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Statistical analysis and evaluation of Greek students' background determinants on Science literacy

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Abstract

Pisa is a program developed by the OECD. The first time it appeared was in 2000. Since then more than 90 countries and about 3,000,000 students worldwide have participated (OECD forum). Students participate every 3 years and are assessed if they can successfully face and solve problems from everyday situations using the basic knowledge they have acquired from the subjects they have been taught at school. The main goal of this paper was to investigate the determinants of student performance. In particular, how students' characteristics, family background, and some school characteristics (type of school, geographic region, curriculum, and class size) affect science performance. We used PISA 2018 data for the case of Greece, as this country requires further research because Greek students perform below the average mean across OECD countries. The sample consisted of 6403 Greek students aged 15-16, who were enrolled in 242 schools. The analysis was carried out with the SPSS statistical program using multiple regression models (OLS) as well as Quantile Regression (QR) method for a more comprehensive study to evaluate whether the above variables affect in the same or different way on low and high-achieving students. Results indicated that family background and student characteristics affect students' performance significantly but to a different degree between high and low-performing students. In contrast, class size was shown to not affect almost the entire performance distribution. Moreover, access to material goods not directly related to education showed a negative effect, instead, the socioeconomic status of the family (ESCS) is a strong positive predictor of scientific literacy. Finally, the Greek education system suffers from several disparities both between different study programs and geographical regions. The above conclusions indicate that educational legislative reforms should be targeted and take into account the variance of student achievement with a focus to reduce the gap between high and low-performing students, which will lead to a robust education system.

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1. Introduction

The education that a person acquires in the first decades of his life shapes his personality, offers him knowledge, and develops his critical thinking, enriching him with the necessary resources to join society and the labor market as an active citizen. It is widely accepted that the economic, social, and cultural development of a country is directly related to education and the robustness of the educational system. The highest level of education is directly linked to social development, the reduction of unemployment and crime, and, in general, an increase in the individual and collective well-being of society. Many countries monitor the performance of students over time to assess to what extent the above goal is achievable. In response to the need for nationally comparable data on student performance, the Organization for Co-operation and Development (OECD) launched the Program for International Student Assessment (PISA) two decades ago (OECD, 2013). The main objective of this competition is to examine and investigate how well the student at the end of his compulsory schooling has acquired the appropriate skills and critical thinking to be ready to successfully face the challenges that will be presented to him later in society. PISA, therefore, focuses on young people's ability to use their knowledge and skills. This orientation reflects a shift in the aims of curricula, which are increasingly concerned with what students, can do with what they learn at school (OECD, 2020b). PISA is designed to collect information through triennial assessments and presents data on students' knowledge and skills in specific areas such as reading, mathematics, and science. It combines the assessment of the above cognitive areas with information about the student's family background, their approaches to learning, etc. Therefore, PISA provides information on the factors that influence the development of skills and attitudes at home and school (OECD, 2019a). The students participating in the competition are between 15-16 years old. These students were chosen because at this age they are close to the end or have just completed compulsory education, which is common worldwide (OECD, 2019b).

Greece has participated in this competition since the first time it was held in 2000 and then in 2003, 2006, 2009, 2012, 2015, 2018, and the most recent competition in 2022. Among OECD countries Greece ranked last in all three examination fields with scores below average. In 2018, Greek students scored low in performance. Among the 78 participating countries they ranked 42nd in reading (with an average of 457 points), 44th in mathematics (with 451 points), and 44th in science (452 points). The percentage of Greek students achieving very high scores is extremely low, while the percentage of students who cannot cope with even basic questions is extremely high. In 2018, only 6.2% of Greek students achieved very high performance in at least one subject (OECD, 2019d). As in previous years, the first places in PISA performance are occupied by students from China, Singapore, Japan, Korea, Canada, the USA, and the countries of Oceania. In Europe, the best performers were students from Estonia, Finland, and Ireland (OECD, 2019d). In the Pisa2018 competition, approximately 600,000 students completed the assessment in 2018, representing approximately 32 million students. Computer-based tests were used in most countries. Also, the students answered a questionnaire, which sought information about their character, family background, attitudes, beliefs, school, and learning experiences. In addition, school principals completed a questionnaire covering the management and organization of the school. Finally, some countries distributed additional questionnaires to obtain more information (OECD, 2019a). One of the three examination fields in this competition is related to the natural sciences. We could say that "Scientific literacy" is a person's scientific knowledge and its use to identify questions, acquire new knowledge, and explain scientific phenomena and their characteristics to draw informed conclusions about how science and technology shape the environment in which he lives (OECD, 2018).

2. Preliminary Notes

It is universally accepted that education affects the lives of individuals. It offers new ways to organize and support social actions that depend on math, reading, science literacy, critical thinking, and skill acquisition. In most countries, the criteria for a person's integration into the labor market focus on the education they have received. Moreover, most developed countries use education as the primary mechanism for selecting and sorting each generation into different social and economic roles (Lewin, 2007). For this reason, the legislation of the education system must provide equal opportunities in the field of education and ensure that social inequalities such as disadvantaged areas of residence or disadvantaged family background do not act as an inhibiting factor in the pursuit of success (OECD, 2012).

Consequently, the need to monitor student performance arose. For example, competitions like IALS (International Adult Literacy Survey). TIMSS (Trends in International Mathematics and Science Study), PIRLS (Progress in International Reading Literacy Study), and PISA (Programme for International Student Assessment). From the middle of the last century to the present, it has been found that students' family background plays an important role in improving student achievement. From the beginning, a comprehensive study was conducted on the key characteristics of schools and students that can influence educational outcomes. Following these main findings, other researchers demonstrated the relationship between student achievement and family background (Coleman, 1968; Lauer, Charlotte, 2003; Giambona, F. and Porcu, M., 2015). Large-scale international assessments such as PISA receive widespread attention. Since its implementation in the early 2000s, PISA has received special attention from around the world, even changing the legislation in the education system of several countries (Bieber & Martens, 2011). Over the past two decades, scientific publications and references to PISA data and the variables extracted through this competition are numerous. Equality in education is a key concern internationally. However, this issue is rarely examined separately for low and high-achieving students and simultaneously in different subject areas. It is accepted that questionnaires that students answer about their broader background in various areas can explain a proportion of their performance. Specifically, student and family characteristics, as well as school-related factors, have been shown to explain student achievement. Some important factors influencing science, mathematics, and reading literacy scores are students' grades, beliefs, interests, and attitudes towards learning, economic social cultural status (ESCS) (Gilleece et al., 2010; Karakolidis et al., 2016; Agassisti & Zoido 2018).

For many years, family scholars have documented the importance of the family as an important institution in performing basic functions for individuals and societies. (Chiu et al. 2007; Bubolz 2001). Although it is widely recognized that student achievement and participation in science are greatly influenced by the family, such relationships are so complex that gender must also be considered (Frome & Eccles, 1998; Tenenbaum & Leaper, 2003; Archer et al., 2012). Several lines of evidence suggest that the family may work differently for children of different genders in STEM subjects, often manipulating them unconsciously or consciously into gender stereotypes in choosing a school major (Bhanot & Jovanovic, 2009; Shapiro & Williams, 2012; Endendijk et al., 2016). According to the literature, it has been observed that in STEM science fields, even though boys and girls receive similar scores, boys consistently show higher expectations for their performance in science and mathematics than girls (Cundiff et al., 2013; Tenenbaum & Leaper, 2003; Nosek et al., 2009; Moote et al., 2020). Continuing with the review of the literature, research studies focusing on PISA data of the last 20 years that have been carried out are very interesting. J. Fonseca, M. O. Valente, and J. Conboy, 2011 used hierarchical linear modeling to compare the performance of Portuguese students in PISA 2006 science literacy with that of students from the OECD, Spain, France, the United Kingdom, Turkey, Greece, and the USA. The results showed that students' performance and attitudes towards science differ from country to country. They further pointed out that the ESCS index is a strong predictor at both the individual and school levels with a statistically significant and positive correlation with student achievement in all countries (Jesuina Fonseca et al, 2011). Gilleece, et al. 2010 examined student and school characteristics associated with low and high achievement in mathematics and science in the PISA competition. Based on the results of a multilevel model, the findings revealed at the student level that home language, intention to leave school early, socioeconomic status, grade level, books at home, and gender were significantly associated with math and science achievement (Gilleece et.al, 2010). Demir 2018 investigated the relationship between mathematics teaching methods and teaching activities with the mathematics scores of Turkish students participating in PISA 2012 using Hierarchical Linear Modeling showing that there are significant differences in mathematics literacy between schools (Demir 2018). Corresponding studies have been carried out for Greek students. For example, Greek researchers conducted an in-depth examination of the achievement of 15-year-old students by applying a multilevel linear model to the Program for PISA 2012. This study investigated the factors, both at the individual and school levels. The results revealed that gender, preschool education, self-confidence in mathematics, and individual and school average socioeconomic status can statistically significantly predict student achievement (Karakolidis et.al, 2016). Another issue that has been investigated has to do with the immigrant background of the students. The number of students with a migrant background has risen significantly over the past two decades in most OECD countries (OECD 2019b). The integration of immigrants is often problematic and these flows have caused in some countries a flight of local students from public to private schools. A key question is whether the increased share of immigrants in schools and classrooms has affected the school performance of natives (Gould et.al, 2009). Brunello and Rocco, 2013 used pooled PISA data for 19 countries over the period 2000–2009 to study whether a higher proportion of immigrant students affects the school performance of native students. The data showed that there is a negative and statistically significant relationship although the size of the estimated effect is small (Brunello & Rocco 2013).

Further studies have been conducted on the difference in educational curriculum between private and public schools. Delprato and Antequera 2021 using the PISA 2016, offered new evidence on whether there is a private-public school performance gap in Latin America. The result showed that there is a positive performance gap for private schools (Delprato & Antequera 2021). An important point to mention is that a large number of researchers have focused on the effects on student achievement in the different geographic areas in which students live and attend school. Extensive studies have shown that in many countries there is a difference between students whose schools belong to disadvantaged or advantaged areas. (Brasington, 2002; Bratti et al, 2007; Tommaso Agasisti & Jose M. Cordero-Ferrera, 2013). Even in China, which ranks first in the PISA competitions, there is a performance gap between urban and rural areas (Lee, 2022). Also, other researchers have shown in the case of Italy that students from northern regions have a better performance than students from southern regions in the field of reading literacy. As well as that there are differences in the extent to which the independent variables affect low and high-grade students, applying Quantile Regression (QR) models (Giambona & Porcu 2015).

Finally, in many studies, PISA data have been used simultaneously with data from outside this competition or the performance of students in PISA played the role of an independent variable to predict the dependent variable of other social and economic data (Eryilmaz & Hernández, 2021; Pulkkinen and Rautopuro, 2022).

2.1 The aim of this paper

According to the literature, there is no doubt about the wide scope and complexity of the relationship between the factors and their effect on the learning abilities and skills that lead to the enhancement of their performance. In this particular work, following the low performance of Greek students in the last twenty years gave us the impetus to approach the reason for such a low performance of Greece in the general ranking of the OASA countries. This fact prompted us to study how a set of student and school characteristics affect PISA performance. The main purpose of this paper is to study the performance of Greek students in the most recent PISA competition (2018) in the field of natural sciences. More specifically, an attempt was made to investigate to what extent performance depends on variables related to the student's characteristics (such as family background, gender, and socioeconomic status) and characteristics of the educational system (such as educational program of attendance, type of school, school area, etc. a.). In addition, an important question is whether these variables act in the same or different way in the distribution of student achievement and whether they affect low and high-achieving students differently, which was also studied.

3. Method

3.1 Ordinary Least Squares (OLS)

In every socio-economic experiment and statistical research, we have a sample of the population where some of its characteristics have been measured, with each characteristic being a variable. In this kind of research, it is interesting to study two or more variables at the same time to determine their degree of dependence. For this purpose, it is of great importance to find a functional relationship between the variables that will lead to a mathematical model of the characteristics of the sample. So suppose we have a sample with n observations (X_i ,Y_i) με i=1,2,…n. Their relationship can be satisfactorily approximated by a population linear function of the form:

$$\Upsilon = \alpha + \beta \cdot X + \ldots$$

where X (independent or input variable) which explains the variability of the variable Y (dependent or response variable) and a, b coefficients. However, because the relationship is not deterministic but stochastic where the same values of X do not correspond to the same values of Y, the model has an additional term where it indicates the difference between the actual measurable value of Y and the predicted value of Y and is called an error term e. So the stochastic linear model will be:

$$\boldsymbol{Y_i = a + b \cdot X_i \ + \cdots + e_i} \tag{1}$$

and the prediction value:

$$\boldsymbol{\widehat{Y_\iota} = \hat{a} + \hat{b} \ \cdot X_i \ + \cdots.} \tag{2}$$

The aim is to determine as precisely as possible the coefficients of the variables. According to the OLS method, the appropriate coefficients will be found by minimizing the sum of the squares of the deviations of the actual value from the theoretical value:

$$\left\{\sum_{i=1}^{n} e_i^2\right\} \to \min \tag{3}$$

If $$\mathrm{F}(e_i) = \left\{\sum_{i=1}^{n} e_i^2\right\} \tag{4}$$

$$\hat{a},\hat{b} = \underset{a,b}{\arg\min}\{\mathrm{F}(e_i)\} \tag{5}$$

$$\mathrm{F}(e_i) = \sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2 = \sum_{i=1}^{n}(Y_i - a - b\cdot \mathrm{X}_i - \ldots)^2 = \mathrm{F}(a,b) \tag{6}$$

Using differential calculus and solving the equations:

$$\frac{\partial \mathrm{F}}{\partial a} = 0\,, \quad \frac{\partial \mathrm{F}}{\partial b} = 0 \tag{7}$$

the appropriate coefficients $\hat{a},\hat{b}$ are calculated.

3.2 Quantile Regression (QR)

Quantile regression (QR) is a more detailed method of regression analysis used in many research fields. It can be seen as an extension of multiple regression. It was introduced by Koenker and Basset (Koenker, R., Basset, G.J., 1978) for application to data in which some assumptions such as homoscedasticity and normality of errors are not met. So with the method of QR, we have a more robust and in-depth analysis, prediction, and description of the data throughout the distribution of the dependent variable, which can give us information about heterogeneity and variability of the influence of the explanatory variables both on different quantiles (Davino C. 2014). QR regression relies on a different loss function to estimate the error. Multiple regression uses the squared error while QR uses the weighted absolute error. While in linear least squares regression, the main goal is to estimate coefficients that approximate the mean of the dependent variable, QR focuses on estimates that approximate the value of the dependent variable across its distribution.
Let's suppose that we want to study how one or more independent variables affect a dependent variable at the q_{th} quantile, where $q_:$ $0<q<1$. So $q\cdot 100\%$ of the values of the dependent variable are below the value corresponding to q_{th} and the rest $(1\text{-}q)\cdot 100\%$ of the values of the dependent variable are above this value. So suppose we have a sample with a dependent variable Y and a set of independent variables X where it holds:

$$\mathbf{Y= b_{q0}+b_{q1}\cdot X_1 + b_{q2}\cdot X_2 + \ldots\ldots + e} \tag{8}$$

Based on the QR analysis, the aim is the prediction of the value of Y corresponding to the point q through the estimation of the coefficients b, i.e. Yq where:

$$\mathbf{Y_q = Q(Y|X) = b_{q0} + b_{q1} \cdot X_1 + b_{q2} \cdot X_2 + \ldots = b_q X} \quad (9)$$

and $\mathbf{b_q X}$ linear combination of independent variables and constant at study points q. So according to the above, we have that the point q is the probability that the values of Y are less than or equal to the value

$$Y_{q}.\ q = P(Y \leq Y_q) = P(Y \leq b_q X) = F(q) \quad (10)$$

Where F(·) is the cumulative distribution function (CDF). Using the inverse function $F^{-1}(\cdot)$ gives us the value of Y_q corresponding to the particular point q for each level of X. The appropriate coefficients b_q are those resulting from the function (11).

$$b_q = \underset{b}{\operatorname{argmin}} [\rho \cdot (Y - b_q X)] \quad (11)$$

The loss function $\rho(Y-b_qX)$ is an asymmetric linear error function where it assigns a weight q to positive errors and a weight (q-1) to negative errors.

$$\min \{\sum_{Y_i > Xb} q[Y - bX] + \sum_{Y_i < Xb} (q-1)[Y - bX]\} \quad (12)$$

So equation (11) is satisfied by solving the following relationship of minimizing the weighted sum of the absolute errors.

$$\min \{\sum_{e^+} q|e^+| + \sum_{e^-} (1-q)|e^-|\} \quad (13)$$

4. Data

Data for PISA 2018 was collected from a sample of over 600,000 students attending a large number of schools worldwide. The selection of the schools was carried out using the method of stratified sampling and the students by random selection, to reflect in the best way the whole of the schools and the student community. In the case of Greece, the sample consists of 6,403 representing 95,000 Greek students. The students were born in 2002 and, at the time of the competition, were attending the curriculum of C gymnasium or A lyceum in 242 different schools. The analysis was carried out with the SPSS-28 statistical program provided by the American multinational technology company IBM after we first merged the files with schools' characteristics with the one containing the characteristics of the students.

The two available files contained more than 1000 variables for analysis. An additional ten plausible values have been calculated through the responses associated with each cognitive domain. These values incorporate students' abilities and the literacy level at which they are ranked. The variables that we included in our analysis were selected from a wider group, following estimates from previous reports in the literature. Also, we included some variables such as the emotional support students receive from their families, the personal effort they make through study time, and a variable related to whether students take extra lessons outside of school. We added the last variable to the analysis models for the reason that attending extra courses is a frequent phenomenon for Greek students due to the nature of the Greek education system.

The dependent variable Y: In the models studied is the average performance of students in natural sciences (**PV_SCIENCE**). ***Independent Scale variables X: SMINS***, is related to the personal effort made by each student to understand and acquire knowledge, which is the time he spends for study [Learning time (minutes per week) – science] (OECD, 2020). The **EMOSUPS** variable reflects the emotional support students receive from their parents. Higher values in this variable mean that students perceive greater levels of psychological support from their parents, and positive values correspond to higher levels of support than the average student in the OECD countries to which a value of zero corresponds [Parents' emotional support perceived by student (WLE)]. The variable **CULTPOSS**, which indicated the level of goods related to cultural resources available to the student's family was created based on responses to whether they have the following items at home: books of classical literature and poetry, works of art, and paintings. Higher values in this index mean more cultural possessions at home (WLE). The WEALTH index, the construction of this index was based on students' answers about whether they have any specific material goods at home, such as a room of their own, an internet connection, a DVD player, mobile phones, televisions, computers, cars, number of bathrooms at home as well as 3 other items separately for each country which in the case of Greece was the availability of the parking space, alarm, and dishwasher. Higher values represent a higher level of wealth [Family Wealth (WLE)] (OECD, 2020). An additional variable, **HEDRES**, measures household goods directly related to education. This indicator reflects the presence of educational resources at home, including a desk and a quiet place to study, a computer that students can use for schoolwork, educational software, books to help students in school, technology books, and a dictionary [Home educational resources (WLE)]. Finally, a continuous variable that according to the literature is a strong predictive factor is the **ESCS** (Index of economic, social, and cultural status). This index is a second-scale variable where 3 individual indicators have been used for its construction, the educational level of the parents, the level of occupational status of the parents, and an indicator concerning the available existing goods at home that are directly related to the education and economic level of the family. The above indicators were combined into one with various weighting factors, the mean value was calculated and this was reconstructed using response theory (IRT) so that the average student in the OECD countries corresponds to zero and a standard deviation equal to one. It is therefore an index that contains a large amount of information about the family background and indicates the general profile of the family in

society [Index of economic, social, and cultural status (WLE)].
Independent variables X-Categorical (Nominal - Ordinal): Student gender was transformed into a dummy variable [**FEMALE**] (OLS model female=1 male=0 /QR-model female=1 male=2). An additional categorical variable that was used in the model is related to the immigrant background of the students. The indicator for immigrant background (**IMMIGRANT_STATUS**) was calculated based on these variables and contains the following categories: (1) native-born students (those students who have at least one parent born in the country), (2) second-generation students (those born in the country of the test but their parents were born in another country) and (3) first-generation students (those students and their parents were born in a different country than the country of the test). For the multiple regression model, we created two dummy variables. One for first-generation students (**FIRST_GEN**: yes=1, No=0) and one for second-generation students (**SEC_GEN**: yes=1, no=0) with native students as a reference. In the models (QR) was entered as a control variable with reference again to native students (**FIRST_GEN**=1, **SEC_GEN**=2, **NATIVE**=3). An additional dummy variable was created by asking whether students take extra lessons to improve their study skills (yes=1, No=0) [**EXTRA_LESSONS**]. We also studied a variable related to books at home, to check how the number of books affects students' performance, i.e. when students live in a family environment with a different number of books. This categorical variable consists of 6 classes and students' answers were given by choosing a class from them depending on how many books they have available [**BOOKS**]. In the analysis we carried out, we merged the above categories into four individual categories for the reason that the range between the categories (0-10 books and 11-25 books) was small, with the result that many students probably answered incorrectly. As well as the categories (201-500 books), (over 500 books) in one category for the reason that also some students who have many books at home answered randomly in one of these two categories due to the difficulty of determining the number of books. For the OLS models we created 3 dummy variables based on reference the category 0-25 books, while for the QR analysis, this variable was entered into the model as a fixed factor variable taking the values (books >201)=1, (101- 200 books)=2, (26-100 books)=3 and based on reference category (0-25 books)=4 for comparable results. An additional variable **REGION_SCH**: the region to which the school belongs and therefore characteristic of the student's place of residence. The OECD, in the case of Greece, classifies school areas in three strata levels with population density as the main classification criterion. Therefore we have rural areas, suburban areas, and urban area. For the OLS models, two variables were created, RURAL area (yes=1, no=0) and SUBURBAN area (yes=1, no=0), while for the QR analysis (**RURAL =1, SUBURBAN=2, URBAN =3**) so that the results are comparable with the urban area as a reference base. Using the same method as before we recorded and created the variable **SCH_PROGRAMM** related to the school program the students were following at the time of the competition. For the OLS models, two variables were created, Secondary School or **GYMNASIO** (yes=1, no=0) and Vocational school

or **EPAL** (yes=1, no=0), while for the QR analysis (**GYMNASIO** =1, **EPAL**=2, **LYCEIO** =3) so that results be comparable to the reference curriculum of the General High School or Lyceum. An additional **TYPE_SCH** variable is the type of school, i.e. whether it is private or public. For the OLS models, a binary variable **PUBLIC_SCH** was created with values (yes=1, no=0) if the student's school is public, while for the QR analysis, we added it to the program as a fixed factor with values (Public=1, Private=2) so that the results give comparable regression coefficients with a common reference base the private school. Finally, the school principals stated in the questionnaire the number of students in the class. Responses were divided into nine categories with the smallest, students less than 15, to the largest category students over 50, with each category receiving the intermediate value. In the data, two classes consist of 36-40 students and 46-50 students. According to the regulations of Greece, the maximum number of students in the class is 30. So the conclusion shows that maybe these categories contain some measurement error. For this reason, we converted the variable above, into the variable **SMALL_CLASS_SIZE** with two categories, a class with students less than 21 and a class with students more than 21 students since it is more in line with the number of students we meet in Greek schools. For the OLS models the variable has SMALL_CLASS_SIZE values (yes=1, no=0), while for the QR analysis (class with students<21=1, class with students≥21= 2), which we added to the program as a fixed factor with reference base the class with students over 21 students.

5. Results

First, we entered into OLS and QR models the variables that we described in the previous section. In the QR method, we created a group of linear regression models at selected points (q=10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90%) of the distribution of performance of Greek students with the main goal of the edges of the distribution, i.e. "low-achieving" students (q=0.1) and "high-achieving" students (q=0.9). The results for the OLS model show that all variables are statistically significant except the variable related to cultural goods at home (p-value=0.201>0.05) and class size (p-value= 0.382>0.05). The same result applies to the model (QR) where we observe that these variables are not statistically significant in the larger range of the distribution. Looking at table 1 below, we see that cultural goods in students' homes in most of the distribution are statistically insignificant and do not affect student achievement for high-scoring students. In contrast to the 10% and 20% percentile, i.e. low-achieving students, this variable is statistically significant with coefficients $b_{0.1}$=4.847 and $b_{0.2}$=3.808. This means that it is observed differences among low-achieving students with different levels of access to these items. That is, for an increase of one unit in the index of cultural goods, the performance increases by approximately 5 and 4 points respectively. We also observe for the class size does not have a statistically significant effect at almost all control points except for the 90th percentile where we observe that it has a statistically significant positive effect on performance ($b_{0.9}$=9.105 indicates an increase in performance of about 9 points). Therefore, we conclude that the number of students in the class does not affect performance, but as far as the very good students are concerned, small classes favor them. Perhaps the teaching is individualized with a focus on the very good students, or because of the more favorable climate because of the fewer students, the transfer of knowledge from the teacher to the excellent students is more efficient. This suggests that maybe the climate between students and the teacher, the degree of "discipline" in the broader sense that prevails in the classroom, innovative teaching methods, and other factors are more important in the degree of teaching performance than the number of students in the classroom.

Table 1: Model 1, b_{OLS} and b estimates by different quantiles

Parameter Estimates by Different Quantiles[a,b]										
Parameter	q=0,1	q=0,2	q=0,3	q=0,4	q=0,5	q=0,6	q=0,7	q=0,8	q=0,9	OLS
Cultural possessions at home (WLE)	4,847	3,808	2,209	1,186	1,868	1,706	1,839	2,143	-0,101	1,793
Class size<21 students	-1,354	-2,418	0,577	0,885	1,127	2,696	3,866	7,229	9,105	2,386
p-value > 0.05										

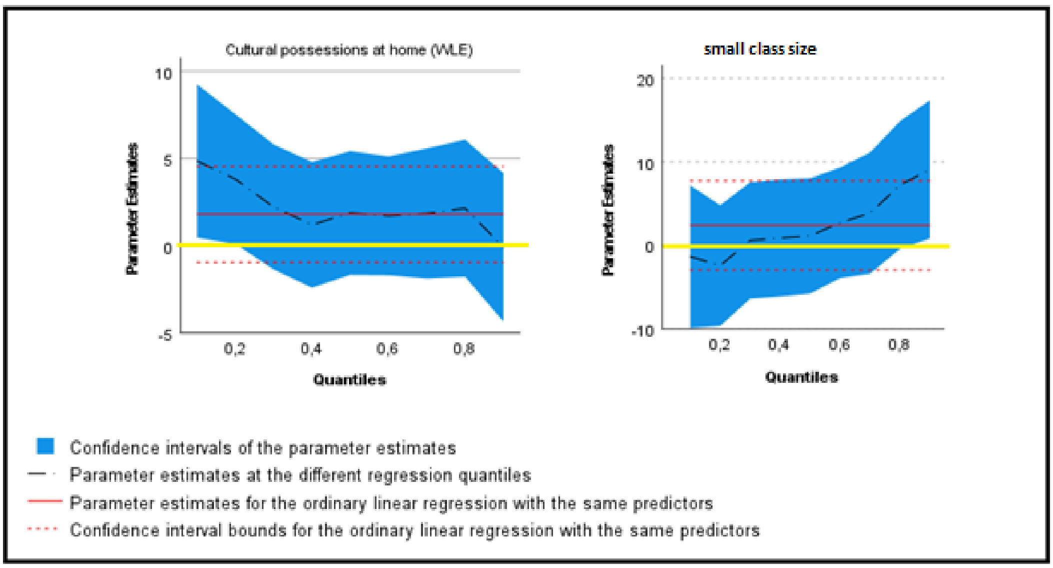

Figure1: b coefficients at various quantiles

The above results are also depicted in figure 1. The red solid line is the beta coefficient of the estimated mean score as derived from the OLS model and the dashed red lines are the upper and lower bounds of the 95% confidence interval.

The blue area represents the limits of the 95% confidence interval according to the QR analysis, and the black dashed line shows the beta coefficients at various points in the distribution from the 0.1 quantiles to 0.9 with a step of 0.1. Finally, the yellow horizontal line shows beta with a value of zero. If the yellow line is within the limits of the confidence interval, then for the specific point the effect of the independent variable on the performance of the score is not statistically significant, so theoretically the variable does not affect the performance. However, despite the positive effect for the CULTPOSS variable, looking at Figure 1, we notice that they are marginally statistically significant for low-performing students [p-value (0,1)=0.031 and p-value(0,2)=0.045]. The size of the class for very high-performing students ($q_{0,9}$) has a p-value=0.03. Then, we removed the two variables that were non-statistically significant in the largest percentage of the performance distribution. The results of coefficients β with p-value < 0.05 ******, for p-value < 0.01 *******, and p-value > 0.05 (**ns**) not statistically significant for the final models are represented in Table 2 and Figure 2. The OLS model is statistically significant and the 17 independent variables we have introduced can explain 31.3% of the average performance of students in natural sciences. All variables are statistically significant with p-value<0.05 as well as at a 1% significance level. According to the OLS model results we observe that the ESCS index has a positive effect (b_{OLS}=15.39). This means that when the student comes from a more advantageous position by one unit on this indicator, his performance increases by about 15 points. The QR model shows a positive statistically significant effect along the length of the distribution, where low and high-performing students are affected almost the same for a one-unit increase (12.8 for the 10% of the distribution and 11.8 for the 90%).

Table 2: Model 2, b_{OLS} and b estimates by different quantiles

Parameter Estimates by Different Quantiles[a,b]										
Parameter	***q=0,1***	***q=0,2***	***q=0,3***	***q=0,4***	***q=0,5***	***q=0,6***	***q=0,7***	***q=0,8***	***q=0,9***	***OLS***
Intercept	396,457 ***	424,179 ***	451,325 ***	466,431 ***	481,694 ***	493,515 ***	503,277 ***	525,219 ***	558,234 ***	480,023 ***
ESCS Index	12,799 ***	13,724 ***	14,781 ***	14,605 ***	15,661 ***	17,780 ***	17,771 ***	14,922 ***	11,772 ***	15,396 ***
WEALTH	-8,345 ***	-8,066 ***	-9,393 ***	-9,719 ***	-10,369 ***	-12,318 ***	-12,784 ***	-11,526 ***	-13,976 ***	-10,506 ***
HEDRES	7,825 ***	6,340 ***	6,276 ***	6,049 ***	5,377 ***	4,130 ***	3,060 **	3,324 **	2,804 (ns)	4,853 ***
SMINS	0,031 **	0,038 ***	0,037 ***	0,046 ***	0,060 ***	0,075 ***	0,092 ***	0,098 ***	0,101 ***	0,050 ***
EMOSUPS	9,642 ***	8,289 ***	8,641 ***	8,800 ***	8,054 ***	7,426 ***	6,981 ***	5,729 ***	6,251 ***	7,723 ***
FEMALE	-5,146 (ns)	-4,371 (ns)	-6,142 ***	-8,245 ***	-7,210 ***	-9,598 ***	-9,086 ***	-8,962 ***	-10,134 ***	-7,544 ***
BOOKS> 201	22,679 ***	24,514 ***	22,633 ***	22,320 ***	22,173 ***	22,550 ***	25,028 ***	32,170 ***	28,556 ***	24,472 ***
101-200 BOOKS	22,395 ***	18,832 ***	14,161 ***	20,267 ***	16,189 ***	16,967 ***	18,591 ***	20,918 ***	20,579 ***	19,657 ***
26-100 BOOKS	18,138 ***	17,063 ***	15,093 ***	15,589 ***	12,039 ***	12,479 ***	15,602 ***	13,964 ***	9,857 **	14,228 ***
PUBLIC_SCH	-10,936 (ns)	-11,317 **	-15,225 ***	-15,350 ***	-15,842 ***	-15,295 ***	-16,177 ***	-20,468 ***	-25,945 ***	-15,542 ***
EXTRA_LESSONS	-26,373 ***	-32,582 ***	-38,507 ***	-37,998 ***	-39,297 ***	-40,941 ***	-40,543 ***	-36,793 ***	-38,986 ***	-37,078 ***
REGION_SCH **RURAL**	-15,909 ***	-15,226 ***	-16,302 ***	-19,874 ***	-15,727 ***	-16,926 ***	-13,854 ***	-20,628 ***	-18,513 ***	-15,600 ***
REGION_SCH **SUBURBAN**	-8,382 **	-6,802 **	-9,477 ***	-10,006 ***	-9,623 ***	-7,312 **	-3,916 (ns)	-6,472 **	-9,283 **	-7,875 ***
SCH_PROGRAMM **GYMNASIO**	-96,121 ***	-77,908 ***	-78,271 ***	-71,301 ***	-73,462 ***	-72,958 ***	-81,624 ***	-79,481 ***	-76,473 ***	-79,463 ***
SCH_PROGRAMM **EPAL**	-50,499 ***	-56,432 ***	-62,676 ***	-63,923 ***	-63,862 ***	-63,577 ***	-63,470 ***	-67,083 ***	-64,794 ***	-62,166 ***
IMMIGRANT_STATUS- **FIRST_GEN**	-31,756 ***	-34,498 ***	-35,566 ***	-35,994 ***	-25,460 ***	-27,029 ***	-15,367 (ns)	-12,573 (ns)	-9,786 (ns)	-25,379 ***
IMMIGRANT_STATUS- **SEC_GEN**	-13,284 **	-12,141 **	-9,394 **	-11,789 ***	-9,062 **	-7,292 (ns)	-6,913 (ns)	-10,828 **	-13,113 **	-10,210 ***

a. Dependent Variable: **PV_SCIENCE**
b. Model: **Intercept , ESCS**, **WEALTH**, **HEDRES**, **EMOSUPS**, ***SMINS***, **FEMALE**, **BOOKS**, **PUBLIC_SCH**, **EXTRA_LESSONS**, **REGION_SCH**, **SCH_PROGRAMM**, **IMMIGRANT_STATUS**

The QR model shows a positive statistically significant effect along the length of the distribution, where low and high-performing students are affected almost the same for a one-unit increase (12.8 for the 10% of the distribution and 11.8 for the 90%). In addition, a larger positive effect is observed at 50% to 70% by an average of about 5 units ($b_{0.5}$=15.7, $b_{0.6/0.7}$=17.8). Figure 2 shows the predicted performance values for a student with different levels in this index. Predictive values were calculated by setting the following values to the other independent variables: female, 26-100 books, public, do you currently attend additional instruction? Lessons to improve your [study skills]: No, region: URBAN, high school, NATIVE, Family wealth: -0,297531, Home educational resources: -0,054005, Parents' emotional support perceived by student: 0,032818, Learning time (minutes per week) - science: 215,67]. We observe that the predictive lines have a constant slope as this index increases. So we conclude that **ESCS** index plays an important role and is a strong predictor of student performance.

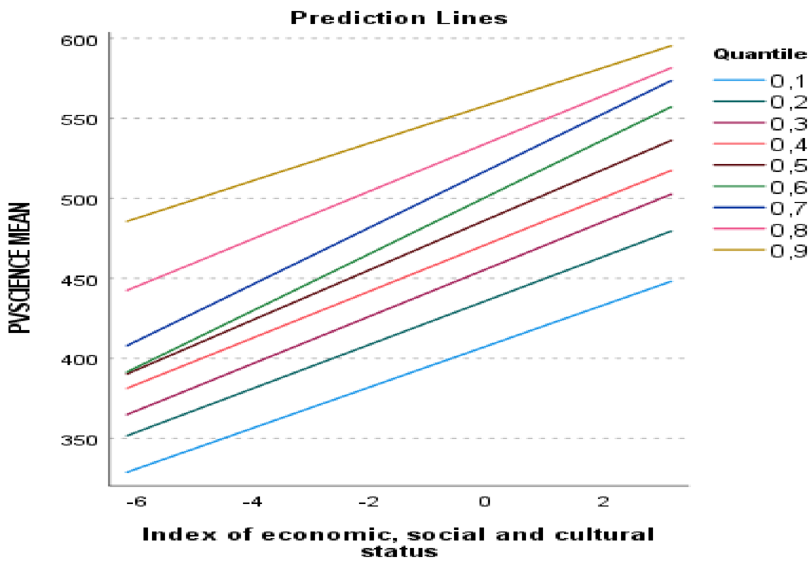

Figure 2: Prediction lines for different level ESCS index

Family wealth has a negative effect across the entire performance distribution. However, the results indicate that it affects low and high-performing students with different intensities for the QR model ($b_{0.1}$=-8.4... $b_{0.9}$=-14). If the level of this index increases by one unit it has a more negative effect by 6 units in absolute terms for high achieving students. So access to consumer goods has a negative influence, indicating that material goods are not positively related to education.

The next index**, HEDRES,** which measures the basic resources related to education has a positive effect (β=4.85) on the average Greek student. However, we notice that it has a stronger effect on low-performing students and as we move toward high-performing students, it decreases and finally ends up not being statistically significant at 90% of the distribution ($b_{0.1}$=7.825 to $b_{0.9}$=2.804^{ns}). This indicates the different effects of the index among students with different performances in the competition, where the results indicate that it is not a predictor of their performance for high-achieving students. This variability of the coefficient indicates that low-achieving students need the necessary access to simple goods that are directly related to education to improve their performance. Based on the results of the last two indicators above, we observe that the learning and performance of the students are related to goods that are directly related to education and not to material goods which may disrupt the student's goal for learning.

Continuing with the variable **EMOSUPS** which is related with the emotional support that students receive from their parents, we observe that it has a positive effect on their performance. However, we notice that as we go from low-achieving students to high-achieving students, the coefficient b decreases ($b_{0.1}$=9.642...$b_{0.9}$=6.251). According to the above, we conclude that low-achieving students need more psychological support from their parents, perhaps due to their low performance.

Next, the variable associated with an important characteristic of the student is the amount of time spent reading science courses (***SMINS)*.** We notice that it has a positive effect (b_{ols}=0.05). This shows that the acquisition of knowledge and skills in school also depends on the extent to which each student tries to assimilate knowledge, improve his way of thinking, and educate himself. Also, increasing study time by one minute per week has a positive effect across all quantiles but with different strengths. At 10% of performance, b is equal to 0.031 and as we go to higher achieving students the coefficient increases, whereas at 90% it triples ($b_{0.9}$=0.1). That is, we observe that the performance of very low -performing students increases by 3 points for an increase in study time by 100 minutes (about 1.5 hours), while for very high performers by approximately 10 points. The above results indicate that high-performing students have a higher rate of performance for the same studying time, which indicates that the learning method they choose is more efficient.

Continuing with the gender effect, girls perform lower than boys by 7.5 points in science according to the OLS model. This suggests that boys are inclined to the sciences, something which may stem from the fact that society, school, and family have not eliminated gender stereotypes in terms of education and the professions to which each different direction leads. About the QR model, we observe that there is no difference between boys and girls at 10% and 20% of the achievement distribution, i.e. among low-achieving students. But as we go through the distribution towards the best-performing students, the difference becomes statistically significant and increases. Boys achieved better grades than girls ($b_{0.9}$=-10.134 for girls). Thus we conclude that boys seem to have a more positive inclination towards science, even though girls achieve equally high grades.

The number of books at home has a positive effect on performance. The reference base is the category of 0-25 books. So according to the b_{OLS} coefficients, we observe that if a student has more than 201 books, from 101 to 200 or from 26 to 100 books at home, then his performance increases by 24.5, 19.7, and 14.2 respectively. Specifically, low-performing students who answered that they have more than 201 books perform 23, 24.5 points higher than students who have 0 to 25 books ($b_{0.1}$=22,679 and $b_{0,2}$=24,514). While as we move towards high-performing students we observe that they achieve higher degrees by 25, 32, and 28 points respectively than students who have 0 to 25 books ($b_{0.7}$=25,028/ $b_{0,8}$=32,170/ $b_{0,9}$= 28,556). Students who have 101 to 200 books perform better than students with 0 to 25 books by approximately 21 to 22 units. This result is similar for low and high-performing students. Finally low–performing students who have between 26 and 100 books perform better by 18 points (q=0.1) while high–performing students by approximately 10 points (q=0.9). The above results indicate that while the number of books is a predictor of performance with a positive relationship, for low-performing students the number of available books matters up to a point. On the contrary, for high-performing students, the greater the number of books at home, the more it affects their performance. We calculated the predictive values of performance for a different level of available books by setting constant values for the remaining variables (the same as the previous example-figure 2 of the ESCS index) for three different points (for low-achieving students, median, and high-achieving students), in order to make more understandable the above conclusion. In Figure 3, we notice that the line for the high-performing students is almost straight and follows an upward trend in contrast to the low-performing students where after 26-100 books the straight line becomes almost horizontal. As we go from students with many books to students with few books, the b coefficient decreases at a low rate for low–performing students ($b_{0.1}$:22.7/ 22.4/ 18), while for high–performing students (q=0.9) the b coefficient decreases at a high rate ($b_{0.9}$: 28,6/20,6/9,9). The above conclusion, which was obtained by examining the effect of the number of books, is consistent with the conclusion obtained by studying the effect of the variable HEDRES (educational resources at home). While low-performing students are more sensitive to basic and necessary goods directly related to education, the performance of high-performing students is more affected by sophisticated sources of knowledge such as the availability of a large number of books.

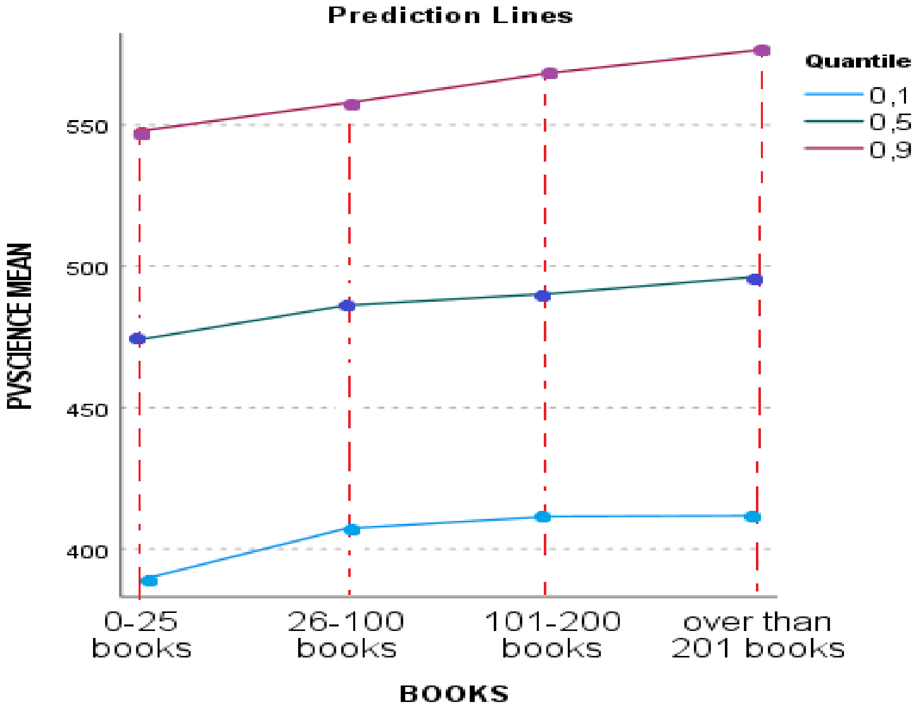

Figure 3: Prediction lines for different level of available

Regarding the type of school, we observe that students enrolled in public schools perform 15.5 points less than students enrolled in private schools (OLS) model. For the QR model, we notice that the variable is not statistically significant for low-performing students (q=0.1), so no difference is observed between low- performing students in public and private schools. But when we turn to high-performing students we observe that the influence of school type on performance becomes statistically significant with the difference constantly increasing in favor of private schools ($b_{0.2}$=-11.317 to $b_{0.9}$=-26). The next variable is related to the extra lessons that students attend to improve their studying skills.

Students who attend extra lessons perform on average 37 points less (bOLS=-37.07). The difference is great and the conclusion is that the mentality of the subjects that the students are asked to face in this competition is different from the mentality promoted by the Greek education system. In the QR model, we observe that students who attend additional lessons to improve their learning skills perform lower at all points of the performance distribution than students who have declared that they do not attend extra lessons, and the difference is large. If we focus on students whose performance is above the performance corresponding to the median, we notice that this difference exceeds 40 points. The above results reinforce the initial conclusion we reached through the average performance estimation model. So, we come to the conclusion that while high-ranking students attend additional courses, they seem to perform lower in the subjects of this competition. A high-performing student who takes extra courses aims for high marks and success in national exams that will propel him to enter into university. This goal requires study time to acquire theoretical knowledge and understanding of complex exercises. The student is forced to sacrifice a large part of his free time in acquiring a large amount of knowledge, without cultivating his critical thinking. Therefore, he does not learn how to think and deal successfully with the challenges he encounters in his life. The Greek education system promotes memorization and theory, which is in contrast to what PISA assesses. In this competition the student is asked to face problems of everyday life, in the field of natural sciences and technology, giving more weight to the way of thinking and the skills acquired in school than to the memorization of complex formulas and theory. The above may explain one of the reasons why Greek students consistently perform poorly and cannot successfully cope with PISA questions.

As regards the variables referring to the geographical area to which the school belongs, we observe that students in schools in rural areas (b_{OLS}=-15.6) perform 15.6 points lower. Students enrolled in schools in semi-urban areas (b_{OLS} =-7.87) perform approximately 8 points lower than students whose schools are located in urban areas. The results indicate geographical disparities between students with different places of residence. Region is a predictor of performance and affects student achievement differently. The previous results indicate geographical disparities between students with different places of residence. Students from rural areas, both low and high achievers, perform lower than students from urban areas. Specifically, there is a decrease in the score by 16 points for low-performing students ($b_{0.1}$=-15.91). For high-performing students, the effect of the area is more negative with the difference being 20.6 points for 80% and 18.5 for 90% of the distribution ($b_{0.8}$=-20.628, $b_{0.9}$=-18.513). Students from disadvantaged areas, distant from cities, perform worse with a stronger negative effect for good students. In addition, regarding students from semi-urban areas, we observe that they achieve lower scores than students from urban centers along the entire length of the distribution except for 70% where it is non-statistically significant. In the remaining quantiles of the distribution, the negative effect on the score due to a semi-urban area is almost half that of the effect due to a rural area. Furthermore, here we observe that low-performing and high-performing students have approximately the same degree of negative effect on performance compared to the corresponding students from urban areas ($b_{0.1}$=-8.38, $b_{0.2}$=-6.8, $b_{0.8}$=-6.5, $b_{0.9}$=-9.3). Therefore, according to the above, we conclude that there are several geographical inequalities.

Additionally, differences are also observed in the curriculum. A student who goes to high school has a lower average performance by about 80 points (b_{OLS} =-79.46) while a student attending a vocational high school curriculum performs on average 62 points less (b_{OLS}=62.16) than students attending a general high school. The above results show great disparities between schools and especially between secondary school and vocational schools with the curriculum of general high schools. Students from the general high schools seem to do better in the PISA competition. We reach the same conclusion through QR analysis. Specifically, a secondary school student with a low performance seems to perform less by approximately 96 units compared to a general high school student with a corresponding performance ($b_{0.1}$=-96.121). Likewise, a high-achieving secondary school student achieves a score approximately 80 points lower than the corresponding general high school student ($b_{0.9}$=-79.481). When the student has enrolled in a vocational school, we observe that for low-performing students the performance is reduced by half compared to a general high school student. And in this case, however, the performance is lower by about 50 points compared to high school students. Moving towards the extreme end of the distribution, the results indicate that high-performing students perform approximately 67 points less than a high-performing secondary school student ($b_{0.1}$=-50.499, $b_{0.9}$=-67.083) with the intermediate points following an almost constant negative trend. Based on the previous results, we notice that the differences are quite great, which shows strong inequalities between the study programs. There is a large gap in the curriculum for a student who transitions from secondary school to general high school, and also a gap between the 1st grade of vocational and the 1st grade of the general high school with a more pronounced effect on high-achieving students.

Finally, the last variable, which refers to the immigrant background, has as a reference base the students without an immigrant background. The results show that first-generation immigrant students, whose scores are below the median, perform worse than native-born students by 31 to 36 points. This difference is important and highlights the problems encountered by immigrant students who leave their country and seek a better life in the host country. These students, due to several problems they face, such as adapting and socializing to the new living conditions, the difficulty of attending classes due to problems with the spoken language, and the fact that they mostly come from a low economic-social family background, may act as an inhibiting factor in the development of their learning abilities. Nevertheless, we notice that for first-generation students with scores above the median of the distribution of scores, the difference decreases, and at 70% and above the difference is not statistically significant, which means that no performance difference is observed related to the performance of native students. This particular result indicates that many children who leave their home country, have the mental strength to conquer their goals by overcoming any obstacles. The score gap follows a steady trend without sharp fluctuations across the achievement distribution and with a similar effect for low- and high-scoring students ($b_{0.1}$=-13.284, $b_{0.9}$=-13.113). According to the results, there is a disparity between the performances of students with different levels of immigrant background.

The graphs in Figure 4 indicate heterogeneity and differences in the degree of influence of student characteristics, family background, and school characteristics on science performance. Although the negative or positive relationship of the variables given by the two methods is identical in most points for all students, the power of the effect is different mainly for low and high-achieving students, i.e. in the tails of the distribution. This can be seen from the course of the dashed black line where near the middle and alternately it follows the red line but at the ends, it follows an upward or downward trend with the b estimators being at two different levels which are separated by the straight line of least squares.

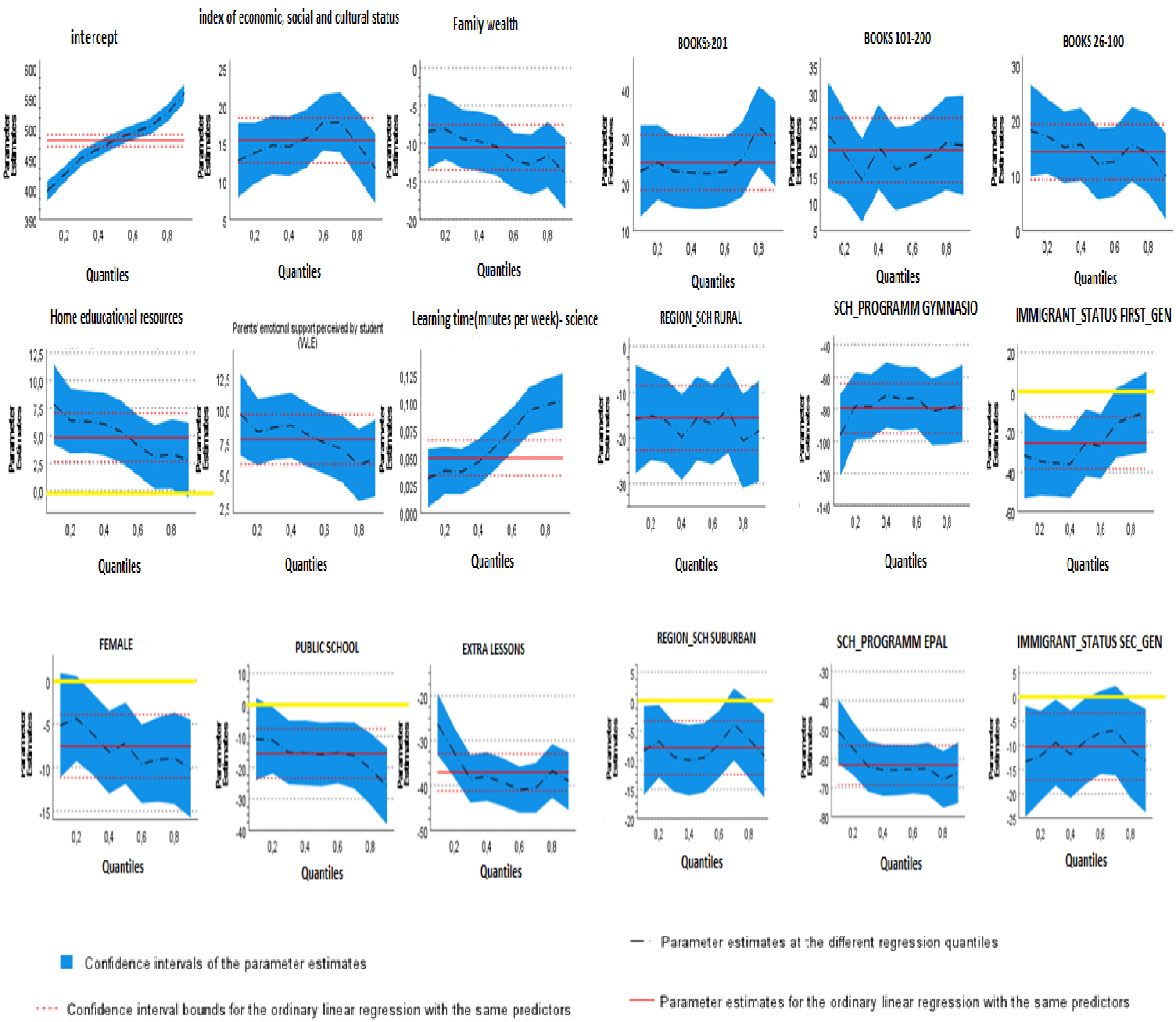

Figure 4: bq coefficients of the independent variables on different quantiles

6. Conclusions

In this paper, we studied a student's profile consisting of a wide set of characteristics. The sample was 6403 Greek students (approximately 4500 students had a valid answer for all independent variables). We used the OLS and QR analysis (SPSS statistical program) for comparison and examination of the degree of influence at different points of the performance distribution. The results showed that several variables differentially affect student grade-dependent science performance. This information could not be obtained if we had not implemented QR analysis.
Specifically, home cultural goods were shown not to affect student performance, as did class size across most of the distribution. Also, family wealth showed a negative effect on performance with greater influence on high-performing students. This fact in combination with the index of cultural goods leads us to the conclusion that learning abilities are not related to easy access to material goods. Family background affects high and low–performing students differently. The results indicated that low-performing students are more sensitive to simple resources which are directly related to education, such as textbooks and a quiet space with their desks to study. Instead, high-performing students are sensitive to more sophisticated resources such as many books at home. Moreover, low-performing students need a higher level of emotional support from their families. In contrast, high-performing students seem to have discovered more efficient study methods and rely on their strengths to optimize the performance of their learning abilities and skills. An additional key element that should characterize educational systems at the global level is whether they offer equal learning opportunities to their students. We could say that this goal is satisfied if social status (ESCS index), gender, and immigration background are not statistically significant predictors of performance. We observe large disparities between study programs and geographical areas for Greek students, as well as significant differences between students with different immigrant backgrounds. The above indicates that the Greek education system needs to make great efforts through targeted and appropriately adapted educational legislative reforms to reduce inequalities and the gap between low and high-performing students. It is also interesting that the students who attended extra lessons perform lower. This specific result directs us to the conclusion that the mindset and definition of learning that is set by the Greek public school are different from those that the PISA competition evaluates. In contrast, students in private schools achieve significantly higher scores. This indicates that their curriculum is more compatible with developing critical thinking and acquiring skills. The previous conclusion partially explains the consistently low position of Greek students in the general ranking among OECD countries.
Finally, the above results could be compared with future work with the same variables in data from the recent PISA 2022. The differences would be interesting because from 2018 to 2022 there existed a difficult period of Covid-19 that affected the field of education to a very large extent. A future development of the above work would be to study variables at a multilevel model. The results showed that the

ESCS index is a statistically significant predictor with a positive effect. However, the average index of the students who go to the same school (the average social status of the school) also plays an important role. The same happens with other variables. So, we could use a model of multilevel analysis to study variables at two levels (student-school), in order to estimate the degree of influence on student performance. The above model could be combined with QR analysis to identify any differences in various quantiles of the performance distribution (QR-Multilevel Regression).

Therefore, it stands to reason that policymakers need to consider not only the average-performing student but also low and high-achieving students. Each country must legislate in its aspects, reducing inequality and offering equal learning opportunities. A successful and robust education system also reflects general progress in other domains. All of the above conclusions indicate that PISA competitions, results, and research paper analyses are important for institutionalizing innovative educational reforms.

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