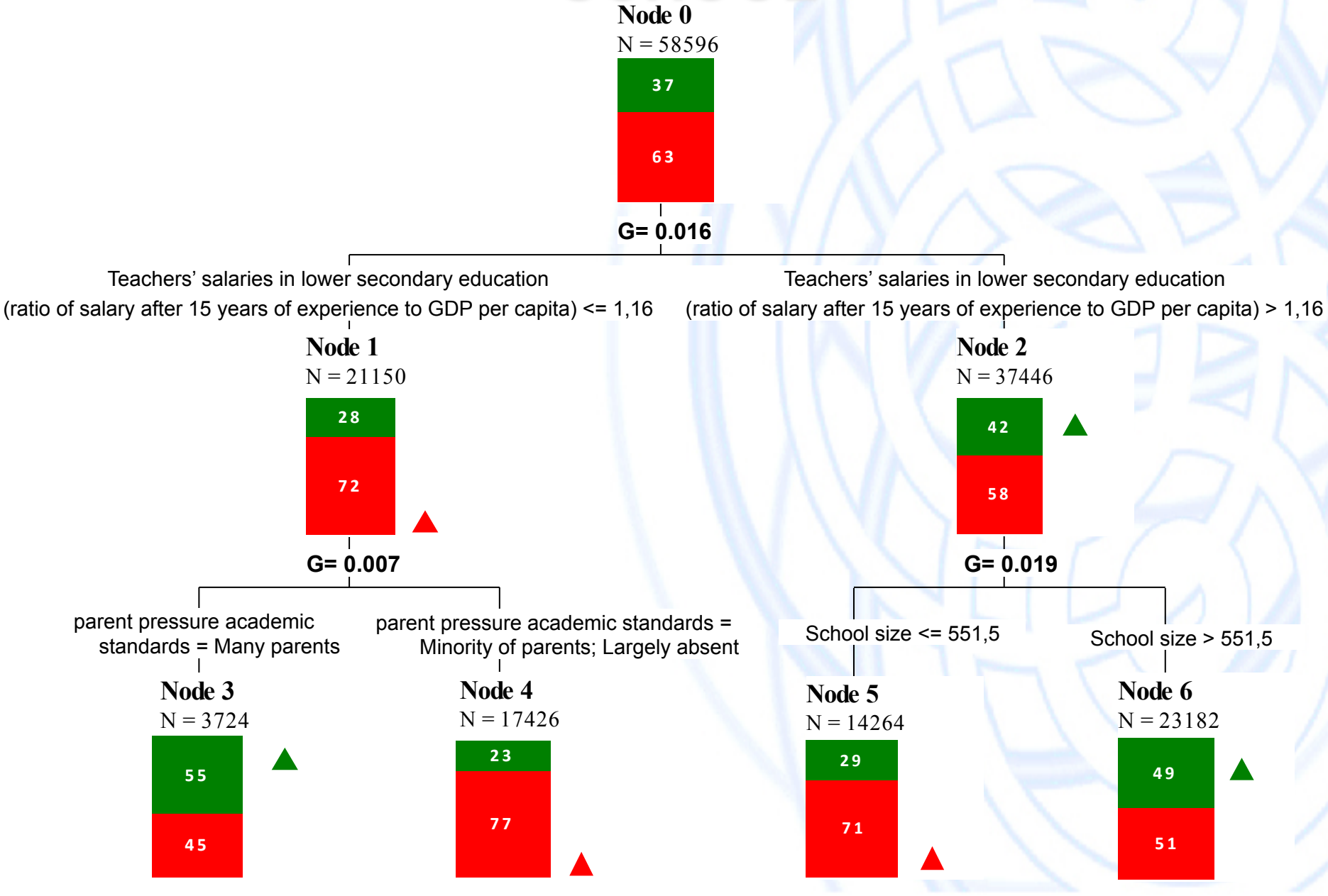
Very Low performers / High performers

COUNTRY



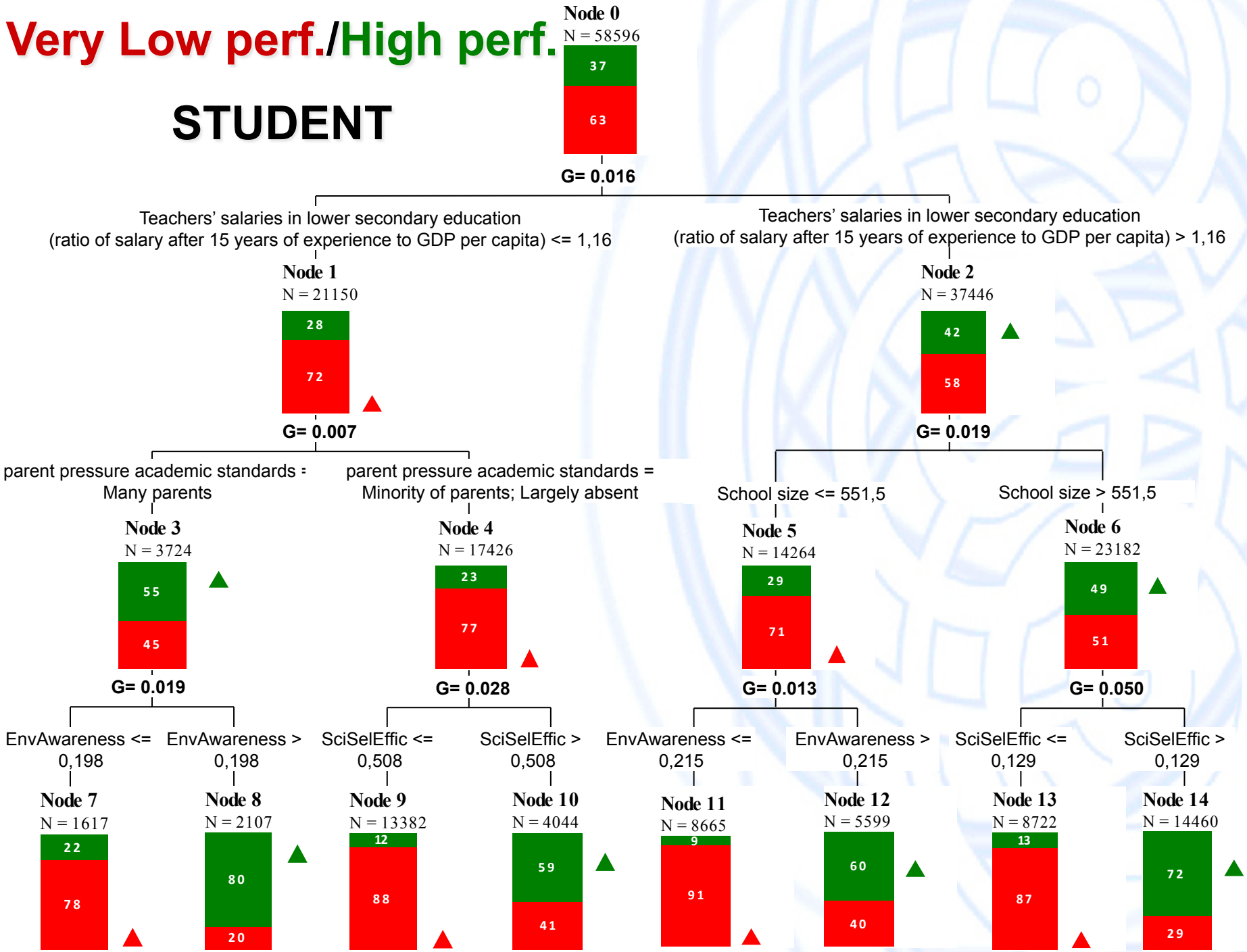
Very Low performers / High performers

SCHOOL

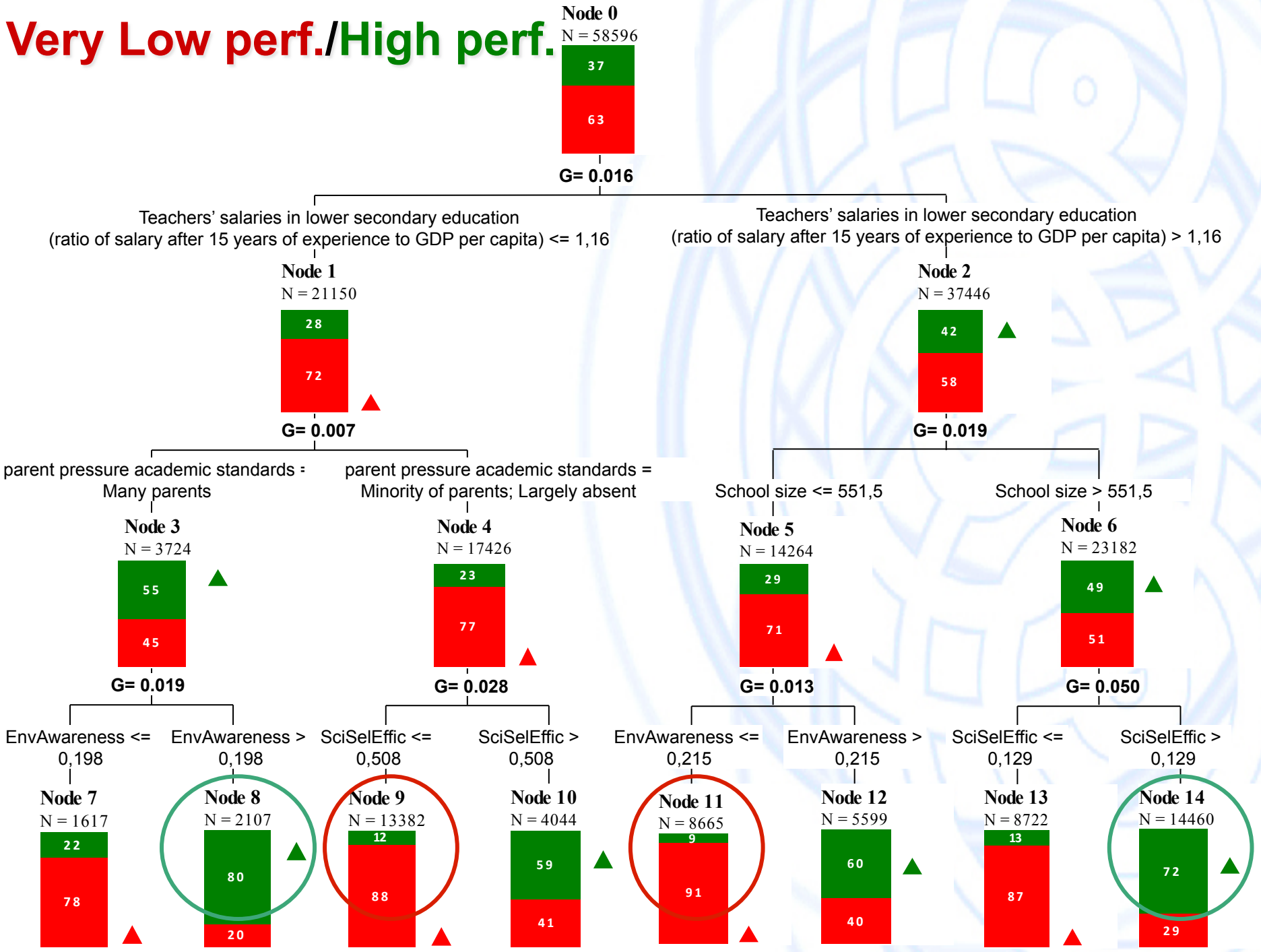


Very Low perf./High perf.

STUDENT



Very Low perf./High perf.



Main Results

The combination of several variables underlies the identification of student groups with particular concentrations of

BEST PERFORMERS

VERY LOW PERFORMERS

Replication model (multilevel logistic regression):

Level-1 Model

Prob(Y=1|B) = P

log[P/(1-P)]=P0+P1*(ESCS)+P2*(I Awar.Envir.Issues)+P3*(I Science Self-Eff.)

Level-2 Model

P0=B00+B01*(I School Size)+B02*(I Parent Pressure)+B03*(ESCS SchMean)+R0

Level-3 Model

B00=G000+G001(I Teacher Salaries)+G002(ESCS Country Mean) + U00

Index of Economic, Social and Cultural Status (ESCS) was included at each level as a control variable

Replication model results:

Results show that the findings from the classification tree have been replicated in the multilevel logistic model

Indicator	Coefficient	Odds Ratio
Country level		
Teacher Salaries L.S.E.	0.90*	2.45
ESCS Country Mean	*0.27*	*1.31*
School Level		
School Size	0.27*	1.31
Parent pressure	0.33*	1.40
ESCS School Mean	*1.6**	*4.94*
Student Level		
Science Self-Efficacy	1.44*	4.24
Awareness of environmental issues	1.61*	5.04
ESCS	*0.5**	*1.65*

**p<.001*

Summing up: Country level variables

- Teachers' salaries in lower secondary education (ratio of salary after 15 years of experience to GDP per capita –year 2005): this variable compares statutory salaries to GDP per capita (a measurement of the relative value of teachers' salaries).

[CUT POINT=1.16]

- Empirical evidence on the relationship between teachers' salaries and student performance has been poor so far (Béteille and Loeb, 2009) and has mostly involved the comparison of states within the USA
- This study suggests that teachers' salaries could be a relevant factor in order to explain large performances' gaps in science.
- In those countries where teacher salaries are higher (OECD, 2007) the students are 2.5 times more likely to be top science performers.

Summing up: School level variables

- Parent pressure academic standards: principals' report about parental expectations towards the school in terms to set very high academic standards and to have the students achieve them. Those students who are in schools where parents' expectations are very high are more likely (1.4 times) to be top science performers.

  [CUT POINT=MANY PARENTS]

- School size: total enrolment at school based on the enrolment data provided by the school principal, summing the number of girls and boys at a school. The effect of school size is quite controversial in literature (Ahn and Brewer, 2009). This study suggests that there could be a cut-off point in investigating this phenomenon: those students who are in schools where the total enrolment exceeds 550 are more likely (1.3 times) to be top science performers.

  [CUT POINT=550]

Summing up: Student level variables

- Student's Awareness of Environmental issues: student's report about how much he/she is informed about several environmental issues (e.g., "nuclear waste", "acid rain")
- Student's science Self-efficacy: student's confidence in performing science-related tasks (e.g., "Describe the role of antibiotics in the treatment of disease", "Interpret the scientific information provided on the labeling of food items").
- These results are consistent with previous findings (e.g., OECD, 2007) which showed a strong association between these two indices and science performance.
- Moreover, they show that for a student is sufficient to be slightly above average (1/5 SD) for the awareness of environmental issue and moderately (1/2 SD) above average for science self-efficacy to be respectively 5 times and 4 times more likely to be a top performer.

Limitations and conclusions:

- In conclusion one should note that this study did not aim to explain the specific reasons why the identified phenomena occur.
- Instead, rather than speculating on the causes of the phenomena, it tprovides a rich and reliable description of the characteristics of these phenomena.
- This description could be useful in that it suggests a number of issues for further investigations and research.

… thank you