



## An analysis of Turkey's Pisa 2015 results using two-level hierarchical linear modelling

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### Abstract

In the field of education, most of the data collected are multi-level structured. Cities, city based schools, school based classes and finally students in the classrooms constitute a hierarchical structure. Hierarchical linear models give more accurate results compared to standard models when the data set has a structure going far as individuals, groups of individuals and communities of groups. In this study, the effects of the school level indicators on overall reading skills performance of 15 year-old group students within PISA 2015 Turkey application, are analyzed by using a two level hierarchical linear model. In the study, socioeconomic indicators of family, education level of the parents and some student level indicators regarding reading skills, school level indicators such as school type, number of students and number of teachers are also integrated to modelling process to reflecting the hierarchical data structure into the statistical model. At the end of the modelling process, factors that effects the reading skills are determined.

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## 1. Introduction

The Programme for International Student Assessment (PISA) is a survey that is conducted every three years to evaluate the knowledge and skills acquisition of the fifteen-year-olds in the leading industrialized countries. The survey is an outcome of collaboration among the governments of the countries that are the members of the Organization for Economic Co-operation and Development (OECD), and it makes use of international expertise services to make valid comparisons between countries and cultures. This study will determine the extent to which fifteen-year-old students are prepared to overcome the future problems of an information society. It also assesses the students' understanding of the complex reading materials they see in their daily lives. Another PISA goal is to see how well fifteen-year-old students can put into practice the things they learn in school mathematics and science in a world order that is rather based on technology and scientific development, revealing the strength of students' knowledge and skills that are required to participate

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in social life effectively. The PISA survey determines the influence on performance of learning motivation, interest in courses and the choice of learning type as observed in students (MEB-EARGED, 2005: 1-2).

The main focus of PISA surveys is to assess students' skills in reading, mathematical and scientific literacy. In framework of the project, each period focuses on only one of these subject areas. However, the other two areas are included in the assessment as well. In other words, one of these subject areas is the primary focus within a nine-year cycle. The first PISA survey was done in the year 2000 and focused on reading skills as the main area. The 2003 survey studied mathematical literacy, and the 2006 survey studied scientific literacy. In 2009, new cycle began with reading skills was the dominant subject area (MEB-EARGED, 2010: 2). The 2015 implementation was the sixth PISA survey, and its dominant subject area was scientific literacy, with fewer questions related to reading skills (Taş et al., 2016: 22).

Reading skills are focused on students' skills to use written information in actual situations (Sarıçoban and Alyas, 2012). In the PISA survey, reading skills are described as, "a person's comprehending, using, thinking of and engaging with written materials with the purpose of participating in the society, improving their potential and knowledge, and achieving their goals" This description goes beyond the traditional concept of analyzing information and comprehending a written text. The concept of reading skills in PISA involves a series of situations where people read and ways of presenting written texts (e.g., printed books, memos, online boards and news). It also involves readers' different ways of approaching and using texts from the functional and limited (e.g., finding specific practical information) to the deep and comprehensive (e.g., othering, understanding the ways to think and exist). The PISA reading skills evaluation has three dimensions: the text, the reader's approach to the text and the text's purpose, although it is not possible to demarcate these three subject areas strictly due to their interdependency (Taş et al., 2016: 22).

In PISA 2015, fifteen-year-old students were asked 103 questions to evaluate their capabilities in the reading skills subject area. Students' competence levels are determined based on their responses to survey questions.

A review of the reading skills literature found a variety of statistical methods that are used to determine the factors that influence achievement. This study claims that most of the data collected in the area of educational research have a multi-level structure, which leads to the use of advanced statistical methods. To determine the influential factors in student achievement on PISA 2009, Gürsakal (2012) used logistic regression analysis, while Özdemir and Gelbal (2014) used canonical common effect analysis. A review of the studies of reading skills indicated that Gülleroğlu, Bilican Demir and Demirtaşlı (2014) analyzed the 2003, 2006 and 2009 PISA data using stepwise multiple regression analysis and identified the best independent variables that affect achievement in reading skills. Similarly, Avşar and Yalçın (2015) examined achievement in reading and used chi-squared automatic interaction detection to evaluate the familial variables that presumably affected achievement.

On the other hand, this study uses a two-level hierarchical linear model to reveal the influential factors in reading skills in PISA 2015. Hierarchical linear models have a multi-level structure, and they are commonly used in statistical analyses. They are very useful models since their data structure clusters individuals with similar characteristics in the same groups. The data researchers encounter in studies in education, health, economy and social sciences mostly have a multi-level structure. In the field of education, the hierarchical structure consisted of provinces, schools based on the provinces, groups based on the schools and finally, the students in the groups.

## 2. Method

A total of 72 countries, including 35 OECD countries, participated in PISA 2015. In this study, the effects of school-level variables on the overall achievement of reading skills of 15-year-olds students in Turkey, were analyzed using a two-level hierarchical linear model. Gender, the social economic cultural index indicators of the family, the education level of the parents and student based reading skills are set as student level variables whereas the school type, number of students, number of teachers are set as school level variables. Both groups are introduced to the modeling process in order to reflect the hierarchical data structure to statistical model.

In the presence of multi-level structured data where the structure consisted of individuals, groups based on the individuals, communities based on the groups, hierarchal linear models result in better compared to standard models (Bryk and Raudenbush, 2002).

### 2.1. Population and Sample

In Turkey, 1324089 fifteen-year olds students are educated, however the reachable sample is assigned as 925366 students. For PISA 2015, the sampling method is obtained as stratified random sampling based on schools and at the end of the sampling process, 187 schools are selected for the survey. Among the fifteen-year olds students in the selected schools, 5895 of them are participated to PISA 2015 Turkey application by using simple random sampling.

In the Turkey sample of PISA 2015, the distribution of girls and boys are homogeneous with equal frequencies, there are 2938 girls and 2957 boys. The distribution of students depending on the school type is more heterogeneous compared to other school level variables. The frequency of students in basic education has a small amount, approximately 2%. There are 121 students in basic education, 3241 in general secondary education and 2533 in vocational technical education. Unlike the previous PISA surveys, in 2015, private schools are also included in Turkey sample with a proportion of 4%. 7 schools are private and 179 are public out of 187 schools.

### 2.2. Data Collection Method

In PISA, data are collected using two separate surveys, which are student-based survey and school-based survey. In the modeling process, answers of the student-based survey set as first-level data whereas the answers of school survey set as second-level data. The first level variables are obtained as reading skill value, social economic cultural index and the education levels of each parents The second level variables are school type (basic/ general secondary/ vocational and technical), regions, kind of school (private/public) and the number of teachers per student.

“The test design for PISA is based on a variant of matrix sampling where each student was administered a subset of items from the total item pool. To increase the accuracy of the measurement, PISA uses plausible values which are multiple imputations drawn from a posteriori distribution by combining the IRT scaling of the test items with a latent regression model using information from the student context questionnaire in a population model” (OECD, 2016).

In the two-level hierarchical linear model that will be used to determine the factors affecting the success of reading skills, the reading skills indicator is determined as the dependent variable. This indicator was included in modeling process by averaging the plausible values presented under PISA 2015. The plausible values for reading skills, are named as PV1READ, PV2READ, PV3READ, PV4READ, PV5READ, PV6READ, PV7READ, PV8READ, PV9READ and PV10READ.

### 2.3. Data Analysis

In the analysis of the data, hierarchical modeling method is used which is also a multi-level modeling technique. The samples obtained from the hierarchical structured main population are called as multi-level samples. It is assumed that, firstly, sub-groups are drawn from groups and then samples are drawn from sub-units included in these sub-groups. In this data structure, the sub-units within the groups tend to be more similar than the units drawn by simple random sampling from the main population. The reason for this resemblance is that the observations in groups are correlated to each other. Common environmental factors and having similar demographic conditions will create dependency between the units in the same group. In this case, the assumption of independence required for the standard models is not provided. Hierarchical linear models can be used as a solution where the observation units are correlated to each other due to the hierarchical structure between them.

### 3. Hierarchical Linear Models

Multi-level modeling techniques were first introduced by Aitkin and Longford (1986) and in the following years, owing to the developed computer programs, they have been used in many areas such as psychology, sociology, demography, econometrics and mainly in the field of education. By the end of the 90's Bryk and Raudenbush (1992) developed a hierarchical linear modeling technique as one of the multi-level modeling techniques.

Hierarchical linear models conceptually appear to be a hierarchical system of regression model equation. The use of known regression models in the presence of dependency resulting from the hierarchical data structure will cause the estimates to be unbiased and misleading. In this case, instead of the known regression models, it would be correct to use multi-level techniques, especially hierarchical models.

In the hierarchical modeling technique, a statistical model is established for each stage of the hierarchical structure and then these models are combined to reach final model. In multi-level models, the combined model has a very complex structure and it is hard to interpret. Therefore, sub-models belonging to stages are used in interpretations. Hierarchical linear models can be considered as two or more level. Although in applications, it possible to encounter three or four-level hierarchical structures, mostly a two-level hierarchical linear model is used.

In a two-level model, first level is individual level and the second level is belong to groups where the first level units come from. There isn't a requirement that group sizes are equal to each other.

Let  $Y_{ij}$  be the response variable for the  $i^{\text{th}}$  unit of the  $j^{\text{th}}$  group. The first level model can be written as:

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \dots + \beta_{qj}X_{qij} + r_{ij} \quad (1)$$

$$Y_{ij} = \beta_{0j} + \sum_{q=1}^m \beta_{qj}X_{qij} + r_{ij}$$

where  $k$  is the number of groups and  $n_j$  is the size of the  $j^{\text{th}}$  group ( $i = 1, 2, \dots, n_j$ ), ( $j = 1, 2, \dots, k$ ). In Equation 1,  $\beta_{0j}$  is the constant term, whereas  $\beta_{1j}, \beta_{2j} \dots \beta_{qj}$  represents the  $m$  slope parameters for

the first level ( $q = 1, 2, \dots, m$ ).  $X_{1ij}, X_{2ij}, \dots, X_{qij}$  are the explanatory variable measurements for the  $i^{\text{th}}$  unit of the  $j^{\text{th}}$  group.  $r_{ij}$  is the error term assumed to distributed normally with 0 mean and variance  $\sigma^2$ ,  $r_{ij} \sim N(0, \sigma^2)$ .

The first level model given in Equation 1 is similar to the known regression model. However, in hierarchical linear modeling, unlike classical regression analysis, the values of  $\beta_{1j}, \beta_{2j} \dots \beta_{qj}$ , which are the slope parameters of the main model, are estimated with the help of second level sub-models. Estimated values are replaced in the main model to achieve the desired predicted values  $Y_{ij}$ . Second level sub-models can be written as:

$$\begin{aligned}\beta_{0j} &= \gamma_{00} + \gamma_{01}W_{1j} + \gamma_{02}W_{2j} + \dots + \gamma_{0n}W_{nj} + u_{0j} \\ \beta_{1j} &= \gamma_{10} + \gamma_{11}W_{1j} + \gamma_{12}W_{2j} + \dots + \gamma_{1n}W_{nj} + u_{1j} \\ &\vdots \\ \beta_{mj} &= \gamma_{m0} + \gamma_{m1}W_{1j} + \gamma_{m2}W_{2j} + \dots + \gamma_{mn}W_{nj} + u_{mj}\end{aligned}\quad (2)$$

where  $n$  is the number of second level independent variables ( $p = 1, 2, \dots, n$ ). Similar to the representation in the main model,  $\gamma_{00}, \gamma_{10}, \dots, \gamma_{m0}$  ( $m+1$ ) are the constant terms and  $\gamma_{01}, \gamma_{02}, \dots, \gamma_{0n}, \gamma_{11}, \gamma_{12}, \dots, \gamma_{1n}, \dots, \gamma_{m1}, \gamma_{m2}, \dots, \gamma_{mn}$  are the slope parameters of the sub-models.  $W_{1j}, W_{2j}, \dots, W_{nj}$  represent the value of  $n$  independent variables. Finally, last component of each mode,  $u_{0j}, u_{1j}, \dots, u_{mj}$  are the error terms and distributed normally with mean 0 and normal variances  $\tau_{00}, \tau_{11}, \dots, \tau_{mm}$ , respectively.

The complex structured main model can be written as in Equation 3 by substituting the sub-model models (2) in the first level model (1):

$$Y_{ij} = \gamma_{00} + \sum_{q=1}^m \gamma_{q0} X_{qij} + \sum_{p=1}^n \gamma_{0p} W_{pj} + \sum_{p=1}^n \sum_{q=1}^m \gamma_{qp} W_{pj} X_{qij} + u_{0j} + \sum_{q=1}^m u_{qj} X_{qij} + r_{ij} \quad (3)$$

In multi-level models, the merged model has a very complex structure and is difficult to interpret. Thus, for convenience, sub-models are used in calculations and interpretations. The most appropriate model for the grouped data is obtained by comparing sub-models step by step. The least squares estimation method is used in parameter estimation process of two level hierarchical linear model (Bryk and Raudenbush, 2002).

#### 4. Application and Results

In this study, the effects of student and school level variables, which are considered to have an effect on average reading skills, were analyzed by a two-level hierarchical linear model within the scope of PISA 2015 Turkey application. In the implementation phase of the analysis, the seventh version of the HLM program, HLM7 which is developed for hierarchical modeling by Raudenbush, Bryk, et. al. (2011), is used. In the modeling phase, missing observations were excluded from the analysis and a total of 5708 students from 176 schools were modeled. The variables used in modeling process are given in Table 1.

**Table 1.** Variables used in modeling process

| Dependent     | Student-Level (Level 1)<br>Independent Variables  | School-Level (Level 2)<br>Independent Variables                |
|---------------|---|--|
| Reading-Skill | Economic social cultural index (ESCS)<br>Mother's education level (MEL)<br>Father's education level (FEL) | School type<br>Kind of school<br>Region<br>Teacher per student |

The effects and their statistical significance of the variables analyzed in the study are summarized in Table 2:

**Table 2.** Estimation of the student level effects and school level effects

|         | Variables | Coefficient | Standard Error | p-value |
|---------|-----------|-------------|----------------|---------|
| Level 1 | ESCS      | 25,167      | 8,287          | 0,002*  |
|         | MEL       | -0,028      | 3,736          | 0,994   |
|         | FEL       | -11,693     | 4,376          | 0,008*  |
| Level 2 | Type      | -20,861     | 6,989          | 0,003*  |
|         | Kind      | 6,440       | 20,612         | 0,755   |
|         | Teacher   | 0,053       | 0,119          | 0,654   |
|         | Region    | -6,184      | 1,129          | <0,001* |

\*: significant at  $\alpha=0.05$

#### 5. Conclusion

Depending on the two-level hierarchical model results given in Table 2, it can be said that, among the first level indicators, economic social cultural index ESCS ( $p=0,002 < \alpha=0.05$ ) and the education level of the father FEL ( $p=0,008 < \alpha=0.05$ ) are statistically significant whereas there is no effect of mother's education level MEL on reading skill achievement. The effect of school type (basic education/ general secondary education/ vocational and technical education) ( $p=0,003 < \alpha=0.05$ ) and the region that the school is located ( $p<0,001$ ) are also statistically significant at level  $\alpha=0.05$ . There is no difference between the mean success of private school and public school ( $p=0,755 > \alpha=0.05$ ).

Similarly, the numbers of teacher per student has no significant effect on the mean reading skill performance of the student ( $p=0,654 > \alpha=0.05$ ).

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## PISA 2015 Türkiye sonuçlarının iki düzeyli hiyerarşik doğrusal modelleme ile analizi

### Öz

Eđitim alanında toplanan birçok veri yapısı, çok düzeyli yapıdadır. İller, iller bazında okullar, okullar bazında sınıflar ve son olarak sınıflardaki öğrenciler hiyerarşik bir yapı teşkil etmektedir. Hiyerarşik doğrusal modeller, birey aşamasından başlayarak, bireyler, bireylerden meydana gelen gruplar ve gruplardan meydana gelen topluluklar şeklinde devam eden hiyerarşik bir yapıya sahip veri kümesi varlığında, standart modellere göre daha doğru sonuçlar veren modellerdir. Bu çalışmada, PISA 2015 Türkiye uygulaması kapsamında 15 yaş grubu öğrencilerin okuma becerileri alanındaki genel başarıları üzerindeki okul düzeyi değişkenlerinin etkileri iki düzeyli bir hiyerarşik doğrusal model ile analiz edilmiştir. Çalışmada ailenin sosyo-ekonomik göstergeleri, ebeveynlerin eğitim düzeyleri ve okuma becerilerine ilişkin birtakım öğrenci düzeyi değişkenlerin yanı sıra, öğrencinin eğitim gördüğü okula ilişkin okul türü, okuldaki öğrenci ve öğretmen sayısı gibi okul düzeyi değişkenleri de modelleme sürecine dahil edilerek, öğrenci ve okul arasındaki hiyerarşik veri yapısı istatistiksel modele yansıtılmıştır. Modelleme sonucunda, okuma becerileri üzerinde etkisi olan değişkenler tespit edilmiştir.

*Anahtar sözcükler:* PISA 2015; okuma becerileri; çok düzeyli modelleme; hiyerarşik doğrusal model; okul düzeyi değişkenleri

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