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Measuring the Efficiency of Secondary Schools in Different Regions in Turkey Using Data Envelopment Analysis

(Türkiye'de Farklı Bölgelerdeki Ortaöğretim Okullarının Etkinliğinin Veri Zarflama Analizi ile Ölçülmesi)

İbrahim Demir*, Özer Depren & Serpil Kılıç*****
Yıldız Technical University, GENAR Research Company, Yıldız Technical University, Turkey

Abstract: The low performance of Turkey in the Programme for International Student Assessment (PISA) was a great disappointment. To investigate the likely causes for the low performance in mathematics, reading and science, this study measured the efficiency of secondary schools in different regions in Turkey. In this study, NUTS 1 (Nomenclature of Territorial Units for Statistics) was used for the regions. The sampling data consisted of the students who participated in the Programme for International Student Assessment (PISA) 2003 in Turkey. The efficient and inefficient schools in different regions in Turkey were determined by analyzing the sample data. Strategies for turning the inefficient schools into efficient were examined using output oriented CCR model. As a result of the study, it was found that 7 of the 48 schools (%14.56) were efficient. Also, it was found that the most efficient region in Turkey was Istanbul and the most efficient school types were science high schools and police colleges.

Keywords: data envelopment analysis, education, performance of secondary schools, PISA

Öz: Türkiye'nin Uluslararası Öğrenci Değerlendirme Programı (PISA)'ndaki düşük performansı büyük bir hayal kırıklı olmuştur. Matematik, Fen Bilimleri ve Türkçe alanlarındaki bu düşük performansın sebeplerini araştırmak amacıyla, bu çalışmada farklı bölgelerdeki ortaöğretim okullarının performansları incelenmiştir. Örneklem verisi Türkiye'de PISA 2003 çalışmasına katılan öğrencilerden oluşmaktadır. Bu çalışmada, bölgeler için İstatistikî Bölge Birimleri Sınıflaması 1 (İBBS 1) kullanılmıştır. Türkiye'nin farklı bölgelerindeki etkili ve etkili olmayan okullar örnek veri seti kullanılarak analiz edilmiştir. Etkili olmayan okulların etkili hale gelebilmeleri için uygulamaları gereken stratejiler çıktı yönelimli CCR modeli kullanılarak araştırılmıştır. Çalışmada sonuç olarak, Türkiye'deki en etkili bölgenin İstanbul Bölgesi ve en etkili okul türlerinin ise Fen Liseleri ve Polis Koleji olduğu bulgulanmıştır.

Anahtar kelimeler: veri zarflama analizi, eğitim, ortaöğretim performansı, pisa

Introduction

Cultural level, knowledge and experience of young people who determine the level of development in society are the most important elements for a cultivated future community. That is why assessing the level of students' knowledge and determining the factors which influence students' achievement negatively and positively are very important to develop countries' cultural level. Similar to the efforts of several countries, Turkey has also been seeking ways to investigate and find how its youth is coping with the demands of modern society and participating in the Programme for International Student Assessment Project (PISA) in 2003 can be regarded as an important step aimed towards this goal.

The OECD's Programme for International Student Assessment (PISA) is a collaborative effort, involving all OECD countries and some of partner countries, to assess how well 15-year-old students are prepared to real life in society.

Two stage stratified sampling design was used for PISA assessment. The first stage sampling units consisted of schools having 15 year-old students. The second stage sampling units were 15 year-old students within sampled schools. Schools were sampled systematically from a comprehensive national list of all eligible schools with probabilities that were proportional to a measure size. This is referred to as systematic probability proportional to size sampling (or PPS). Also, it was necessary to reduce the coverage of the target population by excluding, for instance, a small, remote geographical region due to inaccessibility, or a language group, possibly due to political, organizational or operational reasons, or special education needs students (PISA, 2005).

Purpose of the Study

The purpose of this study was to assess the efficiency of secondary schools in different region in Turkey.

Methodology

Population and Study Group

The sampling data in this study was prepared from the students who participated in Programme for International Student Assessment (PISA) 2003 in Turkey. Efficient and inefficient schools in Turkey were determined by analyzing the sample data by grouping schools by regions. From the sampling selection, some of the schools were not participated in this assessment. Finally, 48 schools were included in the data set.

Data Collection

Data Envelopment Analysis

In this study, the secondary school performances in different regions in Turkey were examined using Data Envelopment Analysis (DEA) approach. It is a linear programming methodology which is used to measure efficiency.

When previous studies were examined, it appeared that there were not many studies about measuring efficiency of secondary schools types in different regions in the countries using Data Envelopment Analysis (DEA).

Kirjavainen and Loikkanen (1998) studied efficiency differences among Finnish

senior secondary schools by DEA. They showed average efficiencies in the most extensive models which were 82–84 percent. When parents' educational level was treated as an additional input, average efficiency increased to 91 per cent. As a second stage after DEA analysis, they explained the degree of inefficiency (100-efficiency score) by a statistical Tobit model. They showed that parents' educational level affected efficiency positively.

Barbetta and Turati (2003) deal with the role of proprietary structure in explaining efficiency within the Italian school industry. They analyzed a sample consisting of 497 private and public schools located in Piemonte, a region in the Northâ, western part of the country. In stage one of the analyses, they provided robust estimates of efficiency scores, using the two most widely known techniques in applied works, namely Data Envelopment Analysis (DEA) and Stochastic Frontiers (SF).

Johnes, Bradley and Millington (2001) assessed the technical efficiencies of all secondary schools in England over the period 1993–1998. Their results suggested that the greater the degree of competition between schools the more efficient they were. The strength of this effect has also increased over time which was consistent with the evolution of the quasi-market in secondary education.

Alfonso and Aubyn (2005) determined the efficiency of expenditure in education provision using outputs of PISA of 25 countries. By regressing data envelopment analysis output scores on nondiscretionary variables, both using Tobit and a single and double bootstrap procedure, they showed that inefficiency was strongly related to GDP per head and adult educational attainment.

Alexander and Jaforullah (2004) showed that the New Zealand secondary school system is a relatively homogeneous one in the sense that it is predominantly state-funded and each school has many obligations placed upon it by a national system of qualifications. Nevertheless, schools do vary along a number of dimensions that have the potential to affect their efficiency, such as the socio-economic backgrounds of their students, the form of school ownership and organization and, of course, the quality of their teaching staff.

In our country, similar studies have been made and some of them are;

Atan, Karpat and Göksel (2002) measured the performance of Anatolia High Schools in Ankara in 2001 by Data Envelopment Analysis. They showed that, 6 inputs and 4 outputs variables belonging to 22 Anatolia High Schools have been taken into account.

Yeşilyurt and Alan (2003) worked on the effectiveness of Scientific High Schools in Turkey. They showed that the efficiency of all schools except Kars Scientific High Schools were over %90.

Davutyan, Demir and Polat (2009) used DEA and econometric methods to evaluate educational efficiency. They founded that 59 of 81 provinces were inefficient and 22 provinces were efficient. The average score and standard deviations were, respectively: 1.0096 and 0.0089.

In Turkey, there are not enough studies about assessing secondary school performance by region using data envelopment analysis. Therefore, we thought that our study could be used for further studies and it could be a good reference for them.

Output Oriented CCR Model

Efficiency is a measure of time, cost and effort. Measures of an efficient information system include its productivity, processing time, operational costs and level of automations.

The Data Envelopment Analysis (DEA) measures the efficiency of multiple Decision Making Units (DMUs) when the production process presents a structure of multiple inputs and outputs. In other words, it is a performance measurement technique which can be used for evaluating the relative efficiency of decision-making units (DMU's) in organizations.

There are two types of orientations in DEA approach. One of them is input oriented and the other one is output oriented. Input oriented model's objective takes the form maximizing weighted outputs given the level of inputs. Output oriented model's objective takes the form minimizing weighted inputs given the level of outputs.

In this analysis, as introduced by Charnes, Cooper, and Rhodes, the ratio of outputs to inputs is used to measure the relative efficiency of the (Decision making unit)$_j$=(Decision making unit)$_0$ to be evaluated relative to the ratios of all of the j = 1, 2, …, n (Decision making unit)$_j$. We can interpret the CCR construction as the reduction of the multiple-output/multiple-input situation for each decision making unit (DMU).

Following equation shows Output Oriented CCR models (Cooper, Seiford & Zhu, 2004).

$$E_k = Min\left(\sum_{i=1}^{m} v_i X_{i0} / \sum_{r=1}^{p} u_r Y_{r0}\right)$$

$$\sum_{i=1}^{m} v_i X_{ik} / \sum_{r=1}^{p} u_r Y_{rp} \geq 1$$

$$u_r \geq \varepsilon \qquad v_i \geq \varepsilon \qquad \varepsilon > 0$$

The Charnes-Cooper (1962) transformation for linear fractional programming yields the model below (Cooper, Seiford & Tone, 2007).

$$E_k = Min\left(\sum_{i=1}^{m} v_i X_{ik}\right)$$

$$\left(\sum_{r=1}^{p} u_r Y_{rk}\right) = 1$$

$$\left(\sum_{r=1}^{p} u_r Y_{rj}\right) - \left(\sum_{i=1}^{m} v_i X_{ij}\right) \leq 0$$

$$u_r \geq \varepsilon \qquad v_i \geq \varepsilon \qquad j = 1, \ldots, n \quad r = 1, \ldots, p \quad i = 1, \ldots, m$$

Y_{rk}: The value of output r for DMU k

X_{ik}: The value of input i for DMU k,

s_i, s_r: Input and output slacks, respectively.

DMU_0 is efficient if and only if β=1 and all slack variables are zero. DMU_0 is weakly efficient if β=1 and some of the slack variables are zero, not all slack variables.

The following equation shows CCR models with uncontrollable input variables (Cooper, Seiford & Zhu, 2004)

$$min\theta - \varepsilon(\sum_{i\epsilon I_D} s_i^- + \sum_{r=1}^{p} s_r^+)$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{i0} \qquad i \in I_D$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{i0} \qquad i \in I_N$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{r0} \qquad r = 1, \dots, s$$

$$\lambda_j \geq 0 \qquad \text{j=1,…,n}$$

I_D and I_N refer to discretionary and nondiscretionary input set. There are several reasons why we preferred to use this model. However, mainly because, education production depends not only upon the levels of discretionary inputs like teacher labor but also upon nondiscretionary factors such as family inputs. When some inputs are uncontrollable, the operational question of interest is often whether a proportional reduction in controllable inputs is possible, within a given environment, while maintaining observed output levels. In our study, the highest occupational status of parents variable was included as an uncontrollable variable.

Nomenclature of Territorial Units for Statistics

To analyze school performance in each region, however, the Nomenclature of Territorial Units for Statistics (NUTS) was used. NUTS was established by Eurostat more than 30 years ago in order to provide a single uniform breakdown of territorial units for the production of regional statistics for the European Union. The NUTS nomenclature was created and developed according to the following principles:

1. The NUTS favours institutional breakdowns.
2. The NUTS favours regional units of a general character.
3. The NUTS is a three-level hierarchical classification

In our study NUTS Level 1 is used because it lets us analyze the data deeply. Table 1 shows the cities including NUTS Level 1 (DPT, 2003).

Table 1: Regions of Nuts Level 1

Regions	Cities
İstanbul	İstanbul
Western Anatolia	Ankara, Konya, Karaman
Eastern Marmara	Bursa, Eskişehir, Bilecik, Kocaeli, Sakarya, Düzce, Bolu, Yalova
Aegean	İzmir, Aydın, Denizli, Muğla, Manisa, Afyon, Kütahya, Uşak
Western Marmara	Tekirdağ, Edirne, Kırklareli, Balıkesir, Çanakkale
Mediterranean	Antalya, Isparta, Burdur, Adana, Mersin, Hatay, Kahramanmaraş, Osmaniye
Western Black Sea	Zonguldak, Karabük, Bartın, Kastamonu, Çankırı, Sinop, Samsun, Tokat, Çorum, Amasya
Middle Anatolia	Kırıkkale, Aksaray, Niğde, Nevşehir, Kırşehir, Kayseri, Sivas, Yozgat
Eastern Black Sea	Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane
Southeast Anatolia	Gaziantep, Adıyaman, Kilis, Şanlıurfa, Diyarbakır, Mardin, Batman, Şırnak, Siirt
Middle East Anatolia	Malatya, Elazığ, Bingöl, Tunceli, Van, Muş, Bitlis, Hakkâri
Northeast Anatolia	Erzurum, Erzincan, Bayburt, Ağrı, Kars, Iğdır, Ardahan

Procedures

The low performance of Turkey in the Programme for International Student Assessment (PISA 2003) was a great disappointment. To investigate the likely causes for low performance in mathematics, reading and science, this study measured efficiency of secondary schools in different regions in Turkey using Data Envelopment Analysis (DEA). The performance of Turkish educational system which was effected multiple input and output factors such as school size, student/teacher ratio, GDPPPP, mathematics, science and reading score etc. could be measured very well using DEA. Because, DEA was the most effected method for the system which has multiple inputs and outputs. Therefore, strategies used for increasing Turkish secondary school efficiency can be created more easily. Turkey reaches the level of contemporary civilization easily with the help of these strategies.

Efficient and inefficient schools in different regions in Turkey were determined by analyzing the sample data.

Input and output variables were chosen after examining the most common variables in previous national and international studies dealing with effects of students' achievement of schools, regions or countries.

In our analysis each school type in each region was called decision making unit (DMU). Effectiveness of each DMU was calculated using input and output variables which were listed below.

Input Variables

1. School Size (SCHSIZE)

2. Student / Teacher Ratio (STRATIO)

3. Highest occupational status of parents (HISEI): it was used as 1/HISEI (Scheel, 2001).

4. Gross Domestic Product Purchasing Power Parity (GDP PPP): In this study, it was used as 1/GDP PPP. GDP PPP values from year 2000 were used because GDP PPP values from 2003 were not computed by regions.

5. Schooling Ratio (SCHRATIO): it was used as 1/SCHRATIO. Schooling ratio values from year 2000 used because GDP PPP values from 2003 were not computed by regions.

Output Variables

1. Mathematics Score (MATH)

2. Reading Score (READ)

3. Science Score (SCIE)

In this study, Nuts Level-1 regions for Turkey were used and following list shows school types for every region. But all of school types are not available for every region in PISA 2003 data set.

1. General High Schools

2. Vocational High Schools

3. Anatolian Vocational High Schools

4. Science High Schools

5. Anatolian High Schools

6. Primary Schools

7. Private Schools

8. Police Collages

Table 2 shows which school types are available according to the NUTS level 1 region for Turkey.

Table 2: Regions and School Types

Regions	1	2	3	4	5	6	7	8
İstanbul	X	-	-	-	X	X	X	-
Western Anatolia	X	X	X	X	X	X	X	X
Eastern Marmara	X	-	X	-	-	-	X	-
Aegean	X	X	X	X	X	X	-	-
Western Marmara	X	X	-	-	-	X	-	-
Mediterranean	X	X	X	-	X	X	X	-
Western Black Sea	X	X	X	-	-	X	-	-
Middle Anatolia	X	X	X	-	-	-	-	-
Eastern Black Sea	X	X	-	-	-	X	-	-
Southeast Anatolia	X	X	X	-	X	X	-	-
Middle East Anatolia	X	-	-	-	-	X	-	-
Northeast Anatolia	X	-	X	-	-	-	-	-

X: Available in data, -: Not available in data

Findings

In this study, 48 different schools were analyzed using output oriented CCR model with EMS (Efficiency Measurement System) program. Table 3 shows descriptive statistics for all variables.

Table 3: Descriptive Statistics

Variables	Minimum	Maximum	Median	Mean	sd
SCHSIZE	116.00	1919.00	774.25	847.69	497.09
STRATIO	7.47	56.56	15.77	20.08	11.49
HISEI	29.80	67.84	39.27	42.64	9.23
GDP PPP	781.00	2749.71	1725.76	1765.84	609.59
SCHRATIO	17.16	37.10	29.59	29.06	6.59
MATH	241.60	703.15	408.64	429.81	107.21
READ	266.45	651.35	427.46	439.87	94.33
SCIE	281.14	679.95	417.70	439.50	95.33

When efficient schools were sorted in ascending order by efficiency score, the most efficient school was Science High Schools in Aegean Region and the least efficient school among the efficient schools were Anatolian High Schools in Istanbul Region. When inefficient schools were sorted in ascending order by efficiency score, Anatolian Vocational High Schools in Western Anatolian Region ranked higher and the worst performing schools

were Primary Schools in Middle Anatolia Region. Table 4 shows the number of efficient schools and total number of schools with percentage of efficiency.

Table 4: Percentage of efficiency for each region

Regions	Number of Efficient Unit	Total Number of Unit	Percentage of Efficiency
İstanbul	2	4	%50.0
Western Anatolia	2	7	%28.6
Eastern Marmara	0	3	%0.00
Aegean	1	6	%16.7
Western Marmara	0	3	%0.00
Mediterranean	0	6	%0.00
Western Black Sea	0	4	%0.00
Middle Anatolia	1	3	%33.3
Eastern Black Sea	1	3	%33.3
Southeast Anatolia	0	5	%0.00
Middle East Anatolia	0	2	%0.00
Northeast Anatolia	0	2	%0.00

According to Table 4, there were not any efficient schools in Eastern Marmara, Western Marmara, Mediterranean, Western Black Sea, Southeast Anatolia, Middle East Anatolia and Northeast Anatolia. Furthermore, successful regions are Istanbul, Middle Anatolia, Eastern Black Sea, Western Anatolia and Aegean, respectively.

It was shown that Science High Schools in Western Anatolian could be referenced 35 times, Private High Schools in Istanbul could be referenced 10 times and Science High Schools in Aegean could be referenced 8 times for inefficient schools. However, Vocational High Schools in Middle Anatolia was not efficient enough to be referenced.

Table 5 shows school types and efficient of percentages.

Table 5:Percentage of efficiency for school types

School Types	Number of Efficient Unit	Total Number of Unit	Percentage of Efficiency
General High Schools	0	12	%0.00
Vocational High Schools	2	8	%25.0
Anatolian Vocational High Schools	0	8	%0.00
Science High Schools	2	2	%100
Anatolian High Schools	1	4	%25.0
Primary Schools	0	9	%0.00
Private High Schools	1	4	%25.0
Police Collages	1	1	%100

According to Table 5, there were not any efficient schools among General High Schools, Anatolian High Schools and Primary Schools. Science High Schools and Private High Schools were the most efficient school types in Turkey.

Average school size, student/teacher ratio and HISEI score of the Anatolian High Schools in Aegean should be decreased by 129,869, 5,628 and 0,005 respectively while mathematics and science score should be increased by 41,719 and 7,669 point respectively to become an efficient school. However, HISEI cannot change in a short term, so it could not be said that it should increase. It only could be said that if it was 19.48 point lower than present value, Anatolian High Schools in Aegean would be efficient.

Table 6: Present and target values for Anatolian high schools in Aegean

Variables	Present Values	Target Values
SCHSIZE	553.00	423.131
STRATIO	14.55	8.922
HISEI	47.19	66.67
GDP PPP	2129.66	2129.66
SCHRATIO	32.34	32.34
MATH	527.49	569.209
READ	528.94	528.94
SCIE	536.80	544.469

Table 6 shows present and target values for Anatolian High Schools in Aegean to become efficient unit. Other schools could be analyzed similarly.

Results and Suggestions

In this study, the secondary school performances in different regions in Turkey were examined using the Data Envelopment Analysis approach. The dataset from Programme for International Student Assessment Project in 2003 was used in the analysis. According to the sample data, the most efficient region came out to be İstanbul Region, but the most efficient schools were Science High Schools in Aegean Region, while the worst performing schools were Primary Schools in Middle Anatolia Region. Also, it was revealed that Science High Schools in Western Anatolian were referenced 35 times as inefficient schools. However, Vocational High Schools in Middle Anatolia was not efficient enough to be referenced. Furthermore, there were not any efficient schools among General High Schools, Anatolian High Schools and Primary Schools. Science High Schools and Private High Schools were the most efficient school types in Turkey.

As a result of the study, it was found that 7 of the 48 schools (%14.56) were efficient and above the average efficiency score which is 1.73. The study showed that Turkish secondary educational performance should increase for better education. Another result of our analysis, generally, schooling ratio of Eastern Turkey should be increased, school size and student teacher ratio for all kind of schools should be decreased for high quality education system in Turkey. Furthermore, the education level of parents should also be increased to bring up cultivated children for an advanced society. Furthermore the knowledge about not only mathematics but also science should be increased because it was showed that examination scores of these subjects were lower than reading score.

Alexander and Jaforullah (2004) showed that school size, socio economic background and schooling ratio have a huge affect on school performance. Similarly, in our study, these factors are the most important factors in achievement and they must be improved for a better education system.

Furthermore, the improvement of some school types such as General High Schools, Anatolian High Schools and Primary Schools should receive priority. It was also revealed that there were not any efficient schools in Eastern Marmara, Western Marmara, Mediterranean, Western Black Sea, Southeast Anatolia, Middle East Anatolia and Northeast Anatolia. Similar results could be found in Davutyan, Demir and Polat's study (2009). They similarly found İstanbul, Ankara, Karaman, Kayseri and Nevşehir etc. as efficient units.

It is a well known fact that performance of schools differs between school types especially in the eastern part of Turkey. In Turkey, resources of education could not be delivered equally to each region (World Bank, 2005). Therefore, government should consider these areas to have top priority for high quality education in Turkey. Also, other problems of these areas were determined in the report of the World Bank in 2005. According to the World Bank report in 2005, sustainability of the education, student-teacher ratio, the number of classified teacher and problems of delivering resources were the most common problems in Turkey. Government should solve these problems to increase not only secondary school performance but also the performance of education. Furthermore, inefficient schools should create better strategies which were used by efficient schools to become efficient schools. As in the study of Alfonso and Aubyn (2005), GDP PPP, Schooling ratio, educational level of parents, mathematics and science scores should be increased while average school size and student teacher ratio should be decreased in Turkey in order to increase the efficiency of education system. Also we thought that increasing the number of teachers and establishing new schools could solve these problems. Besides, increasing the number of certificated teachers, arranging competitive examinations of mathematics and science or arranging some seminars explaining usage of mathematics and science in daily

life could improve the level of Turkish education.

We believe that supplementing the present study with detailed analysis such as multilevel hierarchical modeling and structural equation modeling would be very beneficial to the Turkish educational system and, more importantly, to its students.

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About the Author(s):

** İbrahim Demir graduated at Yıldız Technical University. He is working as an Assistant Professor and vice head of the Statistics Department in Faculty of Arts and Sciences at Yıldız Technical University. He is currently teaching undergraduate and graduate lectures at university. His teaching and research interests are Data Envelopment Analysis and Hierarchical Linear Analysis on PISA and TIMMS data. He has written more than 7 articles. e-mail: idemir@yildiz.edu.tr*

*** Serpil Kılıç is a Research Assistant in the Department of Statistics at Yıldız Technical University, joining department in 2007. She received a B.S. degree in Statistics in 2006 and an M.S. degree in Statistics in 2008 from Yıldız Technical University in İstanbul. She has been studying for her doctor's degree in Statistics at Marmara University since 2008. Her main interest fields are measuring educational performance and multilevel statistical modeling. e-mail: ozerdepren@gmail.com*

**** Özer Depren has been working for GENAR Research Company as a Statistician from 2008. He received a B.S. degree in Statistics in 2006 and an M.S. degree in Statistics in 2008 from Yıldız Technical University in İstanbul. He has been studying for her doctor's degree in Statistics at Marmara University since 2009. His main interest fields are assessing educational efficiency and statistical modeling. e-mail: serkilic@yildiz.edu.tr*