THE ANALYSIS OF TOTAL FACTOR EFFICIENCY IN THE PUBLIC LIGNITE MINING ORGANIZATIONS IN TURKEY

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ABSTRACT

THE ANALYSIS OF TOTAL FACTOR EFFICIENCY IN THE PUBLIC LIGNITE MINING ORGANIZATIONS IN TURKEY

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In recent years, the risks created by the import of energy on the security of energy supply has encouraged countries to utilize local resources to a greater extend, and for many countries including Turkey coal is at the top of the local resources. However, it is not sufficient for countries to have an energy resource itself. Intense competition in today's globalized system requires the resources to be produced and utilized in the most economical manner. The supply of the resources to the market in a competitive way is possible by employing an efficient operation, which is then possible only through the business units producing these resources working efficiently.

In this study, the efficiencies of the eight establishments of the Turkish Coal Enterprises (TKI) between 2006 to 2009 were analyzed by using Data Envelopment Analysis (DEA), Super Efficiency (SE) and Malmquist Total Factor Productivity Index (MI) methodologies. For the analyses, three output oriented models were constructed and used: Production Efficiency, Revenue Efficiency and Work Safety Efficiency models. In determining the input and output data used in the analyses, it was benefited from similar studies searched in the literature, knowledge of business and economics and a series of brainstorming of the expert panel consisting of ten high level representatives of the public and private lignite mining companies as well as that of the Turkish Ministry of Energy and Natural Resources.

As a part of the analyses, first the production and revenue efficiencies of the establishments were analyzed by using Constant Return to Scale (CRS) and Variable Return to Scale (VRS) methods of DEA. Within this context, efficient and inefficient establishments for the years between 2006 to 2009, and benchmarks for inefficient establishments to move to becoming efficient were determined. Furthermore, for the production and revenue efficiency models, the target values and improvement potentials for the inefficient establishments in CRS analyses to becoming more efficient were calculated by using benchmarks tables and 2009 realized values of inputs and outputs. Second, the efficiency rankings of the efficient establishments among themselves between 2006 to 2009 were determined by using SE methodology. Third, to provide the dynamic analysis of the development of the establishments' efficiency levels in time, the changes of production, revenue and work safety efficiencies of the establishments between 2006 to 2009 were analyzed using the Malmquist Index (MI) methodology. MI analyses included the analysis of the efficiencies in four efficiency components (Technical, Technological, Pure and Scale efficiencies) as well as the calculation of the Total Factor Productivity Indexes of the establishments.

Keywords: Coal, DEA, Super Efficiency, Total Factor Productivity, Malmquist Index

ÖZ

TÜRKİYE'DEKİ KAMU LİNYİT İŞLETMELERİNİN TOPLAM FAKTÖR ETKİNLİKLERİNİN ANALİZİ

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Enerjide ithalat bağımlılığının enerji arz güvenliği üzerinde yarattığı riskler son yıllarda ülkeleri yerli enerji kaynaklarını artan oranda kullanmaya yönlendirmektedir. Aralarında Türkiye'nin de bulunduğu çoğu ülke için kömür yerli enerji kaynaklarının başında gelmektedir. Ülkeler için bir enerji kaynağına sahip olmak tek başına yeterli değildir. Günümüzün küreselleşen yoğun rekabet ortamında bu kaynakların en ekonomik bir şekilde üretilmesi ve kullanılması gereklidir. Sahip olunan kaynakların piyasaya en rekabet edebilir şartlarla arzı bu kaynakların üretiminde etkinliğin sağlanmasıyla; bu ise enerji kaynaklarını üreten işletmelerin etkin çalışmasıyla mümkündür.

Bu çalışmada, Türkiye Kömür İşletmeleri (TKİ) Genel Müdürlüğüne bağlı sekiz işletmenin 2006-2009 yılları arasındaki etkinlikleri Veri Zarflama Analizi (VZA), Süper Etkinlik (SE) ve Malmquist Toplam Faktör Verimliliği Endeksi (MI) metodolojileri kullanılarak analiz edilmiştir. Analizler için üç çıktı yönelimli model kurulmuş ve kullanılmıştır: Üretim Etkinliği, Gelir Etkinliği ve İş Güvenliği Etkinliği modelleri. Analizlerde kullanılan girdi ve çıktıların belirlenmesinde literatür araştırmasıyla elde edilen benzer çalışmalardan, temel işletme ve ekonomi bilgisinden ve kamu ve özel sektör linyit işletmeleriyle Enerji ve Tabii Kaynaklar Bakanlığı'nın üst düzey temsilcilerinden (üretimle ilgili Genel Müdür Yardımcıları ve Daire Başkanları) oluşan uzmanlar paneli ile yapılan bir seri beyin fırtınasından elde edilen sübjektif uzman görüşlerinden yararlanılmıştır.

Çalışmada ilk olarak TKİ işletmelerinin üretim ve gelir etkinlikleri VZA'nın CRS ve VRS metodları kullanılarak analiz edilmiştir. Bu kapsamda 2006-2009 yıllarında etkin olan ve etkin olmayan işletmeler ile etkin olmayan işletmelerin etkin olabilmesi için referans (benchmark) alması gereken etkin işletmeler belirlenmiştir. Daha sonra referans (benchmarks) tabloları kullanılarak, üretim ve gelir etkinliği modellerinde etkin olmayan işletmelerin etkin olabilmesi için hedef değerler ve iyileştirme oranları 2009 yılı gerçekleşen değerler baz alınarak hesaplanmıştır. İkinci olarak, etkin olan işletmelerin kendi aralarındaki etkinlik sıralamaları 2006-2009 dönemindeki her bir yıl için SE metodolojisi kullanılarak belirlenmiştir. Üçüncü olarak, zaman içerisindeki etkinlik değişimlerinin analizine imkan sağlamak üzere 2006-2009 döneminde işletmelerin üretim, gelir ve iş güvenliği etkinliklerindeki değişim MI metodolojisi kullanılarak analiz edilmiştir. MI metodolojisi ile işletmelerin etkinlik değişimlerinin analizi dört etkinlik bileşeni (Teknik Etkinlik, Teknolojik Etkinlik, Saf Etkinlik ve Ölçek etkinliği) bazında yapılmış; ayrıca işletmelerin Toplam Faktör Verimliliği Endeksleri hesaplanmıştır.

Anahtar Kelimeler: Kömür, VZA, Süper Etkinlik, Toplam Faktör Verimliliği, Malmquist Index

To My Family

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CHAPTER 1

INTRODUCTION

Energy is among the most basic inputs for nations to sustain their social and economic development. Implementation of a sustainable energy policy covering economical and environmental aspects is important for energy security of countries.

In recent years, the risks created by the import of energy on the security of energy supply has encouraged countries to utilize local resources in addition to other policy orientations such as the use of renewable energy, energy efficiency, and new energy technologies. For many countries, coal is at the top of local resources because coal is present in wide geographic areas throughout the world, and has longer lasting reserves when compared against both oil and natural gas.

It is not sufficient in and of itself for countries to have energy resources. A resource which is not competitive in economic terms often gives rise to harm rather than benefits, and reduces the competitiveness of countries world-wide. In other words, intense competition in today's globalized system requires the resources to be utilized in the most economical manner.

The opportunities or risks being created from the use of resources in the marketplace depend on many parameters. The features of an energy resource are absolutely essential among these parameters. In the coal example, its features such as reserve, calorific value, sulfur and ash content, the geological structure and operating method can put coal at a an advantaged or disadvantaged position.

As a result of assessments, for instance, the features of a coal deposit may put it in advantageous position, but this does not guarantee that the resource will take its proper place in the market. Resources must be produced in an economical way to be able to compete and have a proper place in the market.

The supply of the resources to the market in a competitive way is possible only by employing an efficient operation, which is possible only through enterprises producing these sources working efficiently. That is, the enterprises producing these scarce resources must operate efficiently.

In fact, intense competition in the global system forces enterprises to be efficient world-wide. The concept of efficiency causes enterprises to review their performances compared to competitors within the sector on a regular basis, ultimately directing then using resources more efficiently.

Data Envelopment Analysis (DEA) is a non-parametric, linear programming-based methodology used to determine to what extent enterprises are using their resources to produce outputs, and to what extent they are operating efficiently.

In this study, first, the efficiencies of eight establishments of the Turkish Coal Enterprises (TKİ) were analyzed by using CRS and VRS methods of DEA, and Super Efficiency (SE) methodology for the years 2006 to 2009. For this purpose, two output oriented models were created (Production Efficiency and Revenue Efficiency Models). As a part of the efficiency analyses, benchmarks for inefficient establishments to move to becoming efficient were also determined. SE methodology was used to determine the efficiency ranking of the efficient enterprises among themselves. For the DEA and SE analysis, the Efficiency Measurement System (EMS) software 1.30 version was used.

Enterprises operating in knowledge of their efficiency level, and the analyses that have been made in this regard are very important for the management of enterprises who bear the responsibility to become more efficient. Moreover, analyzing the dynamic development of the enterprises' efficiency level in time is also very important for the management of the enterprises. To provide such richness of evaluation, inclusion of the time dimension is a valuable contribution.

In order to do so, through the three models constructed (The Production Efficiency, Revenue Efficiency and Work Safety Efficiency Models), the changes of efficiency levels in production, revenue and work safety of the establishments between 2006 to 2009 were analyzed using the Malmquist Total Factor Productivity Index (MI) Methodology.

MI analyses included analysis of efficiency changes of establishments in time in four efficiency components: technical efficiency, technological efficiency, scale efficiency and pure efficiency. In addition to these analyses, the total factor productivities of the enterprises were been calculated, and important managerial parameters and proposals for the managers of establishments and TKİ were developed. DEAP Software, version 2.1 was used for this analysis.

In Turkey's coal sector, public enterprises are the market's dominant players. 87% of the known reserves belong to the public enterprises; Turkish Coal Directorate (TKİ), Electricity Generation General Directorate (EÜAŞ), and Mine Survey and Analysis General Directorate (MTA). In 2010, 48% of brown coal production was from the eight enterprises of the General Directorate of Turkish Coal (TKİ), while 38% was realized by EÜAŞ Afşin-Elbistan establishment of EÜAŞ that supplies coal to the Afşin-Elbistan Thermal Power Plant. The remaining 14% was realized by a number of small-to medium scale private companies.

If we put aside EÜAŞ whose main area of activity is generating electricity, TKİ is in a dominant position in the Turkish lignite sector. Therefore, that the eight enterprises of TKİ were included within the scope of this study is important.

In addition to this, with the expectation of providing opportunities for different analyses and achieving different outcomes, the possibility of including the Afşin-Elbistan Establishment of EÜAŞ and of some other selected private companies within the scope of this work was investigated. Further, some draft analyses were performed by using some non-confirmed data. However, since the accounting system of the Afşin-Elbistan establishment of EÜAŞ did not separate based on mining and power plant activities, this establishment could not be included within the scope of this study. Similarly, the selected private sector companies whose production scale would have been enough to be included in the scope of this study were unable to provide reliable data required for this study; therefore, it was not possible to include any private sector companies into this study.

In the second chapter of the study, a general assessment of the coal sector in the world and in Turkey was made by using the most recent reliable data. In this part, most of the graphics and the tables were developed and prepared specially for this study. In this regard, the Coal part of the thesis study has the characteristics of a serious Coal sector report and will be an important reference for researchers interested in the subject and players operating in the market.

In the third chapter, eight establishments of TKİ are presented in detail, because those establishments are the focal point in the analyses performed in this study. The data set of the establishments used in the analysis is also given in this chapter.

In the fourth chapter, the methodologies used in this study in performing efficiency analysis are introduced. In this context, Data Envelopment Analysis (DEA) with its CRS and VRS versions, Super Efficiency (SE) and Malmquist Total Factor Productivity Index (MI) methodologies are explained including their theories and uses in different range of industry based on a literature search.

In the fifth chapter, first the models (Production Efficiency, Revenue Efficiency and Work Safety Efficiency) constructed for the efficiency and total factor productivity analyses of the establishments are introduced, then the efficiency analyses of eight establishments of TKİ were performed for two models, Production efficiency and Revenue efficiency. In this regard first, efficient and inefficient establishments with their efficiency levels or scores in each year between 2006 and 2010 were determined by CRS and VRS analyses. At the same time, the benchmarks for inefficient establishments to become efficient were determined. Second, to determine the efficiency ranking of the efficient establishments among themselves, SE analysis was performed. Third, the changes of efficiency levels in production, revenue and work safety of the enterprises between 2006 and 2009 were analyzed by using the Malmquist Total Factor Productivity Index (MI) Methodology. MI analyses included the analysis of the efficiency changes of the establishments in time in four efficiency components: technical efficiency, technological efficiency, scale efficiency and pure efficiency. In addition to this, the total factor productivity indexes of the establishments were also been calculated.

In the last chapter, discussions and conclusions including recommendations to the managements of establishments and of TKİ, contributions of this study to the research and science, and recommendations for future studies are laid out.

CHAPTER 2

COAL

2.1 Introduction

As the oldest energy resource of the world, coal has played a crucial role in meeting the energy needs of the world for many years. Although there has been a decrease in the role of coal in world's energy balances stemming from the wide utilization of nuclear technology, oil and natural gas, coal still has, and will have, an important role in meeting humankind's energy needs for a long time (IEA, 2010a; BP, 2011).

The known reserve lives of oil and natural gas (50-80 years) are less than coal (118-150 years) (BP, 2011, IEA, 2010a). Moreover, oil and natural gas reserves are concentrated in limited geographic areas of the world. The world has faced, and is facing serious conflicts and crises in recent years, derived from oil and natural gas or from other reasons that affect the supply of the oil and natural gas. These situations risks the physical supply of oil and natural gas, causes increases in price and price fluctuations which are all threats to the security of the world's energy supply. Therefore with those risks in mind, countries are searching for more reliable, long-term energy supply opportunities for their economies.

A different pursuit is also seen in nuclear energy area. The technological and cost based risks of nuclear waste disposal are still valid. Accidents in nuclear power plants in recent years have made the world public opinion more sensitive to the risk of radiation resulting from nuclear energy. The nuclear industry will definitely develop solutions and answers to those risks; however, for countries with reliable alternatives for energy supply, the nuclear energy option will not have priority in their energy policies.

In recent years, increasing awareness of global warming and climate change due to greenhouse gas emissions once again brought into question the place of coal in world energy balance, because coal is blamed as the biggest main source for greenhouse gases. Coal industry seeks to meet this inquiry with new and clean coal technologies.

When assessing all these aspects together, we can say that coal's importance in the world's energy supply balance will continue for many more years (IEA, 2010a).

In terms of reserves, the largest reserves in Turkey are coal when compared to oil and natural gas. In terms of consumption, the primary energy consumption of Turkey was 106 million tons oil equivalent in 2009, while domestic coal had a share of 16,4%. With the share of 19,2%, domestic coal has also an important place in Turkey's power generation (ETKB, 2011a).

Currently, approximately two-thirds of the primary energy needs and the half of the electricity generation depend on imported resources. Therefore, exploiting domestic energy resources maximally and further utilizing coal resources are important for Turkish energy supply security policies (ETKB, 2011b).

Coals can be grouped as Humic and sapropelic, depending on the type of organic matter they contain (Ünalan, 2010).

Humic coals occur with plants accumulated in bogs forming an aggregation that are first turned into peaty from bacteria, then peat is transformed into coal after a series of geological events, such as the burial of peat into earth due to geological and tectonic events. Then, it is converted into coal through increasing pressure and temperature from being buried.

Sapropelic coals occur with the carbonization formed with burial of organic sludge (sapropel) accumulated in the certain depth of water such as see and lake sediments influenced by the temperature.

In both formations, the basis for coal is organic masses. After these organic masses are embedded deep into the earth, they are affected by the pressure, then the increasing temperature of the earth. During this period, with the influence of natural events such as volcanic activity, fault movements etc., the temperature of the earth increases exponentially, and physical and chemical changes occur within this organic matter. Because of the effect of the temperature and pressure conditions to these masses, in peat to hard coal stage water, water vapor, CO_2 and CO; in the hard coal stage CH_4 and O_2; and in the most advanced stage (the stone coal stage) H_2 are released from this environment.

With the increase of the temperature and pressure, this organic mass that was first called 'peat' but couldn't be constituted as coal changes first into 'lignite' and 'sub-bituminous coal', then into 'hard coal', 'stone coal' and at the end if the conditions are appropriate, into 'black lead'. This maturation process is called 'Carbonization', and each rank is called 'Carbonization rank'(Ünalan, 2010).

The developed countries in coal production, have made and use classifications in accordance with their coal features, and also have developed common standards for general international classifications.

Recently, there have been made a large number of classifications of the coals, some parts of which are very simple and some are very complex. Short descriptions of these classifications are given below (Ünalan, 2010).

In the first example of a simple classification, coals are divided into two groups: Paralic Coals and Limnic Coals. Paralic Coals are shaped in the sea environments. Limnic Coals are shaped in the continental environments.

In the second example of simple classifications of coal, as described above, the coals are divided into two groups: Humic and Sapropelic. Sapropelic coals are less abundant than Humic coals. Humic coals are divided into groups as Peat, Brown Coal-Sub-bituminous Coal and Hard Coal-Stone Coal.

In another classification, coals are basically classified taking into account the content of organic matter and volatile matter, calorific value and swelling index (crucible swelling index). Although this classification is known as one of the oldest classifications, because of its complexity it is not used widely.

In the classification made by the English National Coal Board (NCB) and valid for the hard coal and stone coal, coals are classified taking into account their contents of volatility and Gray-King indexes.

Also, for coals having high carbonization contents, the German Ruhr classification takes into account volatile matter content and agglomeration features.

In the Alpern classification covering all Humic and Sapropelic coals, moisture-holding capacity and calorific values of lignite and vitirnitin reflection properties of hard coal and stone coal are taken into consideration.

In the classification made by the American Society for Testing and Materials (ASTM) coals are divided into groups as Lignite, Sub-bituminous coal, Hard coal and Stone coal based on properties.

After the International Coal Board was established in 1957 with members from different countries, the studies on the samples taken from many countries with the support of the International Standards Organizations (ISO) were realized and there was a new general classification. In this classification, coals are divided into two groups: hard (hard coal) and brown (sub-bituminous and lignite) taking into consideration the calorific value, volatile matter content, the fixed carbon amount, coking and agglomeration features.

- **Hard Coal** is coal on a moist and ash-free basis having a calorific value above 24 MJ/kg (5700 kcal/kg). It is sub-divided in accordance with its volatile matter content, calorific value and coking features.
    a) **Coking Coal** can be used in high ovens with coking quality and can also be named as metallurgical coal.
    b) **Other Bituminous Coals and Stone Coals** cannot be classified as coking coals and can also be named as steam coal.
- **Brown Coal** is on a moist and ash-free basis having a calorific value under 24 MJ/kg (5700 kcal/kg). They can be sub-divided in accordance with the moisture content and calorific value.
    a) **Sub-bituminous coal** is coal having a calorific value between 17-24 MJ/kg (4.165-5.700 kcal/kg).
    b) **Lignite** is coal having a calorific value under 17 MJ/kg (4165 kcal/kg).

2.2 Coal in the World

2.2.1 Global Energy Supply Security and Coal

Today, the world's energy balance mainly depends on fossil fuels. In 2010, 86% of the world's total primary energy consumption was met from oil, natural gas and coal. Coal with 30%, has become the second source after oil with 34% of the highest shares of primary energy sources (IEA, 2010a; IEA, 2010c).

Although the reserves of oil and natural gas are concentrated in certain regions of the world, coal reserves are found in wider geographic areas in the world and in many countries. Therefore, for the counties experiencing problems accessing oil and natural gas, coal reserves have become an important pillar in their energy supply policies (IEA, 2010c). In addition, the sensitivity of supply and cost of oil and natural gas to market crises and speculations led to the assessment of oil and natural gas to be in the risk group in terms of energy supply security.

The world primary energy resources consumption values by the end of 2010 are in the Table 2.1, Figure 2.1 and Figure 2.2 (BP, 2011).

Table 2. 1 World primary energy consumption in 2010 (Mtoe)

	Oil	Natural Gas	Coal	Nuclear	Hydroelectricity	Renewable	Total
World	4.028	2.858	3.556	626	776	159	12.003
European Union	663	443	270	208	83	67	1.733
OECD	2.114	1.398	1.104	521	310	123	5.568

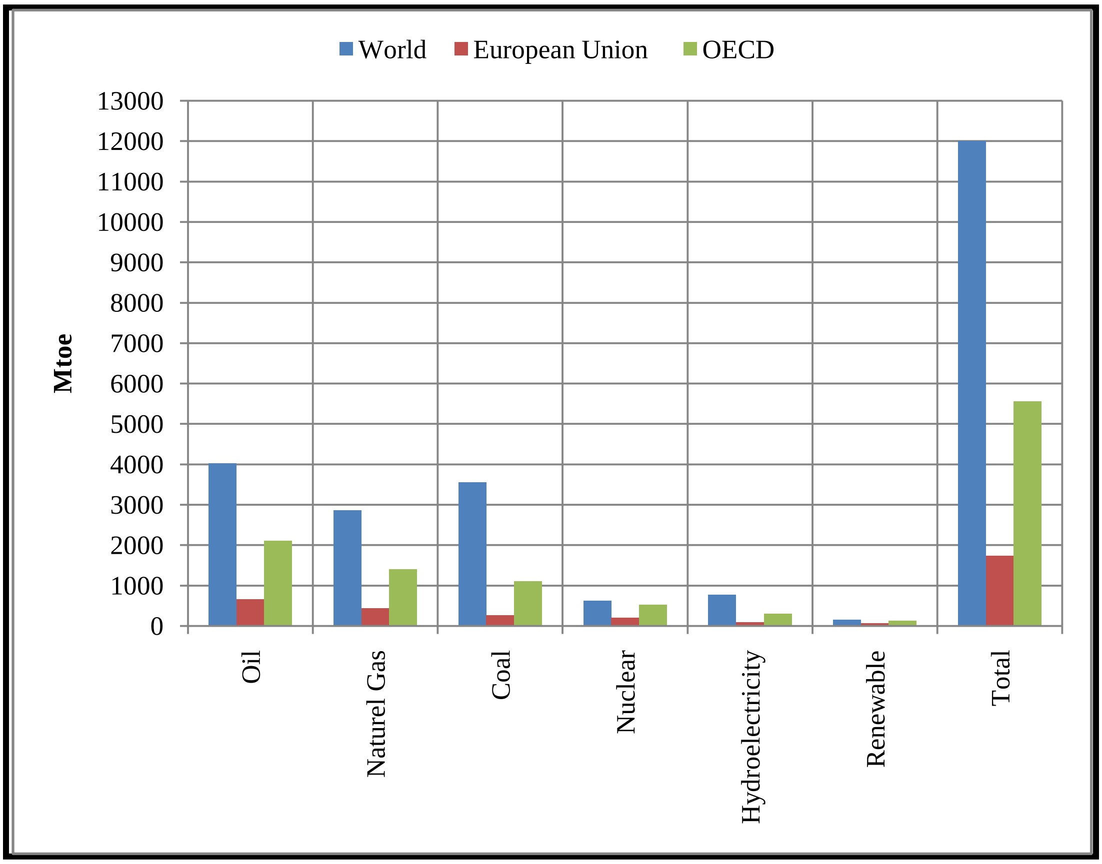


Figure 2. 1 World primary energy resources consumption in 2010

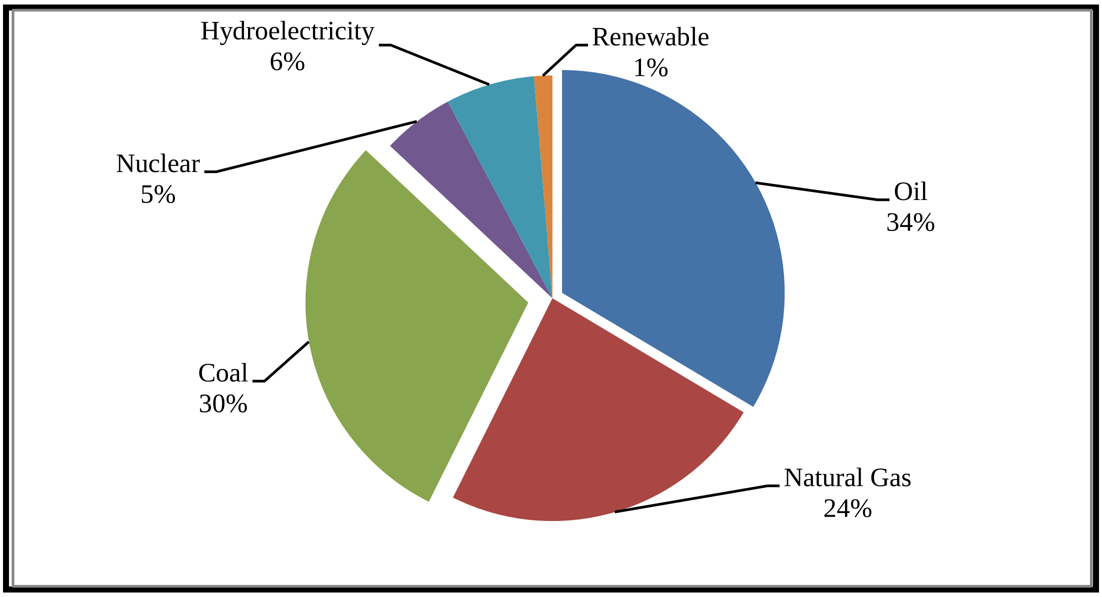


Figure 2. 2 Shares of resources in World primary energy consumption in 2010

According to the long-term projections made by the International Energy Agency (IEA) for the period until 2035, coal will continue to be important for global energy supply policies (IEA, 2010a; IEA, 2010c; IEA, 2011b).

In the World Energy Outlook studies done by the IEA before 2010, a scenario called Reference Scenario had been used. The reference scenario assumed that countries will not change their existing policies. The World Energy Outlook 2010 study, unlike previous years' studies, examined three scenarios.

Scenarios used in World Energy Outlook 2010 are described below (IEA, 2010a).

- Current Policies scenario: this scenario assumes that there will be no change in the current policies of the countries, and that current policies will continue.
- New Policies scenario: this scenario assumes that the countries will implement planned reforms in the field of fossil fuel subsidies, climate change mitigation and other energy topics.
- 450 ppm scenario: this scenario assumes very strict policies for limiting the increase of the global average temperature of 2 degrees in the long-term, and for this purpose to keep the emissions of greenhouse gases in the atmosphere at the level of 450 ppm.

In the New Policies scenario, the world demand for coal is predicted to increase by 20% during 2008-2035. The current policies scenario demonstrates that the increase of the demand will be slightly above then the new policies while in the 450 ppm scenario it will remain well below (Figure 2.3) (IEA, 2010a).

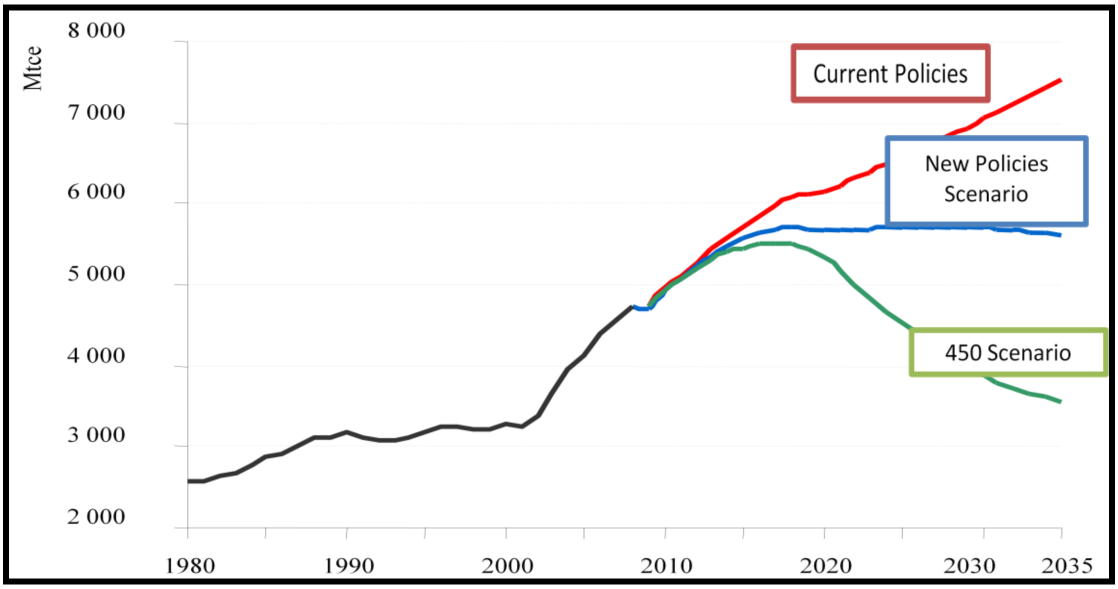


Figure 2. 3 World primary coal demand by scenario

When taking a look at the projections of the share of coal in the global primary energy demand at the year 2035, in all the three scenarios it is seen that the coal will keep its importance in terms of world energy security for many years (Figure 2.4, Figure 2.5) (IEA, 2010a).

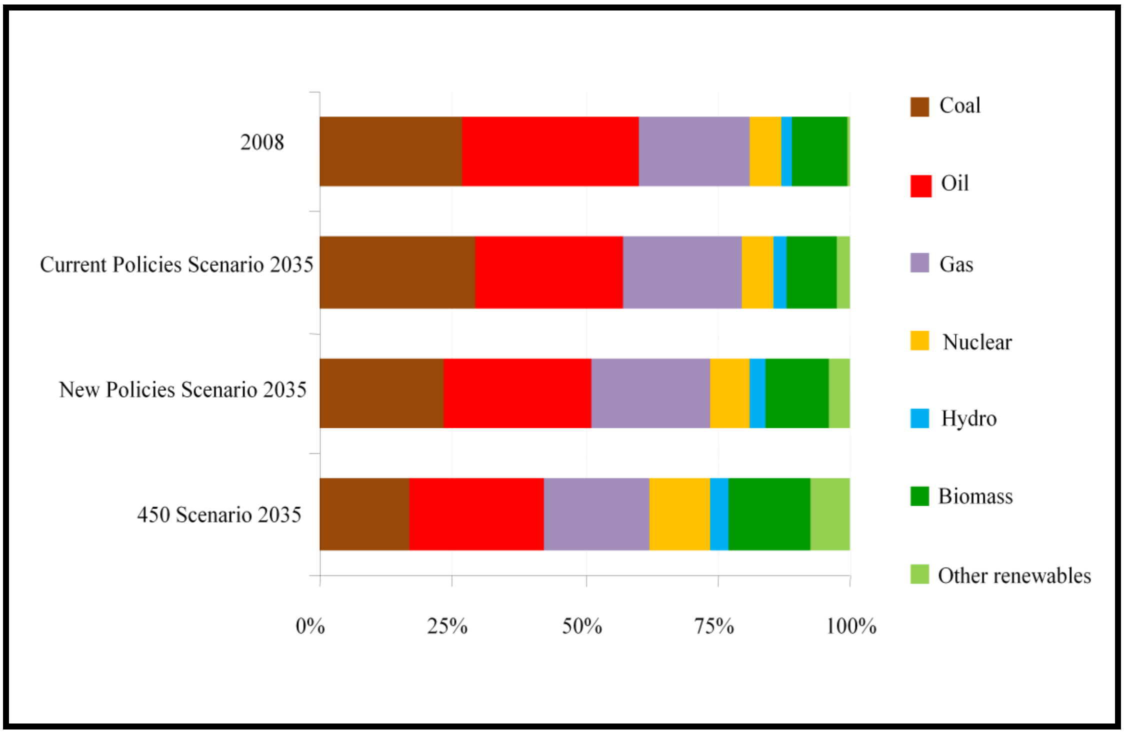


Figure 2. 4 Shares of resources in world primary energy demand

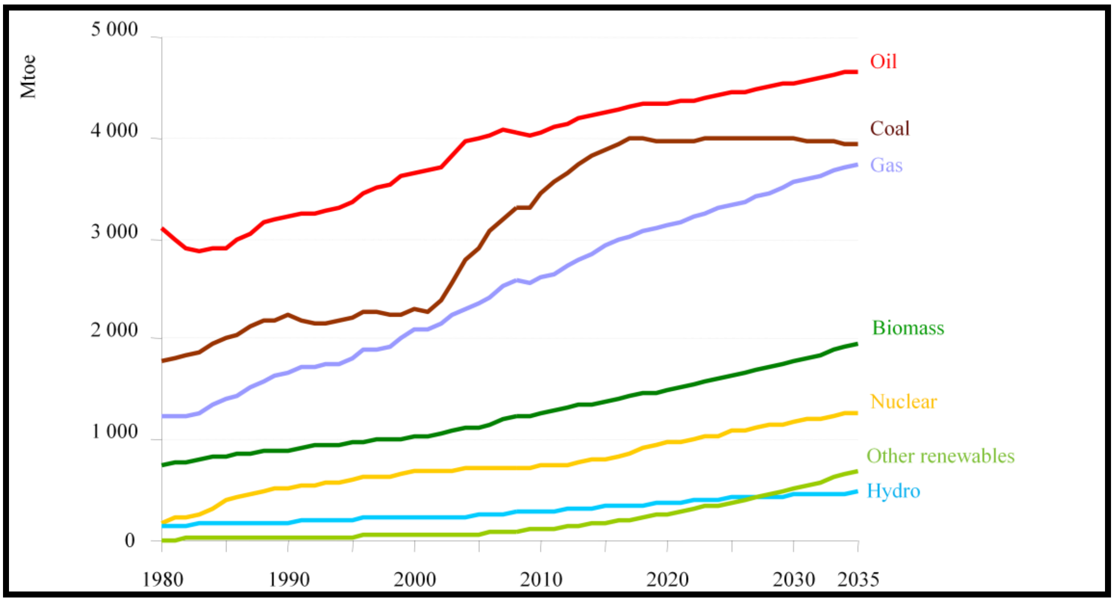


Figure 2. 5 World primary energy demand by fuel, New Policies Scenario

2.2.2 World's Coal Reserves, Production and Consumption

Reserve

The amount of world's coal reserves and the reserve life may differentiate among studies depending upon the assumptions.

In the latest statistical data published by BP (2011), the proven world coal reserves are given as 860.9 billion tons by the end of 2010. According to the present production levels, the Reserve/Production (R/P) ratio which defines the reserve life is calculated as 118 years (Figure 2.6). In preparing this data, proved reserves of coal are taken as the quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. In BP's previous study for the year 2000, however, the R/P ratio was calculated as 210 years (BP, 2011).

In another study, the world's coal reserves are given as approximately 1.000 billion tons and the R/P ratio is given as 150 years (IEA, 2010a).

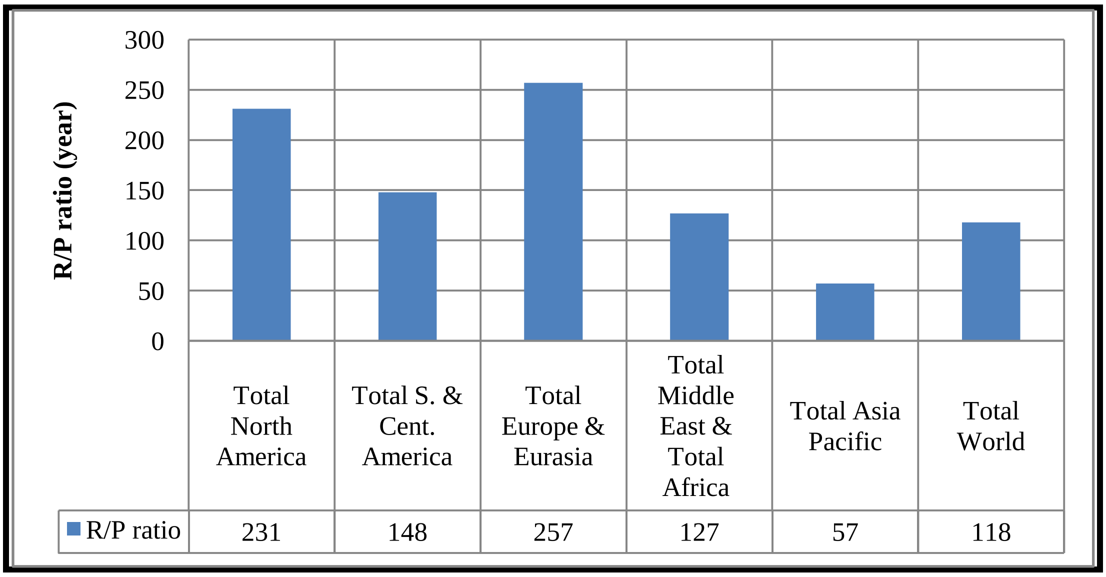


Figure 2. 6 World coal reserves life

The proven total world coal reserves and annual productions and consumptions are given in Table 2.2 and, the geographic distribution of the world coal reserves is given in the Figure 2.7 (BP, 2011).

Table 2. 2 World Coal Reserve, Production and Consumption

Regions	Reserves	Production	Consumption
	Milion Tons	Mtoe/year	
Total North America	245088	591,6	556,3
Total S. & Cent. America	12508	53,8	23,8
Total Europe & Eurasia	304604	430,9	486,8
Total Middle East	1203	1	8,8
Total Africa	31692	144,9	95,3
Total Asia Pacific	265843	2.509	2.385
Total World	**860938**	**3.731**	**3.555**

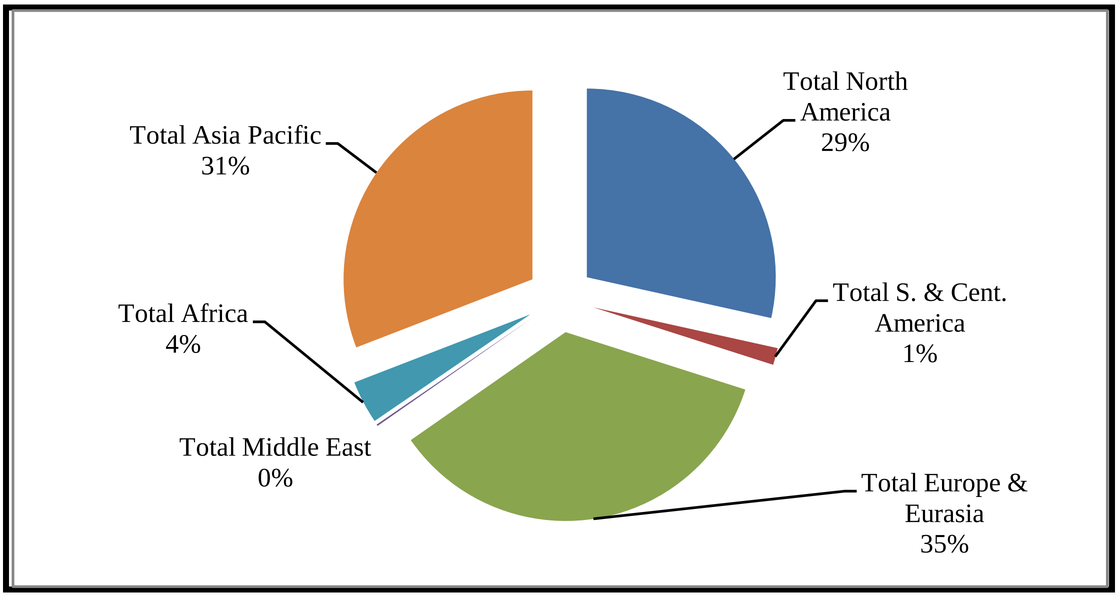


Figure 2. 7 World coal reserves geographical distribution (%)

World Coal Production and Consumption

According to the latest statistical data published by BP (2011), while the production of the world lignite and hard coal in 2009 in total was 3.51 billion tons of oil equivalent/year, in 2010 it increased by 6.3%, and become 3.73 billion tons of oil equivalent/year.

By the end of 2010, out of 3.73 billion tons of oil equivalent coal production, 26,7% was from OECD countries, 6,5% from the former Soviet Republics and 4,2% from the European Union countries.

By the end of 2010, the consumption of coal was 3,55 billion tons of oil equivalent of which 7,6% was by the European Union Countries, 31% by the OECD countries and 4.8% by the former Soviet Republics.

The World coal production amount and the changes in the world coal production between 2006 to 2010 are given in the Table 2.3 and Figure 2.8 (BP, 2011).

Table 2. 3 World coal productions between 2006 and 2010

Coal Production* (Mtoe)	Years					Change 2010 over 2009
	2006	2007	2008	2009	2010	
Total North America	634,5	629,7	637,8	578,5	591,6	2,3%
Total S. & Cent. America	50,8	53,6	55,2	53,8	53,8	2,6%
Turkey	**13,4**	**15,8**	**17,2**	**17,4**	**17,4**	**
Total Europe & Eurasia	444,9	446,1	452,0	422,1	430,9	2,1%
Total Middle East	0,9	1,0	1,0	1,0	1,0	0,0%
Total Africa	140,4	141,8	144,2	143,1	144,9	1,3%
Total Asia Pacific	1965,6	2090,2	2180,1	2314,8	2509,4	8,4%
Total World	**3.237**	**3.362**	**3.470**	**3.512**	**3.731**	**6,3%**

* Commercial solid fuels only, i.e. bituminous coal and anthracite (hard coal), and lignite and brown (sub-bituminous) coal.
**Less than 0.05%.
Note: Growth rates are adjusted for leap years.

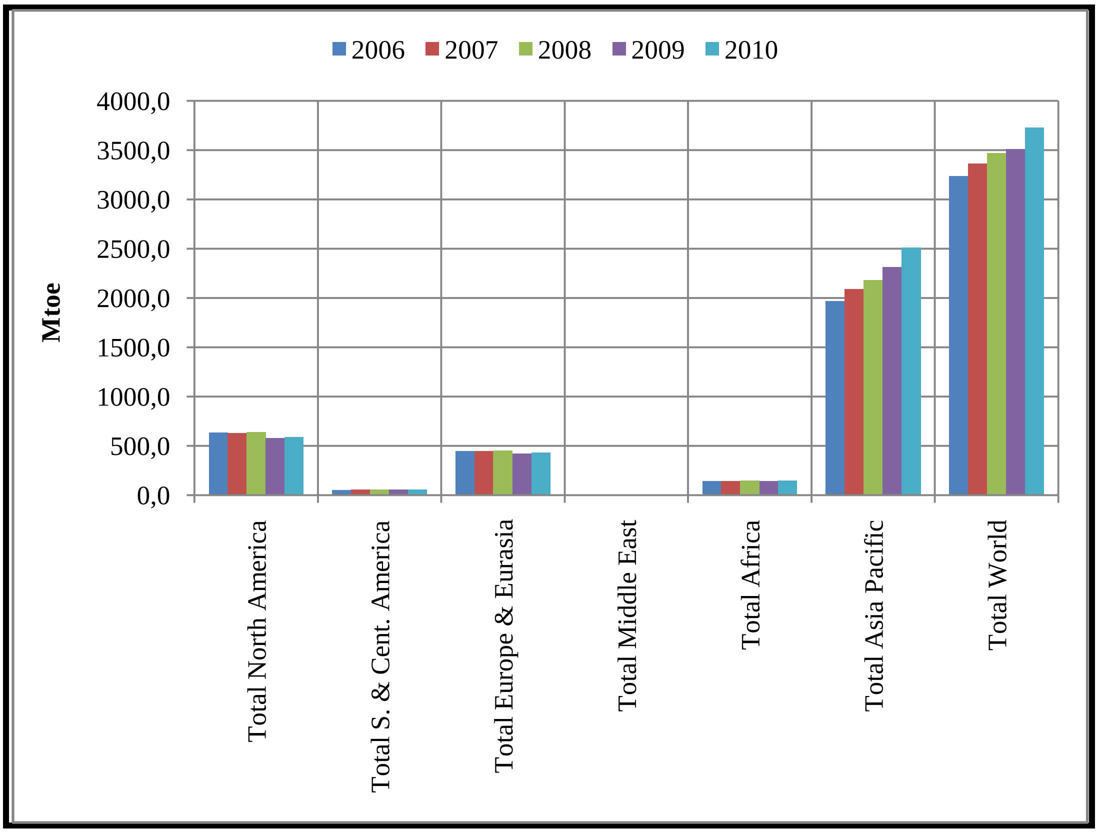
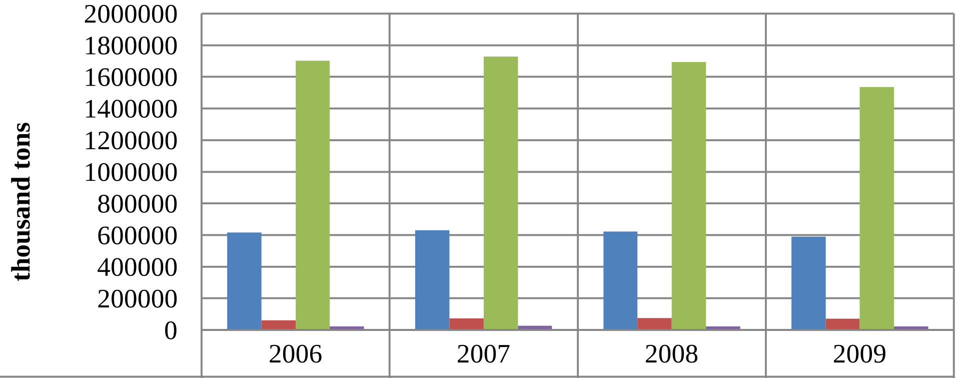


Figure 2. 8 World coal productions between 2006 and 2010

By the end of 2009, the consumption of brown coal by the OECD countries was 588.811 million tons and the consumption of hard coal was 1,53 million tons. The consumptions of brown coal and hard coal of the OECD countries between 2006 to 2009 are given in Figure 2.9 (IEA, 2010c; IEA, 2011b).



	2006	2007	2008	2009
OECD Brown Coal	615712	631184	622835	588811
Turkey Brown Coal	60786	72827	75894	70491
OECD Hard Coal	1701468	1728285	1694628	1535953
Turkey Hard Coal	22798	25350	22720	22246

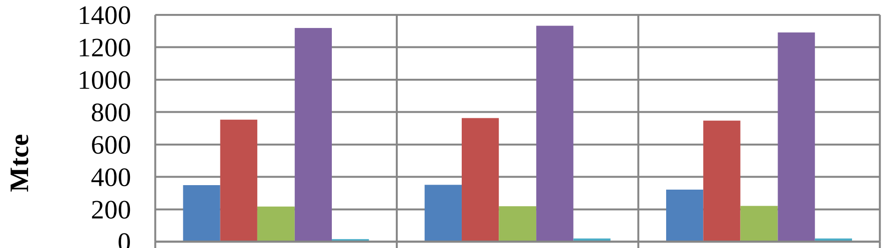
Figure 2. 9 OECD countries brown coal and hard coal consumption

Uses of Coal in the World

Coal is mainly consumed in industry, power generation and heating in the world. Approximately 49% of coal produced is consumed in power generation, 20% is consumed in heating, 15% is consumed in the Iron and Steel Industry, and 5% is consumed in the cement industry. The remaining 11% is consumed in other branches of industry (IEA, 2010c; IEA, 2011b). The share of coal consumed in power generation and industries varies among the countries. The major coal-producing countries give more importance to coal in both power generation and industry, whereas in the countries without sufficient reserves of coal or having other more appropriate energy sources the share of coal in the energy balances is smaller.

About 15% of the total coal production is currently used in the iron and steel industry. Despite the development in the electric arc furnaces in steel plants, 70% of world steel production is dependent on coal. An important part of electricity used in arc furnaces is generated from coal. Approximately 90% of the world's hard coking coal is used for the production of pig iron for raw steel.

Coal is used significantly in the generation of the electricity in the world. The share of coal in the world's power generation is around 41.5% (IEA, 2010c; IEA, 2010d). The amount of coal used in power generation in OECD countries is given in Figure 2.10, and total installed capacity of coal power plants in OECD countries is given Figure 2.11 (IEA, 2010a; IEA, 2010d)



	2006	2007	2008
OECD Europa	349,4	351,2	322,3
OECD North America	753,1	764	748,1
OECD/IEA Pasific	217,5	218,1	221,4
OECD Total	1320	1333,3	1291,8
Turkey	16,2	19	20,5

Figure 2. 10 OECD coal and peat use in power generation and heat

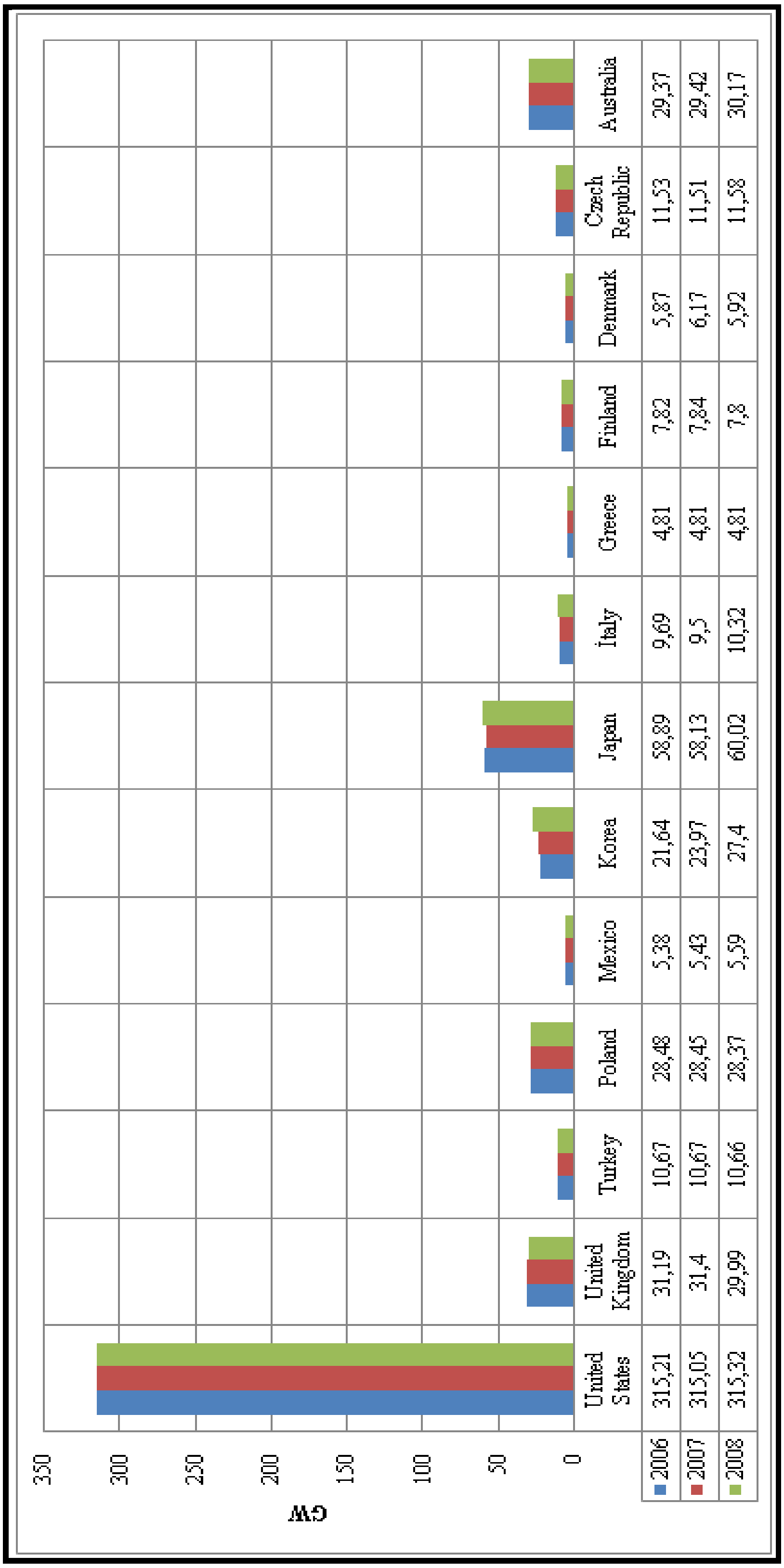


Figure 2. 11 OECD coal-fired installed power plant capacity

2.3 Coal in Turkey

2.3.1 Energy Supply Security of Turkey and Coal

Policies and strategies to ensure the security of Turkey's energy supply are formed by analyzing policies and strategies of all the actors which are important in the dynamics of local, regional and global energy arena and by taking into account the general trends in the world, current geo-political perspective, the needs of the country, and the European Union (EU) acquis. In this context, Turkey's energy policy orientations in recent years can be summarized as follows (ETKB, 2011b; IEA, 2010b):

Key Policies;

- To reduce dependence on imported energy sources to the lowest level possible,
- To give importance to the domestic and renewable resources,
- To minimize the impact on the environment,
- To produce and use the energy efficiently,
- To protect the public interest and consumer rights,
- To mobilize competitive free-market practices,
- To implement policies for meeting the country's energy needs in a secure, continuous and at the lowest cost, and with minimum environmental impact.

While Turkey's energy demand is increasing at very high rates, expectations regarding the emission reduction from the country after 2012 have been increasing. In this regard, to increase energy efficiency at all segments of industry, to use renewable and local energy resources to the greater extend, to implement clean coal technologies in a widespread fashion and to use nuclear energy are among the main policies of Turkey.

The Electricity Market and Supply Security Strategy document adopted by the Higher Planning Council on May 18, 2009 contains a provision stating that '… known sources of lignite and hard coal will have been utilized for electricity generation by 2023' (ETKB, 2011b).

The most common use of lignite in Turkey is for power generation. License applications made to the Energy Market Regulatory Authority for all types of energy resources reached 132.277 MW by June 2011 (EPDK, 2011; TEİAŞ, 2011). The breakdown of license applications is given below:

- 31.215 MW are in application stage,
- 37.284 MW are in the review and evaluation stage,
- 10.571 MW have been found appropriate,
- 53.207 MW have been given the licenses,

The license applications made to the Energy Market Regulatory Authority (EMRA) for lignite, hard coal and asphaltite are shown in Table 2.4 (EPDK, 2011).

Table 2. 4 Coal fired power plant license applications to EMRA

Resource Type	**Application Stage**		**Appraisal Stage**		**Appropriate**		**Licensed**		**TOTAL**	
	Number	Capacity (MW)	Number	Capacity (MW)	Number	Capacity (MW)	Number	Capacity (MW)	Number	Capacity (MW)
Lignite	**4**	1.807	**1**	37	**0**	0	**32**	4.281	**37**	**6.125**
Hard Coal	**8**	6.672	**10**	4.687	**3**	1.051	**23**	8.969	**44**	**21.379**
Asphaltite	**0**	0	**1**	135	**0**	0	**1**	675	**2**	**810**

The primary energy balance table data for 2010 have not been published yet. For 2006-2009, domestic production, imports and total and per capita consumption of primary energy consumption values are shown in Table 2.5 (ETKB, 2011a).

The primary energy supply–demand perspective for Turkey, and the import dependence ratios for the primary energy resources for the years 2006 to 2009 are shown in Figure 2.12 (ETKB, 2011a). As can be observed from Figure 2.12, the trend is towards a reduction in the import dependency ratios – albeit a small one.

Table 2. 5 Selected energy data of Turkey

Years	Domestic Production (thousand toe)	Imported (thousand toe)	Total (thousand toe)	Dependence On Foreign (%)	Consumption Per Capita (koe)
2006	26.580	80.416	99.642	73,30%	1.365
2007	27.454	87.614	107.627	74,50%	1.525
2008	29.257	85.357	106.338	72,50%	1.497
2009	30.328	82.124	106.138	71,40%	1.463

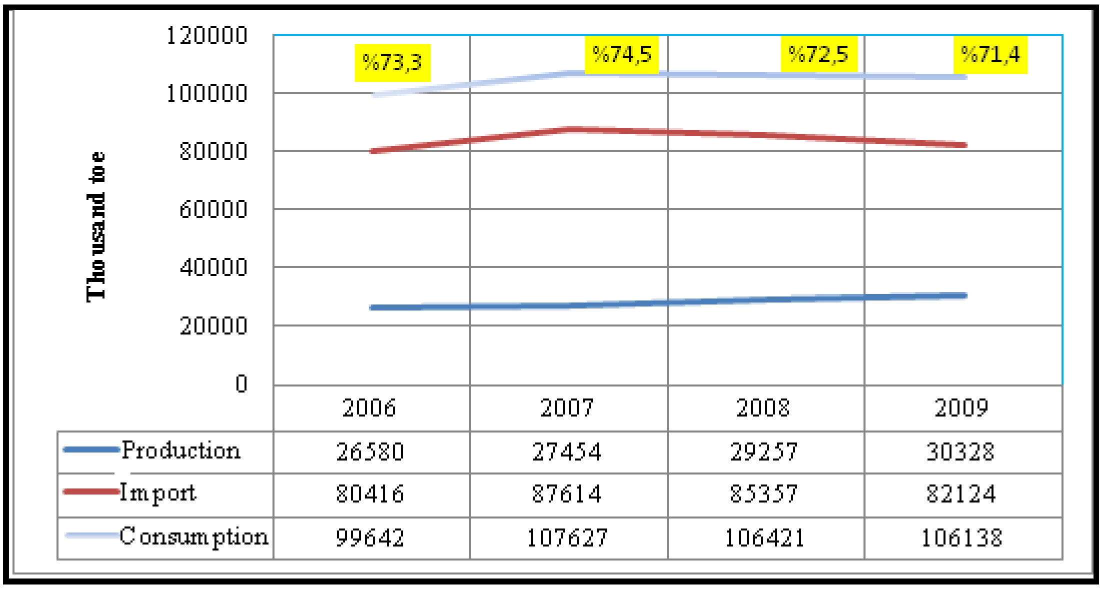
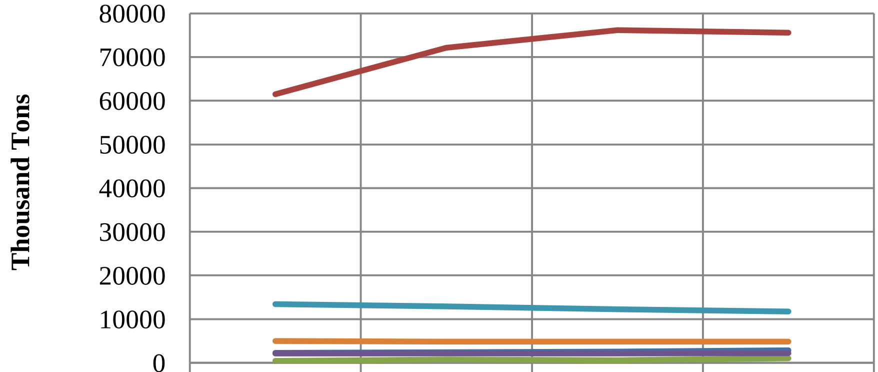


Figure 2. 12 Primary energy supply-demand perspective of Turkey

One of the most important indicators of the policies and strategies being implemented for the reduction of import dependence on primary energy in the last years is the increased use of domestic sources. Within this framework, there have been increases in the production and use of primary domestic energy sources, particularly lignite, coal and asphaltite between the years 2006 to 2009.

The distribution of the consumption of primary energy resources in Turkey between 2006 and 2009 in terms of the type of resource is shown in Figure 2.13 (ETKB, 2011a).



	2006	2007	2008	2009
Anthracite	2319	2462	2601	2863
Lignite	61484	72121	76171	75577
Asphaltite	452	782	630	1058
Oil	2175	2134	2160	2237
Wood	13411	12932	12264	11766
Animal and Plant Waste	4984	4850	4883	4862

Figure 2. 13 Consumption of primary energy resources in Turkey

The energy balance tables for the years 2006, 2007, 2008 and 2009, which were prepared and published by the Ministry of Energy and Natural Resources, and contain important data concerning the production and consumption of primary energy resources in Turkey on a sectoral basis are shown in Table 2.6 and Table 2.7 (ETKB, 2011a).

Table 2. 6 Energy balance tables of Turkey (2006 and 2007)

Year 2006 (thousands toe)	Anthracite	Lignite	Asphaltite	Coal	Petroleum coke	Wood	Plant Residues	Solid fuel	Oil	Natural Gas	Hydrolic	Biofuel	Wind	Electrical	Heat	Solar	Total
Domestic Production (+)	1348	11545	195			4023	1146	18257	2284	839	3886	2	11	0	898	403	26580
Import (+)	13256	9		318	1455			15038	37356	27973				49			80416
Export (-)									6379					192			6572
Bunker (-)									588								588
Stock Exchange (+/-)	116	-366	65	-13	71			-128	-368	55		0					-441
Statistical Error (+/-)								0	247								247
Primary Energy Supply	14721	11188	259	305	1526	4023	1146	33167	32551	28867	3886	2	11	-143	898	403	99642

Year 2007 (thousands toe)	Anthracite	Lignite	Asphaltite	Coal	Petroleum coke	Wood	Plant Residues	Solid fuel	Oil	Natural Gas	Hydrolic	Biofuel	Wind	Electrical	Heat	Solar	Total
Domestic Production (+)	1089	13372	336			3880	1116	19793	2241	827	3217	12	31	0	914	420	27454
Import (+)	14334	0		309	1497			16140	38233	33167				74			87614
Export (-)									6689	29				208			6926
Bunker (-)									92	0							92
Stock Exchange (+/-)	-12	72	-65	27	-52			-28	-367	-12		0					-408
Statistical Error (+/-)								0	-16	0							-16
Primary Energy Supply	15411	13444	272	337	1445	3880	1116	35904	33310	33953	3217	12	31	-134	914	420	107627

Table 2. 7 Energy balance tables of Turkey (2008 and 2009)

Year 2008 (thousands toe)	Anthracite	Lignite	Asphaltite	Coal	Petroleum coke	Wood	Plant Residues	Solid fuel	Oil	Natural Gas	Hydrolic	Biofuel	Wind	Electrical	Heat	Solar	Total
Domestic Production (+)	1.204	15.205	265	-	-	3.679	1.134	21.487	2.268	931	2.861	140	18	73	-	1.011	29.209
Import (+)	12.708	-	-	147	1.740	-	-	14.595	36.801	34.013	-	-	-	-	68	-	85.477
Export (-)	-	-	-	-	-	-	-		6.688	399	-	-	-	-	97	-	7.183
Bunker (-)	-	-	-	-	-	-	-		761	0	-	-	-	-		-	761
Stock Exchange (+/-)	267	-202	-	2	56	-	-	122	371	-738	-	-	-	-		-	-244
Statistical Error (+/-)	-	-	-	-	-	-	-	0	-76	0	-	-	-	-		-	-76
Primary Energy Supply	**14.179**	**15.003**	**265**	**149**	**1.795**	**3.679**	**1.134**	**36.205**	**31.915**	**33.807**	**2.861**	**140**	**18**	**73**	**-29**	**1.011**	**106.421**

Year 2009 (thousands toe)	Anthracite	Lignite	Asphaltite	Coal	Petroleum coke	Wood	Plant Residues	Solid fuel	Oil	Natural Gas	Hydrolic	Biofuel	Wind	Electrical	Heat	Solar	Total
Domestic Production (+)	1 294	15 632	476	-	-	3 530	1 136	22 068	2 349	627	3 092	375	9	129	-	1 250	30 328
Import (+)	13 119	-	-	183	2 039	-	-	15 341	33 887	32 827	-	-	-	-	70	-	82 124
Export (-)	-	-	-	-	-	-	-	-	6 048	649	-	-	-	-	133	-	6 829
Bunker (-)	-	-	-	-	-	-	-	-	657	-	-	-	-	-	-	-	657
Stock Exchange (+/-)	355	40	- 26	- 174	- 24	-	-	170	- 441	- 30	-	-	-	-	-	-	- 301
Statistical Error (+/-)	-	-	-	-	-	-	-	-	1 473	-	-	-	-	-	-	-	1 473
Primary Energy Supply	**14 768**	**15 672**	**450**	**8**	**2 015**	**3 530**	**1 136**	**37 579**	**30 565**	**32 775**	**3 092**	**375**	**9**	**129**	**- 63**	**1 250**	**106138**

2.3.2 Coal Reserves, Production and Consumption of Turkey

Lignite Reserves

Coal prospecting has been given a priority in Turkey in recent years as a result of the policies prioritising the development and use of domestic energy resources. New coal reserves have been discovered in the Thrace, Soma and Karapınar Basins, and reserves in the previously known basins have been increased. A total of additional 4,1 billion tons of lignite reserves have been determined within the scope of the project, which has been ongoing since 2005 (495 million tons in Thrace, 170 million tons in Manisa-Soma-Eynez, 275 million tons Eskişehir-Alpu, 1,9 billion tons in Afşin-Elbistan and 1.28 billion tons in Konya-Karapınar). As a result of these explorations, the lignite reserves in Turkey have risen to 11,5 billion tons (MTA, 2010; TKİ, 2011e), and hard coal reserves have been determined as 1,34 billion tons (TTK, 2011b).

Lignite reserves are distributed throughout the country, and it is possible to come across lignite deposits in almost every geographical region including in 37 cities (MTA, 2010). Figure 2.14 shows the distribution of important lignite reserves in lignite basins within Turkey on a city basis.

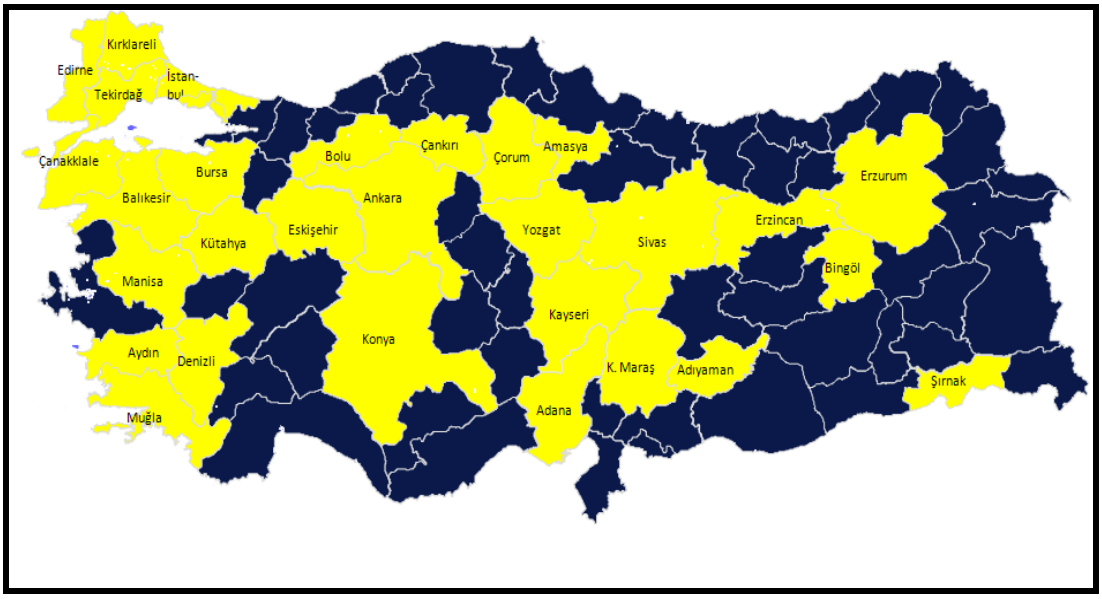


Figure 2. 14 The geographical distribution of lignite reserves in Turkey

42% of the total lignite reserves in Turkey are possessed by the EÜAŞ General Directorate, 23% by the TKİ General Directorate, 22% by the MTA General Directorate, and 12% by the private sector (Figure 2.15) (MTA, 2010, TKİ, 2011e).

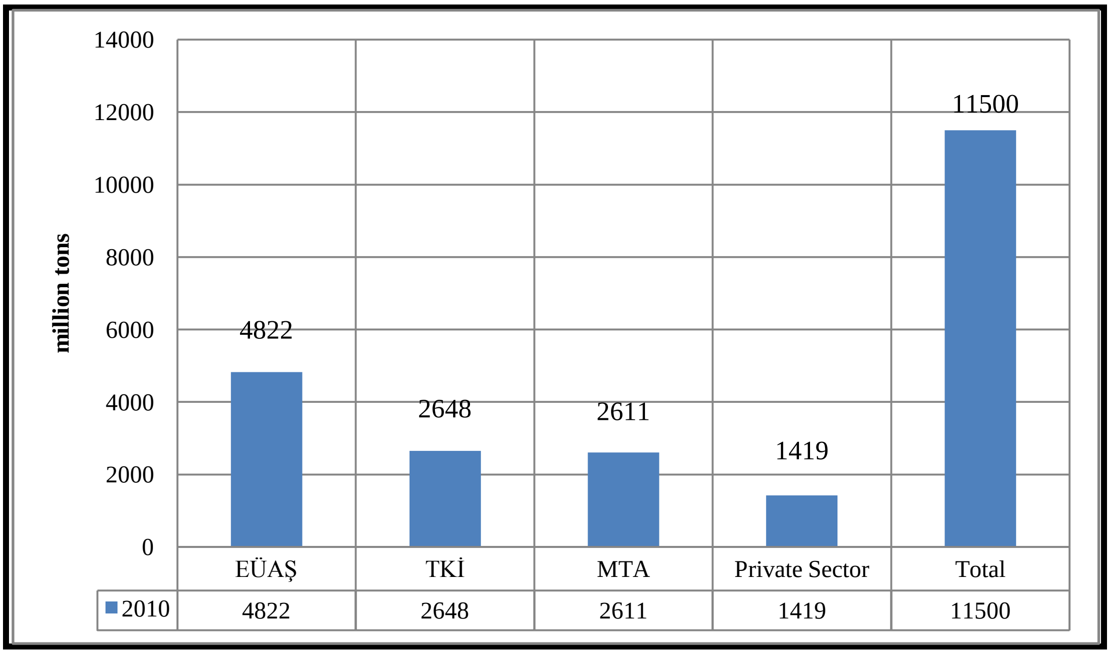


Figure 2. 15 The distribution of lignite reserves amongst organizations in Turkey

Among other geological and geophysical duties, the MTA General Directorate is responsible for the exploration of mines, but not mine production. The reserves owned by the MTA are in the areas licensed for exploration. The MTA General Directorate does not operate mines; these areas are later assigned to TKİ, EÜAŞ or other interested companies in accordance with legal procedures.

EÜAŞ General Directorate specialises in power generation. The main reason why the amount of coal reserves of EÜAŞ is high is due to the 4,4 billion tons of reserves in the Afşin-Elbistan basin which supply low calorific value lignite to the power plants. There are a further 79 million tons in Kangal and 340 million tons in Çayırhan, which are also under the responsibility of EÜAŞ, and coal production in these areas is carried out by the private sector.

The coal reserves owned by the TKİ General Directorate as of the end of 2010 were approximately 2,648 billion tons, and the distribution of these reserves, by year and by establishment, is shown in Table 2.8 below (TKİ, 2011e).

Table 2. 8 Lignite reserves of TKİ

Establishments	2006	2007	2008	2009	2010
EGESOMA	624.416	608.145	662.983	632.574	623.679
ÇAN	86.058	84.214	82.924	80.421	79.073
YATAĞAN	144.501	166.211	160.651	156.098	152.485
YENİKÖY	298.968	292.341	277.844	274.644	267.499
GARP	291.943	290.106	283.017	275.379	276.595
ILGIN	102.557	102.222	102.291	102.152	424.111
SEYİTÖMER	155.774	149.405	152.509	132.691	180.533
ORHANELİ	103.679	99.254	99.112	98.065	96.938
SİLOPİ	78.012	77.477	76.977	76.306	72.996
OTHERS	612.471	682.735	669.456	659.453	474.306
TOTAL	**2.498.379**	**2.552.110**	**2.567.764**	**2.487.783**	**2.648.215**

When lignite reserves of Turkey are grouped into categories according to their calorific values, it can be seen that lignites with a calorific value of 1000-1500 kcal/kg has a 55% share, and lignite with a calorific value of 1500-2000 kcal/kg has a 12% share. Therefore, 67% of Turkey's lignite reserves does possess a lower calorific value, with the largest part of this being in Afşin–Elbistan. Of the remaining, the distribution is 23,5% above 2000-3000 kcal/kg, 5,1% above 3000-4000kcal/kg and 3,4% above 4000 kcal/kg calorific value reserves. 90% of the lignite in Turkey is produced by using surface mining, and the rest is by using underground mining methods (TKİ, 2011e).

The distribution of lignite reserves in Turkey according to their calorific values is shown in Figure 2.16.

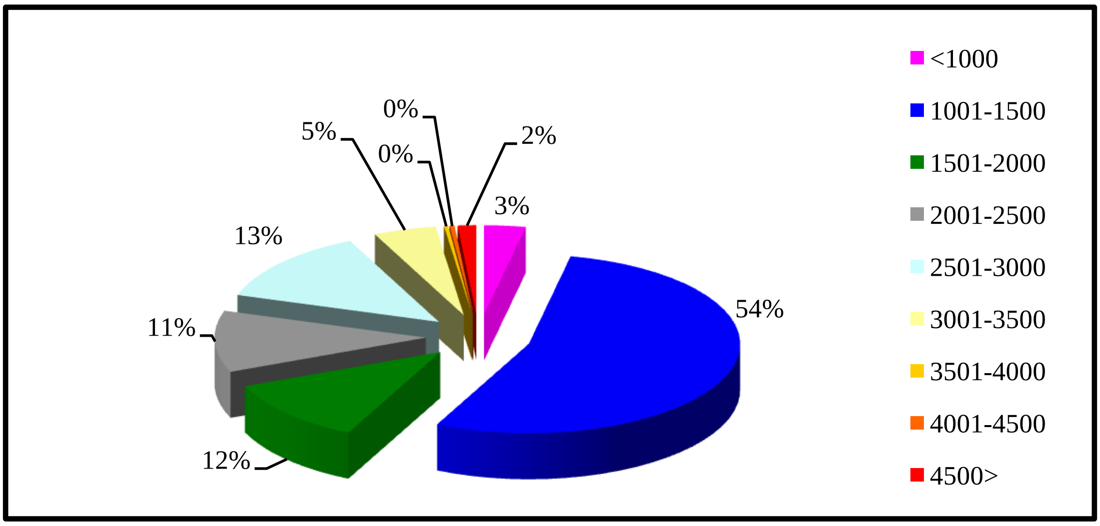


Figure 2. 16 The distribution of lignite reserves in Turkey in terms of calorific value

Hard Coal Reserves

The most important hard coal reserves in Turkey are located in the Zonguldak Basin. In exploratory works undertaken within the basin to date, the total amount of geological reserves determined down to a depth of – 1.200 meters is around 1.34 billion tons (Table, 2.9). The calorific values of the coal within the basin vary between 5.450-7050 kcal/kg (TTK, 2011a; TTK, 2011b).

Table 2. 9 Hard coal reserves of TTK General Directorate

LOCATION	RESERVES (1000 tons)			
CITY	PROVED	POSSIBLE	PROBABLE	TOTAL
Zonguldak	11.241	15.860	7.883	34.984
Zonguldak	351.272	294.043	239.029	884.345
Bartın	172.107	115.052	121.535	408.694
Bartın		1.000		1.000
Kastamonu		5.593		5.593
TOTAL	**534.620**	**431.548**	**368.447**	**1.334.615**

Coking reserves within the basin are situated in the regions of Kozlu, Üzülmez and Karadon, and the share of coking coal as a percentage of total hard coal is approximately 67%. The reserves situated in the region of Armutçuk possess a semi-coking characteristic, high calorific values, and low ash content. Due to this, Armutçuk hard coal deposit is suitable for both blending with coking coal, and using in iron and steel plants as pulverised injection coal. Figure 2.17 shows the coal basin reserves according to their coking characteristics.

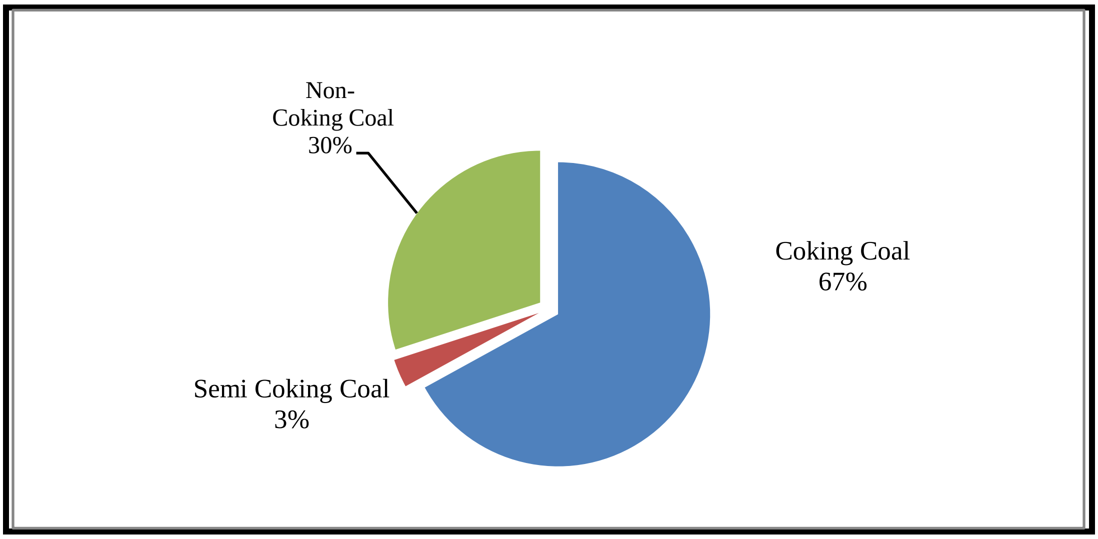


Figure 2. 17 Hard coal reserves according to coking characteristics

Lignite Production, Consumption and Use

Lignite production in Turkey is directed towards meeting the demands of three main sectors: power sector (thermal power plants), industrial sector and heating sector. The total pit-run lignite production by TKİ General Directorate was 42,7 million tons in 2009, and 39,9 million tons in 2010. The production of the EÜAŞ General Directorate was 36,3 million tons in 2009, and 32 million tons in 2010.

Total productions of the TKİ and EÜAŞ General Directorates in 2010 was 71,9 million tons. In addition to TKİ and EÜAŞ, there are a large number of private companies which produces coal under the licenses acquired from the Mining Affairs General Directorate. The amount of production undertaken by the said private companies cannot be given as it has yet to be determined from the activity reports submitted to the Mining Affairs General Directorate at the end of April 2011, in accordance with the Mining Legislation. The shares of TKİ and its establishments in Turkey's total pit-run lignite production in 2009 are given in Figure 2.18.

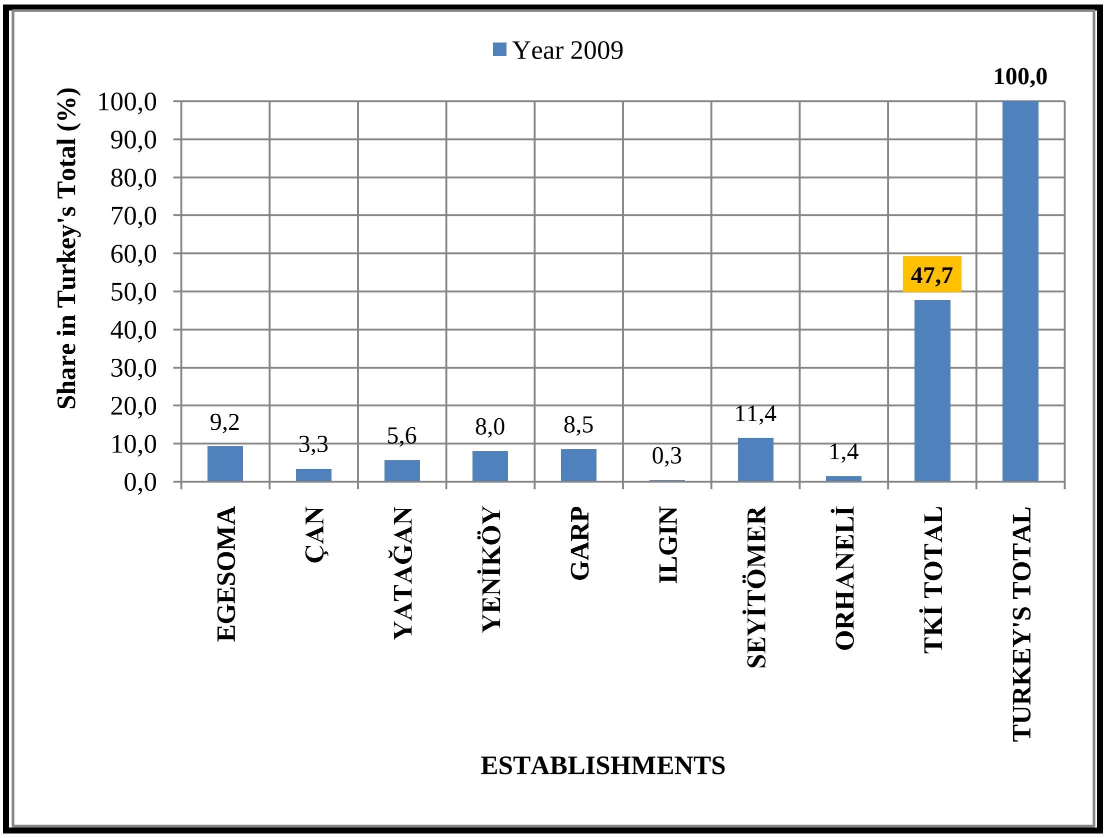
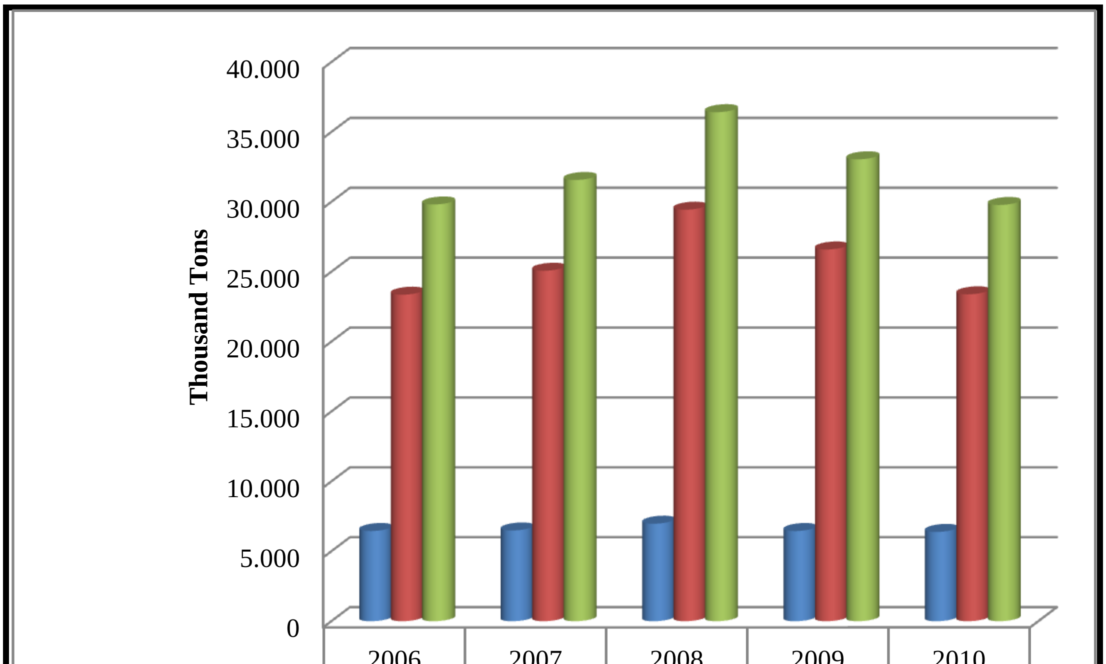


Figure 2. 18 Shares of TKİ in Turkey's total pit-run lignite production in 2009

39,9 million tons of pit-run lignite were produced from the areas belonging to the TKİ General Directorate in 2010. Production of the saleable lignite for the same period was 297 million tons. 24,1 million tons of lignite was produced by using surface mining, and 5,6 million tons by using underground mining methods. Total sales in 2010 were 29,8 million tons of which 23,4 million tons going to thermal power plants and 6,4 million tons to the heating and industrial sectors (TKİ, 2011e).

The sectoral distribution of the sales as the end of 2009 were as follows: 8,4% for industry, 11% for heating and 80,6% for thermal power plants. In 2010 these figures were: 11,7% for industry, 9,7% for heating and 78,6% for thermal power plants (TKİ, 2011e).

The sectoral distribution of the saleable coal produced by the TKİ General Directorate between the years of 2006 to 2010 is shown in Figure 2.19 (TKİ, 2011a; TKİ, 2011b; TKİ, 2011c; TKİ, 2011d; TKİ, 2011e).

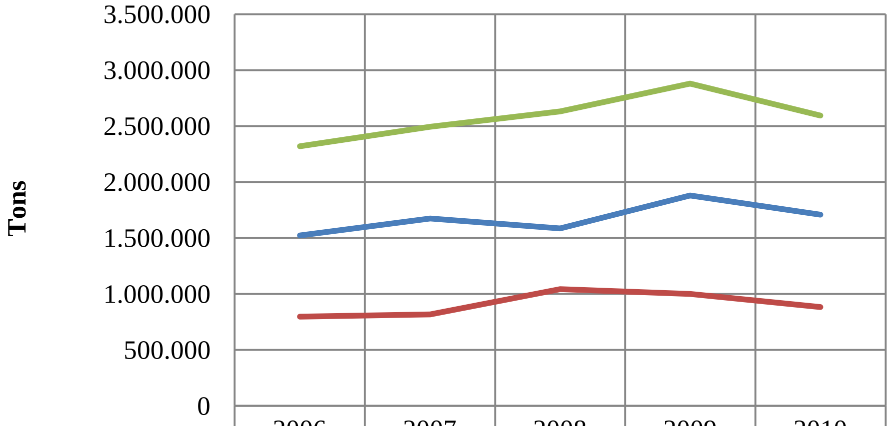


	2006	2007	2008	2009	2010
Heating and Industry	6.453	6.493	6.977	6.452	6.389
Power Generation	23.362	25.074	29.442	26.596	23.390
Total	29.815	31.567	36.419	33.048	29.779

Figure 2. 19 Sectoral consumption of coal produced by TKİ

Hard Coal Production, Consumption and Use

Due to the complicated geological structure of the Zonguldak Basin, where deep underground coal mining is carried out, the production of hard coal is mainly labour intensive. Figure 2.20 shows the hard coal production in the basin (TTK, 2011a; TTK, 2011b). Approximately 2.6 million tons of coal were produced in the basin in 2010, with 1,7 million tons of this was produced by the Turkish Hard Coal Enterprises (TTK) General Directorate, and 0,9 million tons by private companies which carried out their production in areas leased from the TTK.

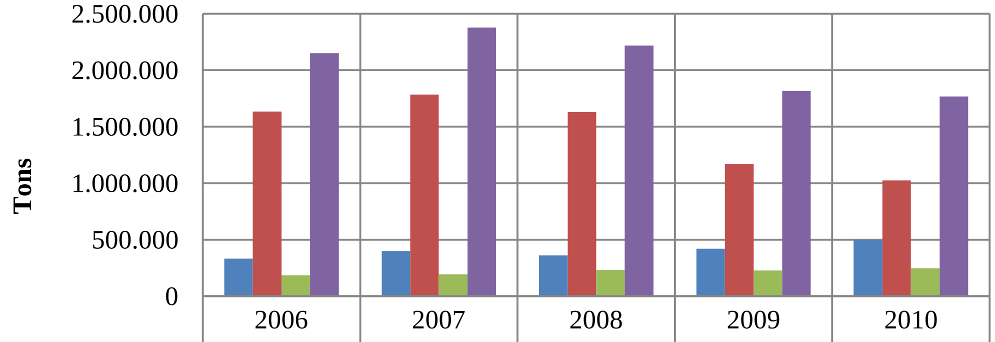


	2006	2007	2008	2009	2010
TTK Saleable Production	1.522.698	1.675.283	1.586.532	1.879.630	1.708.844
Private Sector	795.931	817.092	1.043.909	999.776	883.074
Total	2.318.629	2.492.375	2.630.441	2.879.406	2.591.918

Figure 2. 20 Hard coal production of Turkey

Most of the consumption of hard coal within Turkey takes place in the industrial sector (cement factories, sugar plants and other industrial plants), and coke plants (iron and steel plants). While in 2000 350.000 tons of coal was sold to the iron and steel sector, this figure fell to below 300.000 tons in 2008. It began to increase again in 2010, when the sales were 598.000 tons.

The sales made by the TTK between 2006 to 2010 according to sectors, (TTK+Royalties / Leasing Companies) is shown in Figure 2.21 (TTK, 2011a; TTK, 2011b).



	2006	2007	2008	2009	2010
Iron and Steel	331.340	398.743	359.918	419.139	498.640
Power Generation	1.635.014	1.786.179	1.628.146	1.168.796	1.023.558
Heating	185.057	192.954	231.505	228.023	246.713
Total	2.151.411	2.377.876	2.219.569	1.815.957	1.768.911

Figure 2. 21 TTK hard coal sales by sector

2.3.3 Coal in the Power Sector in Turkey

In terms of primary energy resources, Turkey's dependency on imported resources was 71,4% in 2009. While the data for 2010 has yet to be published by the Ministry of Energy and Natural Resources, import dependency rate is expected to be around the same level. This high level of dependency on imported energy resources creates pressure on the country's balance of trade.

Coal is the most important domestic energy resource for Turkey. However, when the quality of the coal reserves is taken into consideration, it is seen that most of the reserves are suitable only for power generation.

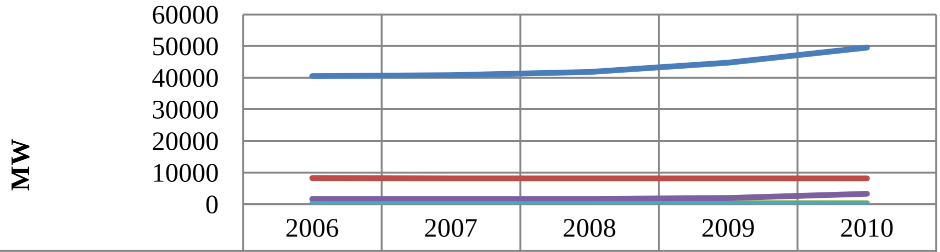
Installed Power Capacity and Coal Resources

Table 2.10 shows the coal fired installed power capacity (MW) between 2006 and 2010, together with other resources (TEİAŞ, 2011; ETKB, 2011a).

Table 2. 10 Development of installed power capacity in Turkey (MW)

INSTALLED CAPACITY (MW)	2006	2007	2008	2009	2010
FUEL-OIL	2.164	1.767	1.745	1.541	1.483
	5,3	4,3	4,17	3,4	3,0
DIESEL	214,4	206,5	26,5	26,5	26,5
	0,5	0,5	0,06	0,06	0,05
IMPORTED COAL	1.651	1.651	1.651	1.921	3.281
	4,1	4,0	3,95	4,3	6,6
ANTHRACITE	335,0	335,0	335,0	335,0	335,0
	0,8	0,8	0,8	0,8	0,7
LIGNITE	8.211	8.111	8.109	8.110	8.140
	20,3	19,9	19,4	18,1	16,4
ASPHALTITE	-	-	-	135,0	135,0
	-	-	-	0,3	0,3
NATURAL GAS	12.641	12.853	13.428	14.555	16.112
	31,2	31,5	32,1	32,5	32,5
NAPHTHA	21,4	21,4	21,4	21,4	16,9
	0,1	0,05	0,05	0,05	0,03
RENEWABLE+WASTE	41,3	42,7	59,7	81,5	96,9
	0,1	0,10	0,14	0,2	0,2
MULTI-FUEL (SOLID+LIQUID)	453,7	560,3	560,3	551,5	551,5
	1,1	1,37	1,34	1,2	1,1
MULTI-FUEL (LIQUID+NATURAL GAS)	1.625	1.725	1.659	2.062	2.101
	4,0	4,2	4,0	4,6	4,2
TOTAL MULTI-FUEL	**2.079**	**2.285**	**2.219**	**2.614**	**2.653**
	5,1	**5,6**	**5,3**	**5,8**	**5,4**
HYDROLIC DAMS	11.967	12.262	12.423	12.682	13.067
	29,6	30,0	29,71	28,3	26,4
HYDROLIC STREAM	1.096	1.133	1.406	1.872	2.764
	2,7	2,8	3,36	4,2	5,6
TOTAL HYDROLIC	**13.063**	**13.395**	**13.829**	**14.553**	**15.831**
	32,3	**32,8**	**33,1**	**32,5**	**32,0**
WIND	59,0	146,3	363,7	791,6	1.320
	0,15	0,36	0,87	1,8	2,7
GEOTHERMAL	23,0	23,0	29,8	77,2	94,2
	0,06	0,06	0,07	0,2	0,2
TOTAL INSTALLED CAPACITY (MW)	**40.502**	**40.836**	**41.817**	**44.761**	**49.524**

The development of total installed power capacity and the coal fired installed power capacity in Turkey between 2006 and 2010 are shown in Figure 2.22. The share of coal within the total installed capacity between 2006 and 2010 is shown in Figure 2.23 (TEİAŞ, 2011a).



	2006	2007	2008	2009	2010
Total Installed Capacity	40502	40836	41817	44761	49524
Lignite	8211	8111	8109	8109	8140
Anthracite	335	335	335	335	335
Imported Coal	1651	1651	1651	1921	3281
Asphaltite	0	0	0	135	135

Figure 2. 22 The place of coal within the total installed power capacity

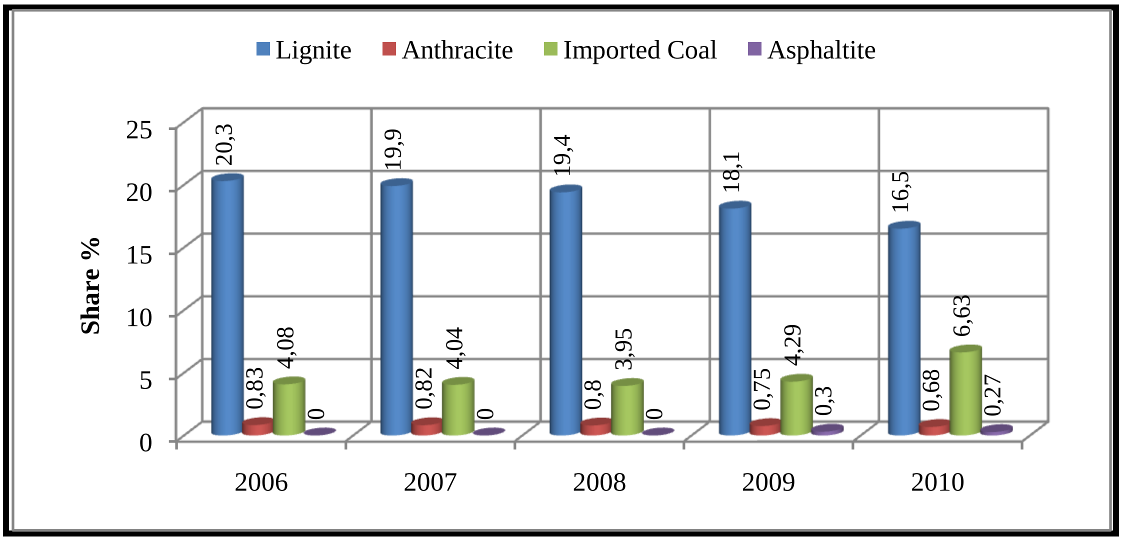


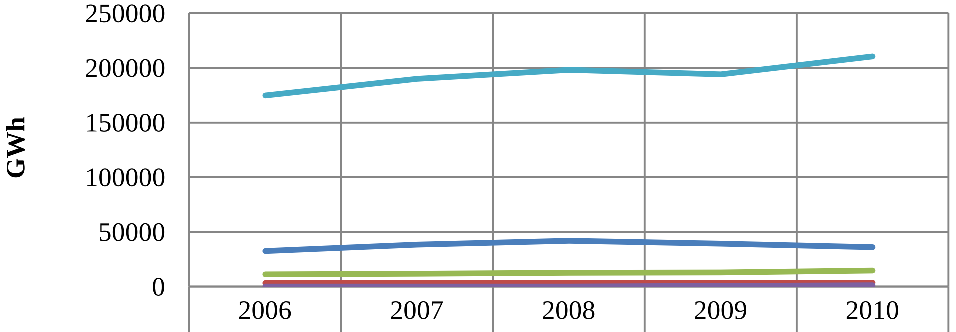
Figure 2. 23 Share of coal in total installed capacity

The share of coal in power generation between 2006 to 2010 as GWh and (%) are shown in Table 2.11.

Table 2. 11 Shares of resources in power generation in Turkey (GWh)

PRIMARY RESOURCES			**2006**	**2007**	**2008**	**2009**	**2010**
FUEL-OIL	Generation	GWh	4.232	6.470	7.209	4.440	2.144
	Share	%	2,4	3,4	3,6	2,3	1,0
DIESEL	Generation	GWh	57,7	13,2	266,2	345,8	4,2
	Share	%	0,0	0,0	0,1	0,2	0,0
IMPORTED COAL	Generation	GWh	11.143	11.847	12.567	12.813	14.532
	Share	%	6,3	6,2	6,3	6,6	6,9
NATURAL GAS	Generation	GWh	80.691	95.025	98.685	96.095	98.144
	Share	%	45,8	49,6	49,7	49,3	46,5
LPG	Generation	GWh	0,1	0,0	0,0	0,4	0,0
	Share	%	0,0	0,0	0,0	0,0	0,0
NAPHTHA	Generation	GWh	50,3	43,9	43,6	17,6	31,9
	Share	%	0,0	0,0	0,0	0,0	0,0
TOTAL FOREIGN SOURCE	Generation	GWh	**96.175**	**113.398**	**118.771**	**113.712**	**114.855**
	Share	%	**54,6**	**59,2**	**59,9**	**58,4**	**54,4**
ANTHRACITE	Generation	GWh	3.074	3.290	3.291	3.335	3.588
	Share	%	1,7	1,7	1,7	1,7	1,7
LIGNITE	Generation	GWh	32.433	38.295	41.858	39.090	35.942
	Share	%	18,4	20,0	21,1	20,1	17,0
ASPHALTITE	Generation	GWh	-	-	-	447,6	984,3
	Share	%	-	-	-	0,2	0,5
RENEWABLE+WASTE	Generation	GWh	153,9	213,7	219,8	340,1	457,5
	Share	%	0,1	0,1	0,1	0,2	0,2
TOTAL HYDROLIC	Generation	GWh	44.244	35.851	33.270	35.958	51.796
	Share	%	25,1	18,7	16,8	18,5	24,5
WIND	Generation	GWh	126,5	355,1	846,5	1.495	2.916
	Share	%	0,1	0,2	0,4	0,8	1,4
GEOTHERMAL	Generation	GWh	94,0	156,0	162,4	435,7	668,2
	Share	%	0,1	0,1	0,1	0,2	0,3
TOTAL DOMESTIC SOURCE	Generation	GWh	**80.125**	**78.160**	**79.647**	**81.102**	**96.352**
	Share	%	**45,4**	**40,8**	**40,1**	**41,6**	**45,6**
GENERATION OF TURKEY	Generation	GWh	**176.300**	**191.558,1**	**198.418**	**194.813**	**211.208**
	Share	%	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**
IMPORTS			573,2	864,3	789,4	812,0	1.144
EXPORTS			2.236	2.422	1.122	1.546	1.918
CONSUMPTION OF TURKEY (GWh)			**174.637**	**190.000**	**198.085**	**194.079**	**210.434**

Total power generation and the power generated from coal between 2006 to 2010 are shown in Figure 2.24 as GWh and in Figure 2.25 as % (TEİAŞ, 2011a).



	2006	2007	2008	2009	2010
Lignite	32433	38295	41858	39090	35942
Anthracite	3074	3290	3291	3335	3588
Imported Coal	11143	11847	12567	12813	14532
Asphaltite	0	0	0	448	984
Total of Turkey	174637	190000	198085	194079	210434

Figure 2. 24 Power generated using coal (GWh)

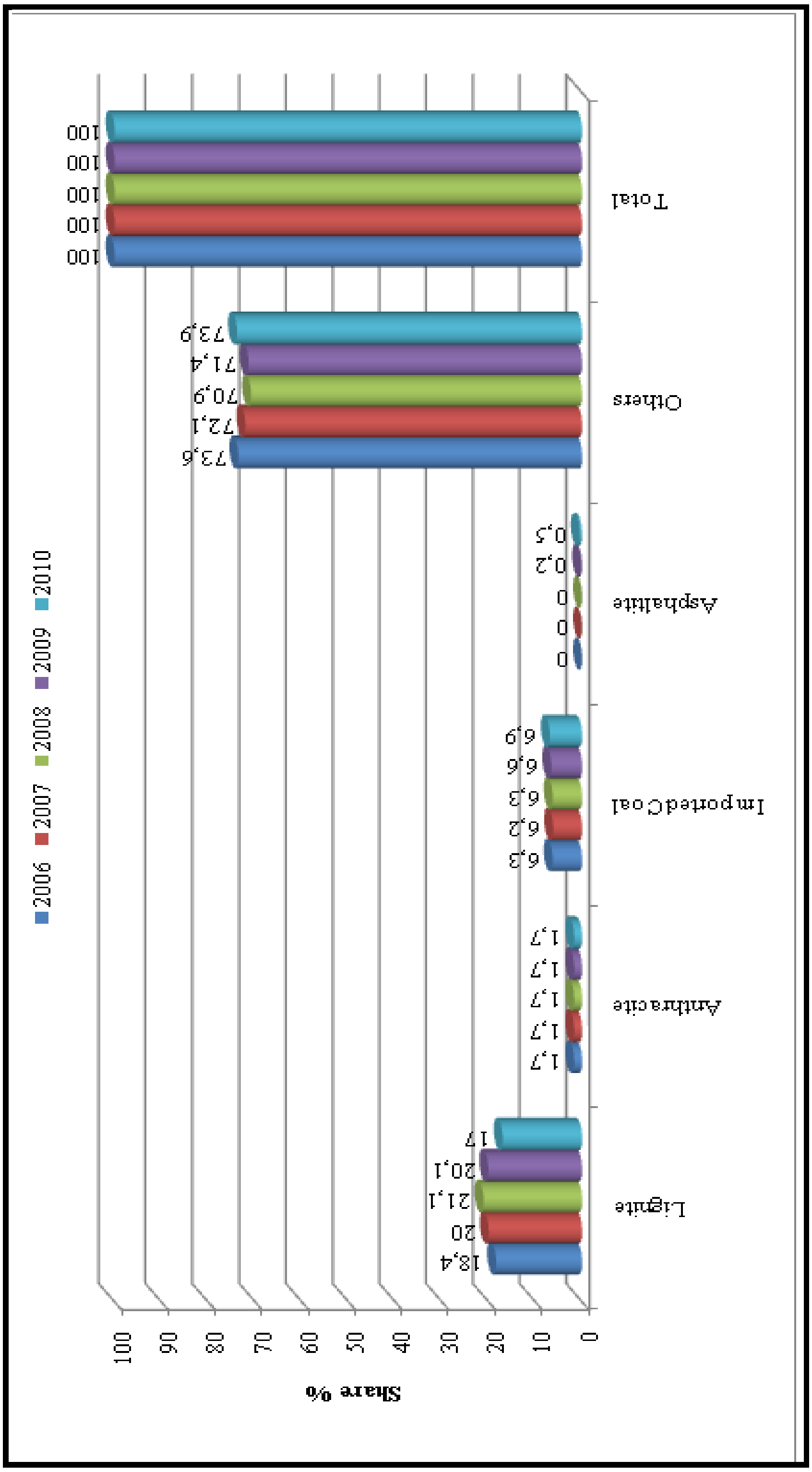


Figure 2. 25 Share of coal in total power generation

CHAPTER 3

ESTABLISHMENTS OF TKİ

3.1 Introduction

Turkish Coal Enterprises (TKİ) is the leading public lignite coal producer of Turkey as explained in Chapter 2. It was established in 1957.

TKİ realizes its lignite production through 8 establishments:

- EGE Lignite Establishment (**EGESOMA**)
- ÇAN Lignite Establishment (**ÇAN**)
- GÜNEY EGE Lignite Establishment (**YATAĞAN**)
- YENİKÖY Lignite Establishment ((**YENİKÖY**)
- GARP Lignite Establishment (**GARP**)
- ILGIN Lignite Establishment (**ILGIN**)
- SEYİTÖMER Lignite Establishment (**SEYİTÖMER**)
- BURSA Lignite Establishment (**BURSA**)

The lignite reserves of those establishments in the years between 2006 to 2010 are shown in Figure 3.1. The lignite production of TKİ and its breakdown to the establishments between 2006 to 2010 are shown in Figure 3.2, Figure 3.3, Figure 3.4 and Figure 3.5 (TKİ, 2011a; TKİ, 2011b; TKİ, 2011c; TKİ, 2011d; TKİ, 2011e).

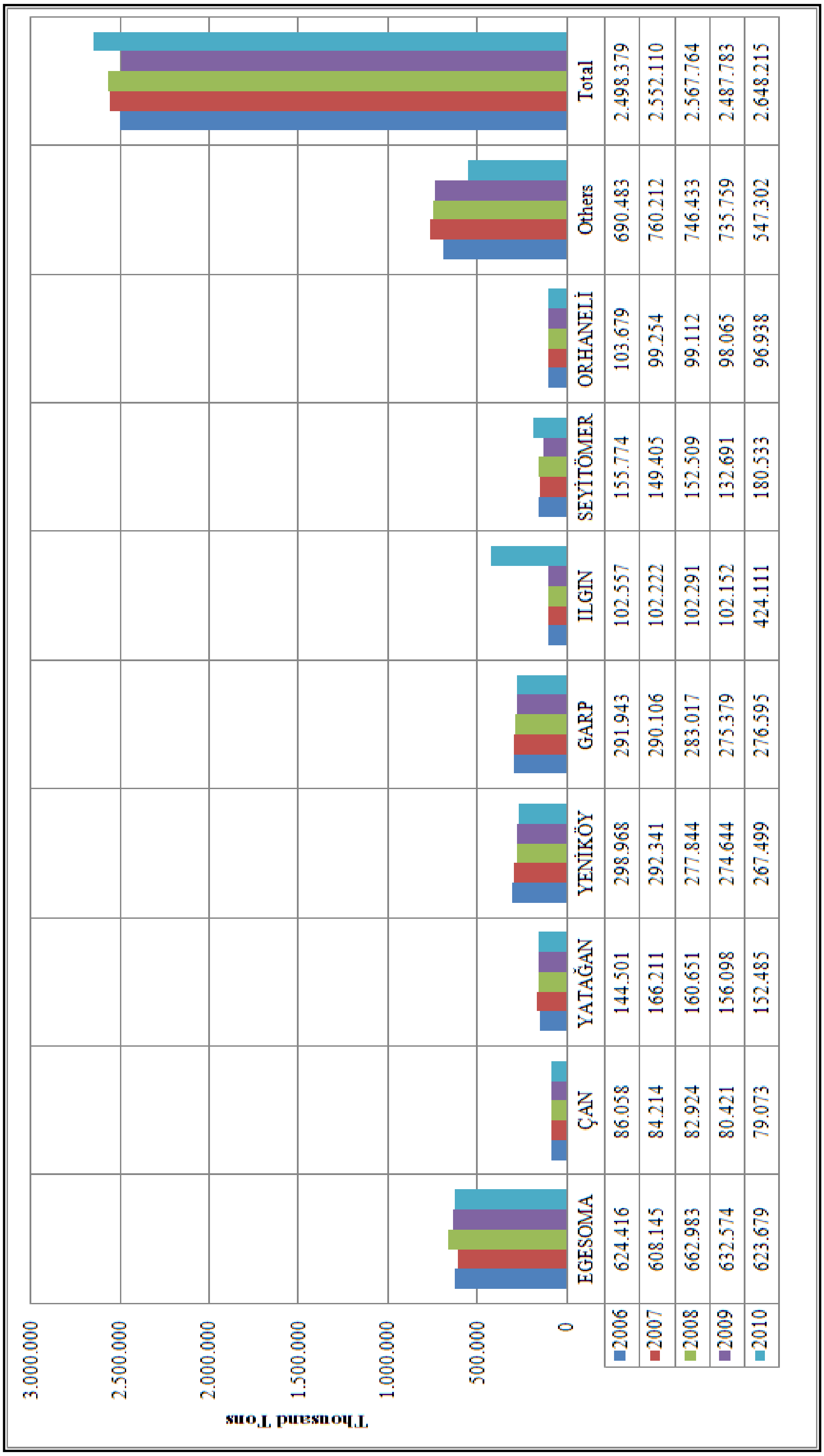


Figure 3. 1 Lignite reserves of TKİ establishments

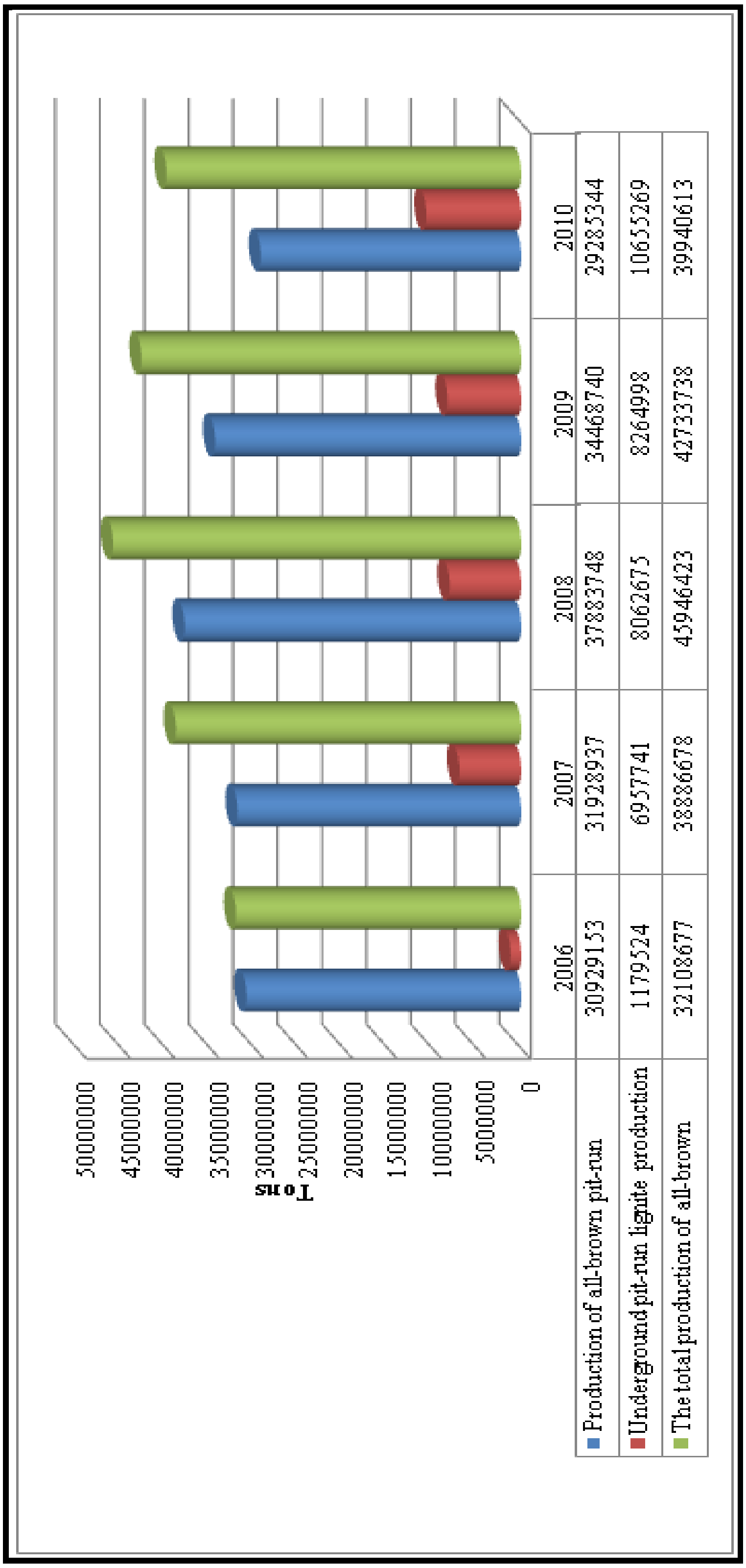


Figure 3. 2 Underground and open-pit run lignite production of TKİ

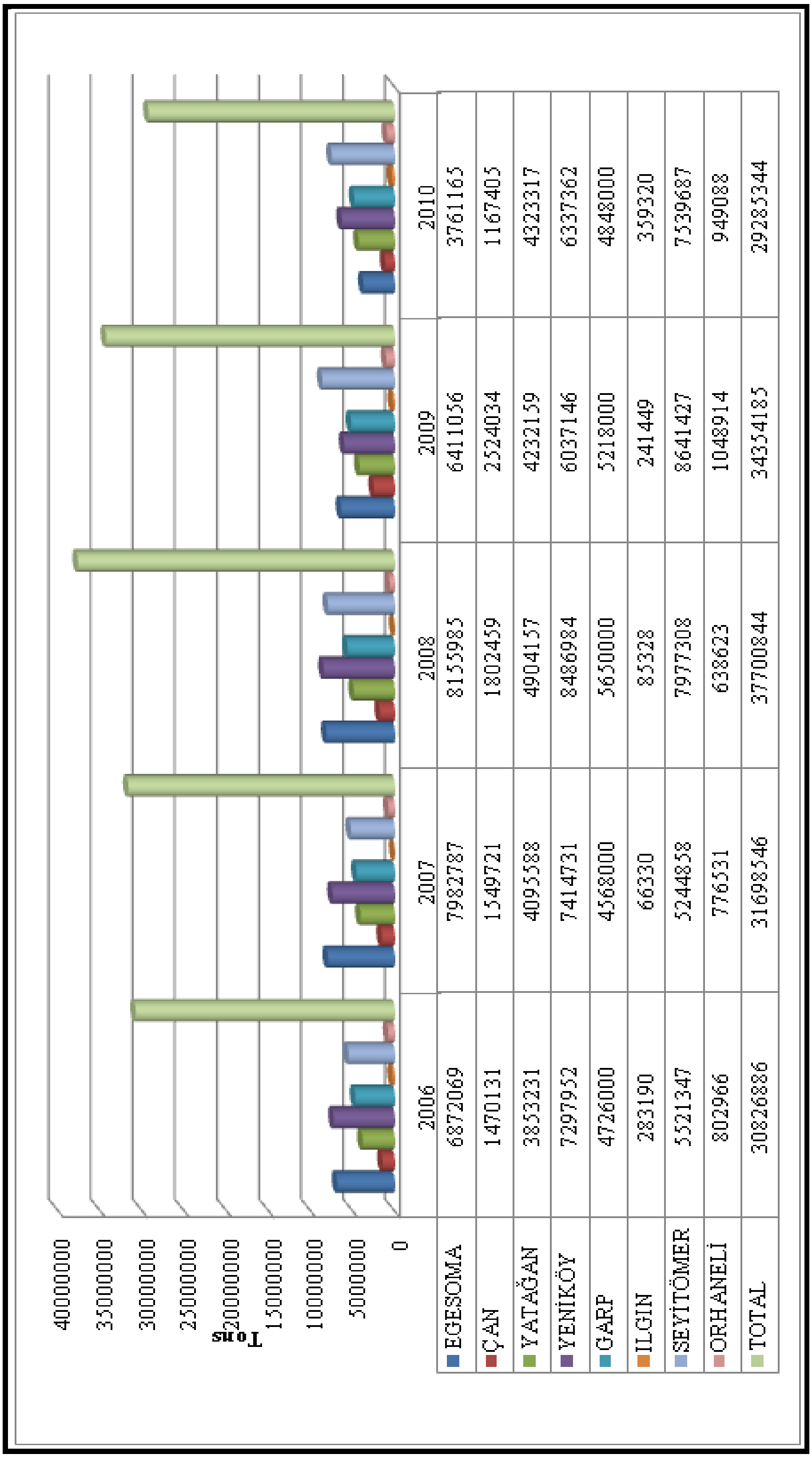
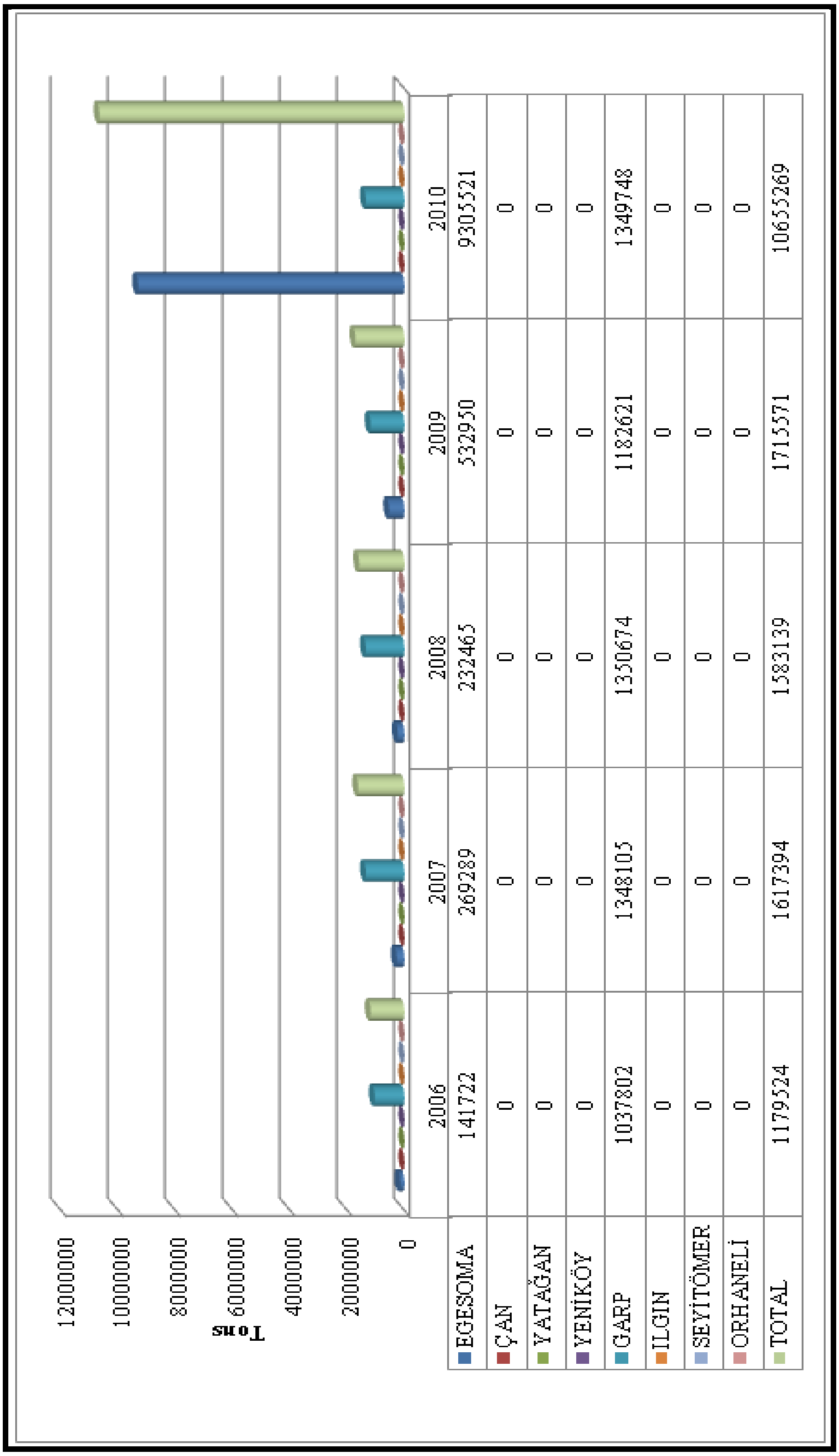
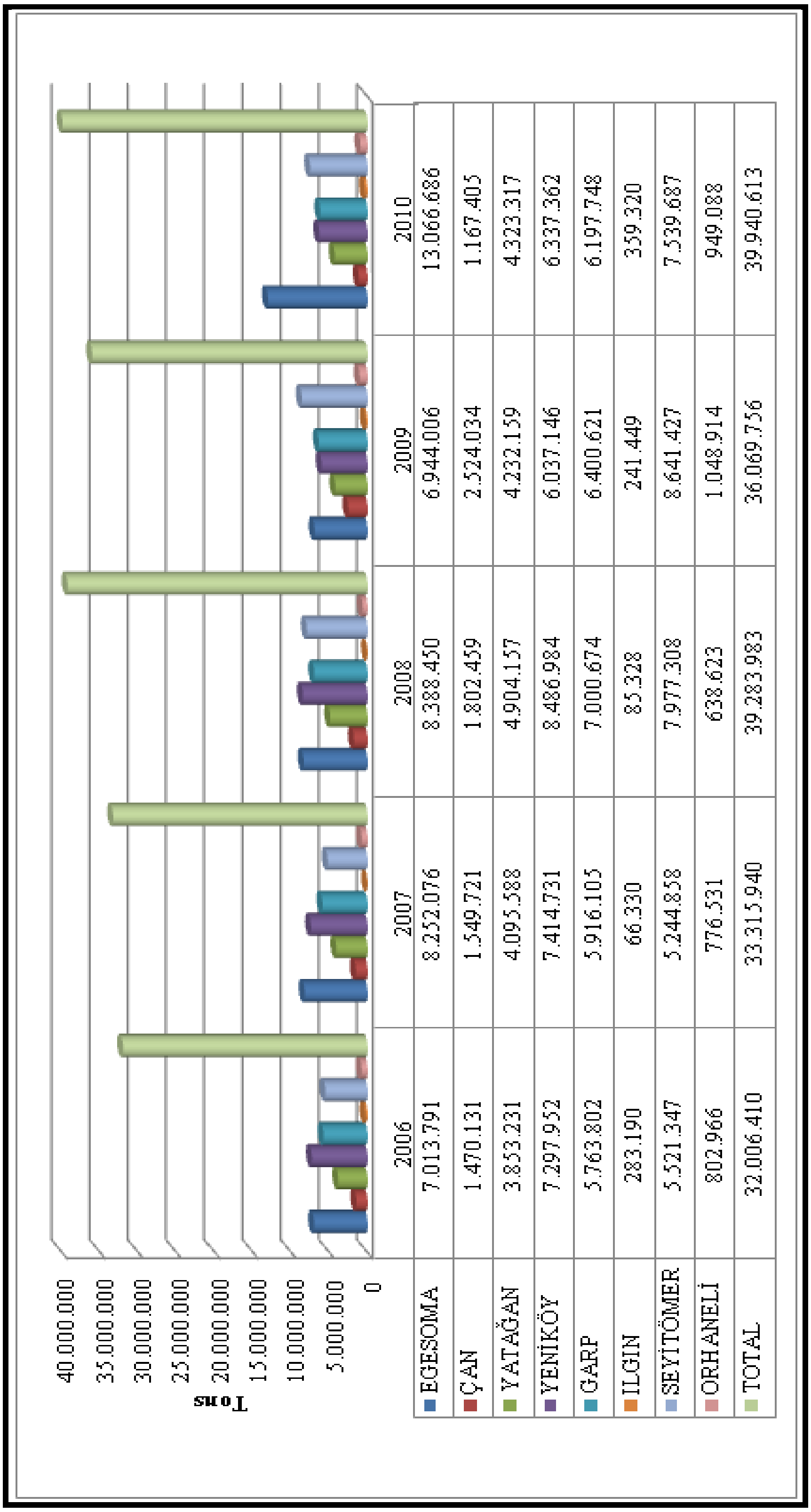


Figure 3. 3 Open-pit run lignite production of TKİ establishments



	2006	2007	2008	2009	2010
EGESOMA	141722	269289	232465	532950	9305521
ÇAN	0	0	0	0	0
YATAĞAN	0	0	0	0	0
YENİKÖY	0	0	0	0	0
GARP	1037802	1348105	1350674	1182621	1349748
ILGIN	0	0	0	0	0
SEYİTÖMER	0	0	0	0	0
ORHANELİ	0	0	0	0	0
TOTAL	1179524	1617394	1583139	1715571	10655269

Figure 3. 4 Underground pit run lignite production of TKİ establishments



	2006	2007	2008	2009	2010
EGESOMA	7.013.791	8.252.076	8.388.450	6.944.006	13.066.686
ÇAN	1.470.131	1.549.721	1.802.459	2.524.034	1.167.405
YATAĞAN	3.853.231	4.095.588	4.904.157	4.232.159	4.323.317
YENİKÖY	7.297.952	7.414.731	8.486.984	6.037.146	6.337.362
GARP	5.763.802	5.916.105	7.000.674	6.400.621	6.197.748
ILGIN	283.190	66.330	85.328	241.449	359.320
SEYİTÖMER	5.521.347	5.244.858	7.977.308	8.641.427	7.539.687
ORHANELİ	802.966	776.531	638.623	1.048.914	949.088
TOTAL	32.006.410	33.315.940	39.283.983	36.069.756	39.940.613

Figure 3. 5 Total pit-run lignite production of TKİ establishments

As explained before, the core of this study is to perform an efficiency and total factor productivity analyses of TKİ establishments. Therefore the detailed introduction of the 8 establishments is given in this section. Within this context, the data which are used in the models constructed and in the analyses is also provided in this section.

The abbreviations used in the analysis, tables and graphs in this study are explained below:

Name of Establishments:

- EGE Lignite Establishment (**EGESOMA**)
- ÇAN Lignite Establishment (**ÇAN**)
- GÜNEY EGE Lignite Establishment (**YATAĞAN**)
- YENİKÖY Lignite Establishment ((**YENİKÖY**)
- GARP Lignite Establishment (**GARP**)
- ILGIN Lignite Establishment (**ILGIN**)
- SEYİTÖMER Lignite Establishment (**SEYİTÖMER**)
- BURSA Lignite Establishment (**BURSA**)

Data:

- Total Number of Employees : NE
- Investment Expenses (TL) : IE
- Operating Expenses (TL) : OE
- Saleable Production (Tons) : SP
- Sales revenue (TL) : SR
- Total Number of Accidents : TA
- Work Safety Education and Training (Hours) : ETP
- Work Safety Expenses (TL) : WSI

3.2.1 EGE Lignite Establishment (EGESOMA)

In the region, there are 624 million tons of lignite reserves with a calorific value of 2080 to 3.150 kcal/kg. 70% of the reserves can be produced with underground mining methods.

Designed production capacity in EGESOMA is 14,2 million tons per year. EGESOMA provides lignite for Soma Power plant with the total installed capacity of 1.034 MW. It provides almost half of the total sales of TKİ to the market. As of 2010, 41% of the sales were for heating and industry.

Data for EGESOMA establishment used in the analyses is given in Table 3.1.

Table 3. 1 Data for EGESOMA

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	4132	1654792	75	7788116	495183466	3158	44481099	657472023
2007	2646	1830840	46	8690564	600792258	2920	43715531	593134460
2008	2644	2135692	35	10096626	789008529	2452	46660144	651383233
2009	3818	2449668	32	8852555	826489437	2298	51852888	731149343

3.2.2 ÇAN Lignite Establishment (ÇAN)

In Çan region, there are 79 million tons of lignite reserves with a calorific value of 3.000 kcal/kg. All of the reserves can be produced with open-pit mining methods

The designed lignite production capacity is 2,3 million tons per year. ÇAN provides lignites to a thermal power plant with the total installed capacity of 320 MW. 90% of the total sales of the enterprise is for this power plant.

Data for ÇAN establishment used in the analyses is given in Table 3.2.

Table 3. 2 Data for ÇAN

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	626	278768	5	1340701	83352050	532	16560690	161199588
2007	525	308484	4	1932801	108852927	492	17658272	158411527
2008	765	383240	10	1930330	108471678	440	15925609	142975257
2009	451	492492	1	1694648	113757532	462	15115809	122571715

3.2.3 GÜNEY EGE Lignite Establishment (YATAĞAN)

In the region, there are 152 million tons lignite reserves. 65% of the reserves can be produced with underground mining methods.

The designed lignite production capacity of YATAĞAN is 5,4 million tons per year. It provides lignite for a thermal power plant with the total installed capacity of 420 MW. 99% of the total sales of the establishment are for that power plant. The current production method in YATAĞAN is open-pit mining.

Data for YATAĞAN establishment used in the analyses is given in Table 3.3.

Table 3. 3 Data for YATAĞAN

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	2058	17627	23	4005317	110794635	1089	12688793	122227776
2007	754	26448	10	4033727	141981295	1027	13065011	130826143
2008	1489	18334	6	5076815	183853991	909	13503150	150075743
2009	1286	13415	12	4255164	177200521	869	13837037	148495572

3.2.4 YENİKÖY Lignite Establishment (YENİKÖY)

In the YENİKÖY establishment, there are 267 million tons of lignite reserves. 11% of the reserves can be produced with underground mining methods.

The designed lignite production capacity of the establishment is 9,8 million tons per year. It provides lignite to power plants with a total capacity of 1.050 MW. Lignite production is carried out by open-pit mining methods.

Data for YENİKÖY establishment used in the analyses is given in Table 3.4.

Table 3. 4 Data for YENİKÖY

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	1062	16832	15	6718621	152765713	631	9472837	105474283
2007	33	24297	14	6424363	174385439	598	11298434	133140120
2008	774	21717	13	6962156	199429859	488	12083334	124696780
2009	759	29516	15	5689927	187792690	478	11888905	105567379

3.2.5 GARP Lignite Establishment (GARP)

There are 277 million tons of lignite reserves in the region. 86% of the reserves can be produced by underground mining methods.

The designed lignite production capacity is 6,1 million tons per year. It provides lignites to power plant with 429 MW installed capacity. 55% of the total sales of the establishment are for heating and industry. 76% of the total production is realized by open-pit mining methods.

Data for GARP establishment used in the analyses is given in Table 3.5.

Table 3. 5 Data for GARP

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	4582	874162	47	3414978	285886309	2933	31348409	352838084
2007	299	587841	57	3371692	306559167	2835	33588990	371554000
2008	2053	415371	69	3801379	391692960	2382	40073209	402589705
2009	354	390149	32	3398862	417461635	2243	50908148	324111850

3.2.6 ILGIN Lignite Establishment (ILGIN)

In the region, there are 424 million tons of lignite reserves with a calorific value of 2.180 kcal/kg.

Lignite production is realized by open-pit mining methods. In 2010 only 358.000 tons lignites were produced to meet the demands of local households and small scale industry.

Data for ILGIN establishment used in the analyses is given in Table 3.6.

Table 3. 6 Data for ILGIN

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	221	5000	2	211566	9298097	182	5028356	14742819
2007	336	3750	1	76560	8782479	155	6551951	20821661
2008	182	4000	1	139387	9891407	147	6150239	14717284
2009	206	3750	1	260796	21855839	148	5761733	23649900

3.2.7 SEYİTÖMER Lignite Establishment (SEYİTÖMER)

There are 181 million tons of lignite reserves in the region with a calorific value of 2.080 kcal/kg. The designed lignite production capacity is 7,7 million tons per year. It provides lignite to power plants with the total installed capacity of 600 MW. It also provides lignite to heating and industry. All of the production in the region is realized by open-pit mining methods. Data for EGESOMA establishment used in the analyses is given in Table 3.7.

Table 3. 7 Data for SEYİTÖMER

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	1555	229754	25	4602873	123898005	1086	16439673	102561475
2007	525	217816	13	4891348	144912386	1020	15998154	94396721
2008	1756	183935	13	6140686	192615404	812	15629575	103555534
2009	2663	135014	16	6597124	232610388	875	13462794	105598067

3.2.8 BURSA Lignite Establishment (BURSA)

There are 97 million tons lignite reserves in the region with a calorific value ranging between 1900 and 2500 kcal/kg. The designed production capacity is 2,7 million tons per year. It provides lignite to a power plant with an installed capacity of 210 MW, and to heating and industry. Lignite production in the establishment is realized by open-pit mining methods. Data for BURSA establishment used in the analyses is given in Table 3.8.

Table 3. 8 Model Data of BURSA

Years	ETP (Hours)	WSI (TL)	TA (Number)	SP (tons)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
2006	932	4776	6	1218771	51407504	687	17793126	78944449
2007	1205	3847	4	1468941	62400880	611	16845340	88008820
2008	662	6200	3	1495976	69572656	534	16547802	71329693
2009	242	14054	3	1470955	79919993	574	16577917	87014310

CHAPTER 4

METHODOLOGIES USED IN THE ANALYSES

4.1 Introduction

The Data Envelopment Analysis (DEA) technique, as developed by Charnes, Cooper and Rhodes, is named CCR for the initial letters of the surnames of its founders. The CCR technique is a linear programming based technique for measuring the relative performances of decision making units (DMUs) (Charnes, Cooper, Rhodes, 1978).

Being a nonparametric and multivariate measurement technique, DEA was first adopted as a new tool in the analysis of the comparative technical productivities of public sector decision making units in the management science (Fare, Grosskoph and Lovell, 1994). The theory of DEA had been further developed from the 1980s onwards. The CCR model was modified by Banker, Charnes and Cooper into the BCC model, named again for the initial letters of the surnames of its founders (Banker, Charnes, Cooper, 1984).

DEA has been used to measure the efficiencies in a wide application area, for instance by Cingi and Tarım (2000), Atan (2003) and by Vassiloglou and Giokas (1990) in the Banking sector; by Lewin and Morey (1981) in Public Sector organizations; by Banker, Conrad and Strauss (1986) in Health Services and Hospitals; by Ahn (1987), by Johnes (2005), by Ruggiero (2005) and Kao and Hung (2006) in Schools, education services and Universities; by Chen (1997), Shim (2000), Shim (2003), Ethelene (2002), Hammond (2002), Sharma, Leung and Zane (1999) and Vitaliano (1998) in Libraries; by Düzakın and Düzakın (2007) and Kahraman, Ulukan and Tolga (1999) in the Manufacturing Industry; by Chen, Liang, Yang and Zhu (2006) in the Information Technology area; by Mao and Koo (1997) in the Agriculture sector; by Zhu (1998), Martic and Savic (2001), Athanassopoulos (1996), Aslankaraoğlu (2006) and Özyiğit (2000) in Socio-Economic Development and Regional Development areas; by Drake and Simper (2002) in the Security area and Police departments; by Roll, Golany and Seroussy (1989), Bowlin (1987) and Bowlin (1999) in the Military and Defense industry; by Yu (2004) in airports; by Sözen and Alp (2009) and by Zhang, Hung, Lin and Yu (2009) in environmental studies; and by Easton, Murphy and Pearson (2002) in marketing.

In recent years DEA and DEA-based methodologies have been widely used in the energy and mining sectors as well.

Vaninsky (2006) used DEA in assessing efficiencies in electric power generation in the US between 1991-2004. In his model, he included operating expenses and energy losses in inputs and net capacity in output.

Jamash, Pollitt and Triebs (2008) analyzed the efficiencies of 39 US gas transmission companies between 1996-2004 by using DEA.

Ramos, Tovar, Iootty, Almeaida and Pinto (2009) analyzed efficiencies of 18 Brazilian electricity distribution firms between 1998-2005 by using DEA. In their model, the length of electricity grid (km), number of employees and losses (GWh) were taken as inputs, and sales (GWh) and number of customers were taken as outputs.

Wang, Ngan, Engriwan and Lo (2007) studied efficiencies of Hong Kong electricity supply industry between 1978-2003 by using Malmquist Index methodology. They took capital increase and labor as inputs, and electricity delivery sales (MWh) and Customer density (customer/km^2) as outputs.

Kulshreshtha and Parikh (2002) studied the efficiencies of underground and opencast coal mining firms in India between 1985-1997 by using Malmquist Index methodology.

Reyes and Tovar (2010) studied the efficiencies of 14 Peruvian electricity distribution companies by using Malmquist Index methodology. In their analysis, number of employees, power delivery losses (MWh) and network length (km) were included among inputs, and sales (MWh) and number of customers among outputs.

Hawdon (2003) analyzed the efficiencies of 33 International gas firms between 1998-1999 by using DEA. In the analysis, employment and pipeline length were taken as inputs, and gas consumption and number of customers were taken as outputs.

Wolf (2009) analyzed the efficiencies of 1001 international petroleum gas firms between 1987-2006 by using Multivariate regression methodology. In his model, petroleum/gas reserves, total assets and number of employees were taken as inputs, and revenue and net profit as outputs.

Abbott (2006) analyzed the efficiencies of the electricity supply industry of Australia between 1969-1999 by using DEA. In his analysis capital stock, energy consumed (in TJ) and labor employments were used as inputs, and electricity consumed as output.

Barros (2008) performed the efficiency analysis of energy production of thermo energy plants in Portugal between 2001-2004 by using Malmquist Index methodology. In the study, the number of employees, capital, operating expenses and investment were taken as inputs, and energy produced (MW) and capacity usage as outputs.

Sözen, Alp and Özdemir (2010) studied the efficiencies of thermal power plants in Turkey by using Data Envelopment Analysis.

Estache and Rossi (2005) studied the efficiencies of 12 electricity firms in African countries between 1998-2005 by using Malmquist Index methodology. Capital and labor were taken as inputs, and sales, electricity consumption and customers as outputs.

Wei and Wang (2005) studied the efficiencies of 10 listed Chinese coal companies in 2003 by using DEA. In their analysis, total assets per share, total net assets per share and operating costs per share were taken as inputs, and earnings per share and operations gains per share as outputs.

Ran and Hui (2006) analyzed the efficiencies of 16 Chinese coal companies in 2005 by using DEA. The total capital, number of workers and operating cost were taken as inputs, and net gains and operation gains as outputs.

Hong, Wu and Zeng (2009) studied 17 Chinese and 8 US coal mining companies between 2001-2005 in their efficiency analysis by using DEA. The total net assets, number of workers and operating expenses were used as inputs, and gains per share and operating profit/net profit ratio as outputs.

Wei, Liao and Fan (2007) studied the efficiencies of 25 Chinese iron and steel plants between 1994-2003 by using Malmquist Index. Fuel oil, natural gas, electricity, coal, charcoal and coke were used as inputs, and pig iron, raw steel and steel as outputs.

Mukherjee (2008a) studied the efficiencies of 18 Indian manufacturing sectors between 1998-2004 by using DEA. Labor, capital, energy and materials were used as inputs, and gross production value of state manufactured products as output.

Mukherjee (2008b) again studied the efficiencies of US manufacturing sector between 1970-2001 by using DEA. Capital, labor, energy, materials and services were used as inputs, and production value and consumption value as outputs.

Lei and Ri-jia (2008) studied the efficiency in Entrance security for coal mines in China by using DEA. The rate of professional personnel security, the per-employee cost of protection equipment of security personnel, security training and training cost per personnel and management cost of security personnel were taken as inputs, and reduction in the risk degree and reduction in injures as outputs.

Kasap (2008) studied the development of productivity and efficiency in Turkish coal sector in 2006 by using Data Envelopment Analysis. In her study, investment expenses, number of employees, amount of coal sold and total revenue were assumed as the parameters that can be controlled, and reserve, calorific value and sulphur content of coal as the parameters that cannot be controlled. In the DEA model, amount of coal and total revenue were taken as output and other parameters were taken as inputs.

In response to the widespread applications around the world, the studies in Turkey have been generally limited with the papers presented in economics and operational research congresses and with applications that are intensified in health and banking areas.

4.2 Key Concepts and Definitions

Performance

Performance is defined as a concept which includes the quantitative and qualitative evaluation of how much of targets relating to a job performance are achieved by the individual, the group or the institution that perform the job. In addition to this, performance can also be interpreted as a ratio that determines the acquired things as a result of a planned activity.

Performance in an organization level, or performance for a decision making unit (DMU), can be defined as the level of performing of the target or competence of an organization in terms of output/result in a certain time period.

Performance can be defined by taking into consideration several different approaches (Sözen, 2010). By using the "aim" approach, it can be said that a DMU is successful as it achieves its objectives. In "System Resource" approach, a DMU can be accepted as successful as it obtains its necessary resources. In "Internal Process" approach, A DMU can be viewed as successful as it shows compatibility with its interior components. In "High Performance System" approach, a DMU is successful when it is relatively superior to its counterparts.

Performance assessment

Performance assessment is an analytic process for a DMU intended to evaluate its products, services and/or results together according to its pre-determined goals and targets. In order to make an enterprise follow the resources to be used, products and services to be produced, and results to be obtained, it should include regular and systematic data gathering, analyzing and reporting steps.

Performance measurement is highly significant to evaluate whether an enterprise achieves its aimed objectives in their operations, whether it wastes its resources while obtaining its own results, whether it performs its services in a productive and efficient way or not. Performance measurement elements for a DMU are presented in Figure 4.1 (Sözen, 2010).

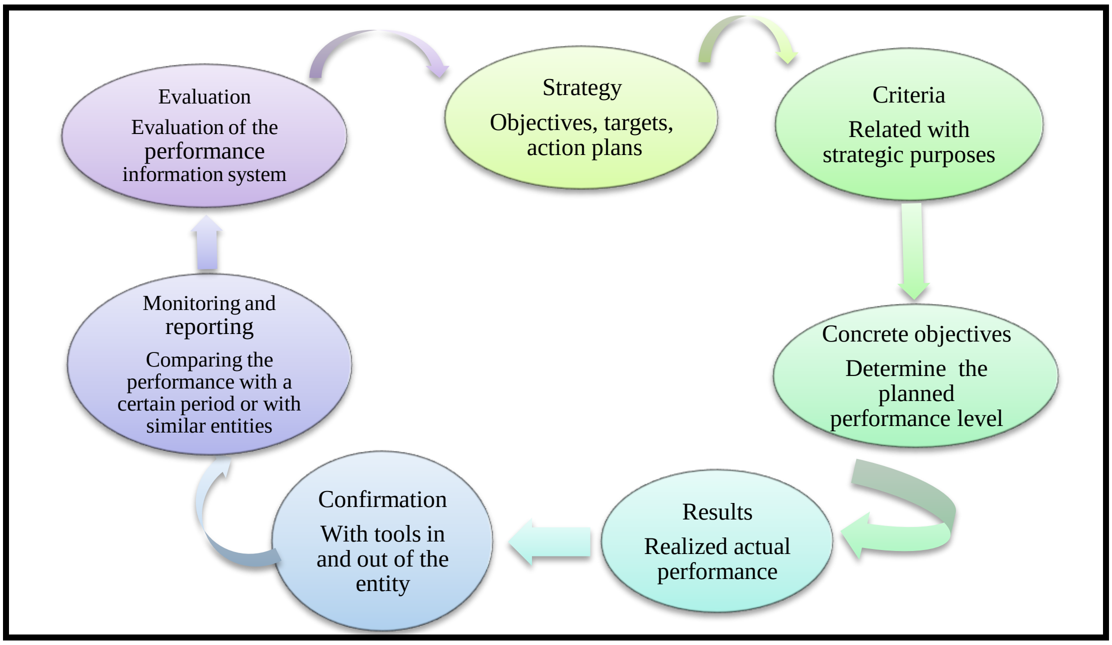


Figure 4. 1 Performance measurement elements

The concept of performance is defined with seven dimensions and the relationships of these dimensions with each other are illustrated in Figure 4.2 (Sözen, 2010).

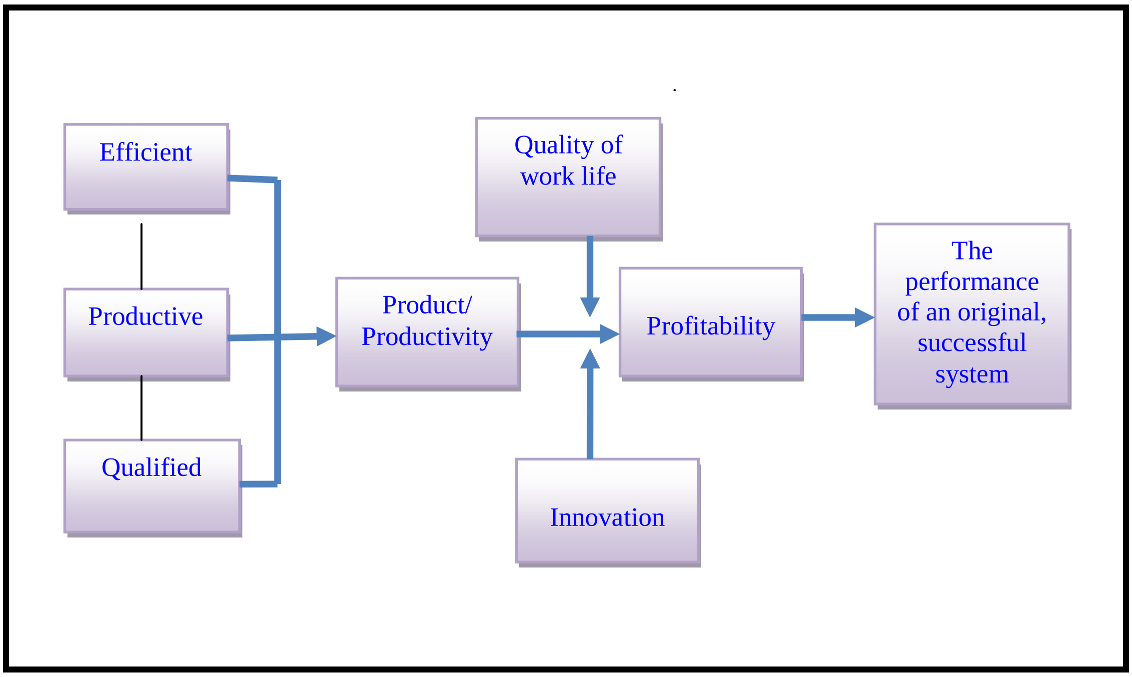


Figure 4. 2 Performance dimensions

Product

Product can be defined as a concept that shows the relationship between the existing resource potential of a DMU and the part of this potential that is used for the production of a product or a service. It is intended to the tools of an organization instead of its targets. This concept is not related to the characteristics such as amount, ratio, monetary value of outputs that are produced or planned to be produced by a DMU; hence it intends to relate to resource consumption for direct production.

Production

Production is the ability to transform inputs to outputs in the best way. It can be described as a function which shows the relationship between maximum output that can be produced technologically and a set of inputs in producing outputs.

Frontier

When obtained function lies in the set that is constituted by the possible observations, this constitutes to a frontier. If any decision units are located under its own production function, this is defined as the measurement of the “relative productivity” (Fare, Grosskoph and Lovell, 1983).

Production Frontier

The boundary of the DMUs that give the best combinations of input-output combination among the set of production possibilities shows the production frontier, and it is impossible to observe a decision unit beyond this boundary (Fare et al., 1983).

Productivity

Productivity is the ratio of outputs to inputs. When a DMU with an input and an output is considered, it can be simply defined as the ratio of output to input.

When it is shown in the coordinate axes (Figure 4.3), as X and Y represent input and output respectively, the productivity is shown with the slope from the origin for each letter representing the decision making unit of (A, B, C….).

With this regard, the most productive DMU is E whereas the least productive DMU is B. The DMUs of C, D and F and the DMUs of B and G have the same productivity levels. The DMU of E is the one with the highest scale size and it is defined by Banker as the one that has the most productive scale size (Fare et al., 1983; Banker, 1984).

Production processes generally include multiple inputs and outputs; in other words, they have multiple parameters. Therefore, the concept of Total Factor Productivity is developed. In total factor productivity, virtual inputs and outputs are obtained by obtaining one input and one output through weighted total of inputs and weighted total of outputs.

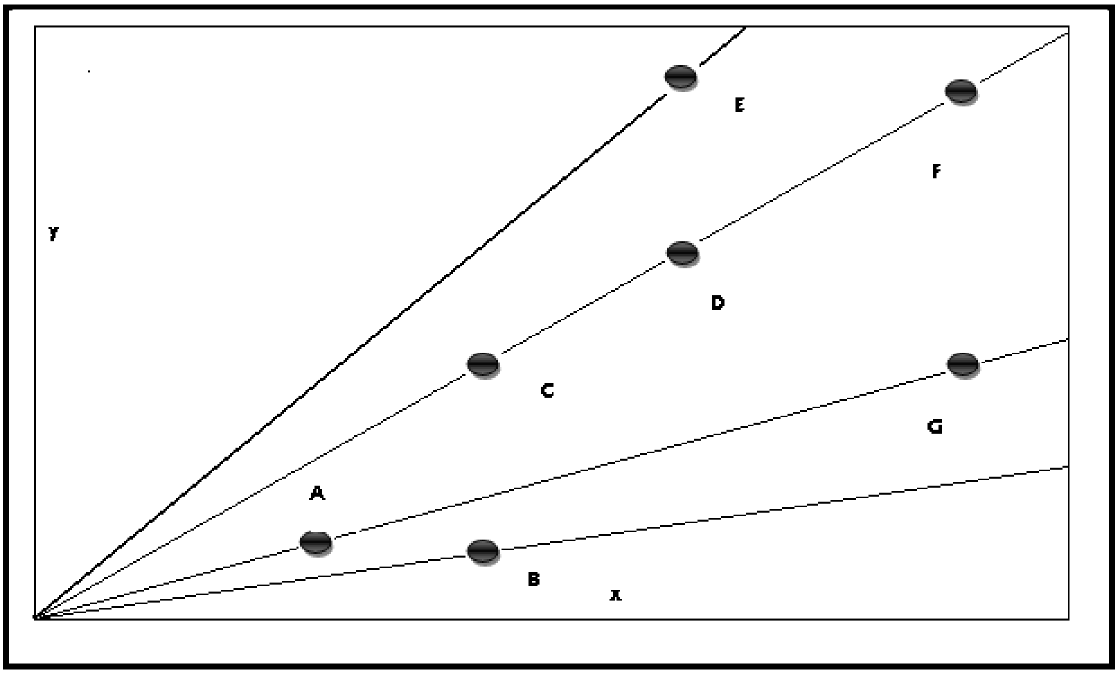


Figure 4.3 Productivity

While the product examines the relationships between the potential resources of a DMU and consumed amounts of these resources, the productivity seeks for the relationship between the consumed resources and obtained outputs, in other words, the transformation power of the resources to a product or a service. This relationship can be illustrated with Figure 4.4 (Sözen, 2010).

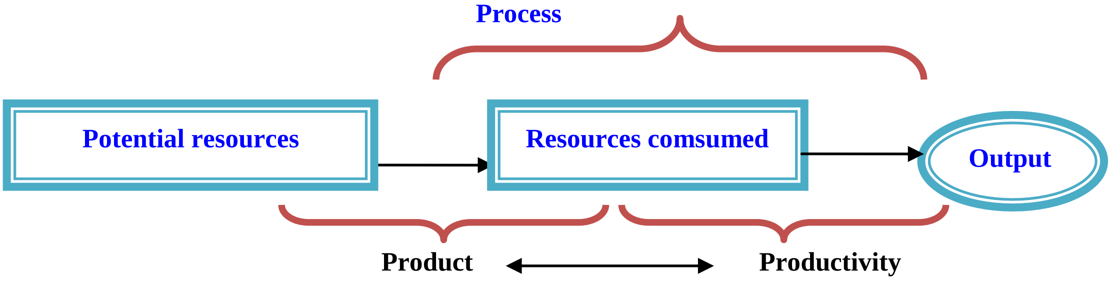


Figure 4. 4 The relationship between product and productivity concepts.

Efficiency

Efficiency can be accepted as an indicator that is obtained by comparing input elements or actual used amount of a production resource with the standards that are pre-determined by certain techniques, and can be defined as follows:

$$\text{Efficiency} = \text{Standard value} / \text{Actual value}$$

Through the efficiency measurement, while obtaining an indicator regarding to where the DMU is, at the same time indicators regarding to how the best output levels and the existing capacity usage can be attained.

Technical efficiency

An efficient production process depends on the production of an output by using the minimum input in the framework of existing technology in a unit of time.

If the inputs that are used during the production process are represented with the $\vec{x}$ vector and outputs are represented with the $\vec{y}$ vector, total set of Xt inputs and Yt outputs through time can be defined with Ω. Therefore Ω indicates the set of all possible input-output combinations at time t or for the decision unit of t. The DMU that has the input and output included in this Ω set is less wasteful and it can be defined as more efficient.

Technical efficiency is defined as the ability to minimize the use of inputs in reaching the given outputs or the ability to obtain the maximum output from a given set of inputs. By this definition, it can be stated that technically efficient decision units should be on the production frontier. It can also be stated that the decision units that lie below the frontier waste their resources. Therefore, the referenced decision units are the ones that define the production frontier and the hypothetical DMUs that are formed as a result of the linear combinations of these referenced decision units (Coelli, 1996).

Production frontier is the set of technically possible production combinations and it can be defined as efficient frontier.

Figure 4.5 is given in order to show the difference between technical efficiency and productivity.

As seen on Figure 4.5, the decision units of A and B are on the production frontier and they are technically efficient. P uses more inputs for the same output level with A, and P produces less output despite of using the same amount of inputs with the DMU of B. Therefore, the DMU of P is referred to as the inefficient DMU.

Productivities of these three DMUs are calculated from their input/output ratios and as a result it is found that the DMU of B is more productive than other DMUs, and P is the least productive DMU. Even though the DMU of A is evaluated as efficient, it is inefficient when compared with the DMU of B.

According to Figure 4.5, technical efficiency and productivity of the DMU of P increase as a result of its movement toward the DMU of B. This is respectively due to increase in the output/input ratio and the fact that it becomes closer to the production frontier. The DMU of A can increase its efficiency by getting closer to B, since it departs from the production frontier and its output/input ratio increases. As being relatively the most productive one, the DMU of C is in the most productive scale size as defined by Banker (1984).

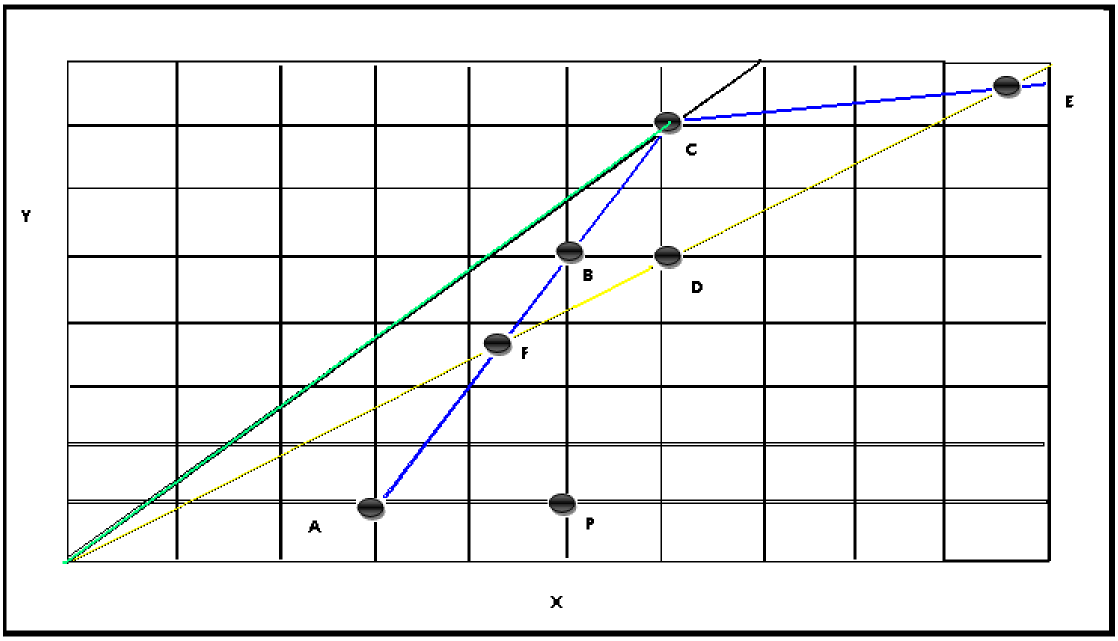


Figure 4. 5 Technical efficiency and productivity

If the DMU of C is compared with the DMU of D, it can be stated that since the DMU of D is not located on the production frontier it wastes its resources. However, the DMU of D is in the same input scale with C that has the most productive scale size. It can be stated that the DMU of D is in the optimal scale but do not use its resources well.

The DMUs of F, D and E are in the same productivity levels but the DMU of D is in the optimum scale. Even thought they are technically efficient, E and F are not in the optimum scale.

If a decision unit or linear combination of other decision units do not produce the same output level by decreasing the amount of at least one input that is used, then the decision unit has the technical productivity. In other words, decision unit's productivity ratio is equal to "1" and its all dummy variables are equal to "0", then this decision unit is productive.

Figure 4.6 shows a hypothetical efficiency frontier based on 5 DMUs (B, D, E, F, G) that use two inputs (x1 and x2) while producing an output. G, F and E are on the line and constitute "the best observed" set. This means that one of the DMUs and linear combinations of any DMUs do not produce the same level of output by using fewer amounts from one or both of these inputs. Efficiency ratio of these DMUs (G, F, E) are equal to "1" and all dummy variables are equal to 0.

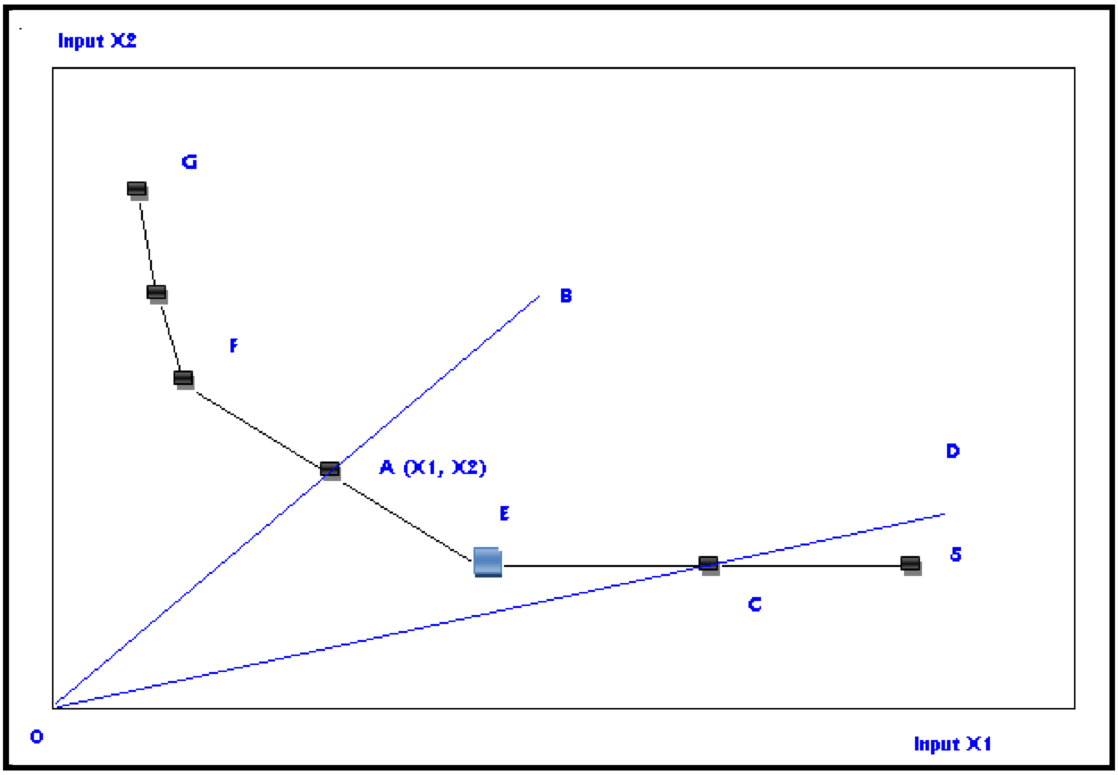


Figure 4. 6 Efficiency frontier (input minimization)

The decision units of B and D are not efficient relative to frontier performance, since it is possible to find another DMU or another DMU combination that can produce the same level of output by using less amounts of at least one of the inputs. For instance, efficiency ratio is less than 1 for decision making unit of B. This ratio is defined as OA/OB based upon the distance to the centre. If the ratio is less than 1, this indicates that linear combinations of the decision units of E and F can produce the same amount of output with the decision unit of B by using less from the inputs of X1 and X2. The efficiency ratio can be used to determine a target for the decision unit of B above the frontier. This target improves the actual performance of the decision unit of B as its performance never be below the other decision units ((OA / OB) – OB = OA). Input consumption that is conceptually defined in OB vector can be adjusted to OA target vector with the help of the efficiency indicators given above. Target states that the input consumption in the decision unit of B can be reduced to X_1 and X_2 in Figure 4.6 by keeping the same output level. In the literature, it is emphasized that examining the performances of similar groups are beneficial to accessing these targets. Decision units of E and F constitute the reference group for the decision unit of B in the example in Figure 4.6. Since these units can at least produce the output amount of B by consuming less inputs, it is thought that the performance of the inefficient decision unit (here, decision unit of B) can be improved by taking efficient decision units as an example in order to improve its performance. The decision units in the reference groups are the units with the weights more than zero in the optimal solution of the dual program. The solution for the decision unit of B is:

$$h_{b*} = OA/AB < 1$$

Constraints,

For input 1; $x_{1B}h_B - 0 = x_{1E}\lambda_F . x_{1F}\lambda_F *$

For input 2; $x_{2B}h_B - 0 = x_{2E}\lambda_F . x_{2F}\lambda_F *$

For output; $y_{1B} + 0 = y_{1E}\lambda_F . y_{1F}\lambda_F *$ **(4.1)**

as in the above.

The target performance for this DMU is shown with x1BhB* (i=1, 2) and it is a linear combination of performances of the DMUs of E and F. While λE*, λF*>0 (weights on DMUs of E and F), weights on other DMUs are equal to zero.

As seen, there exist some constraints on inputs and outputs in the dual program. Input constraints define a radial (with same proportion) contraction given by the efficiency ratio (hp^*) and additional reductions given by the input dummy variables with positive values.

In the input minimization dual program, constraints on output do not require an equal-proportion input arrangement and they only show significance if the optimal output dummy variables si*, (i = 1…... t) are not equal to zero. All the input and output dummy variables are equal to zero for the decision unit of B. However, the decision unit of D has a positive dummy variable for x_1 input. The efficiency ratio is equal to OC/OD for the decision unit of D and it requires an equal-proportional reduction for both inputs. However, it is seen from point C that the decision unit of E produces the same output level with less amount of x_1 and same amount of x_2. Therefore, the decision unit of D cannot be totally (relatively) efficient unless it increases its x_1 consumption as well as the horizontal distance between the point C and point E. The distance between the decision units of C and E (the difference in the x_1 usage) is defined with a positive s1* dummy variable for the decision unit of D in the dual program;

$h_{D*} = OC/OD$

Constraints,

For input 1; $y_{1D}h_{D*} - s_{1*} = x_{1E}\lambda_E$
For input 2; $x_{2D}h_{D*} - 0 = x_{2E}\lambda_E$
For output; $y_{1B} + 0 = y_{1E}\lambda_E . y_{1F}\lambda_F *$ **(4.2)**

The target (indicated with h_D^*) for the decision unit of D is defined with the radial contraction in both inputs and with an additional reduction in the x_1 input that is given with the dummy variable of s_1*. The decision unit of D can achieve target performance through the required contraction and additional reduction.

Only the decision unit of E is included in the reference group since its target performance is fully coincided with the performance of “the best observed” decision unit ($\lambda_E^* = 1$ and $\lambda_C^* = 0$, $c \neq E$).

An output area is seen in Figure 4.7. There exists a sectional linearity and each section shows an output constraint in the dual program. In the dual program, the solution for the DMU of A is as mentioned above, and there are two constraints on outputs.

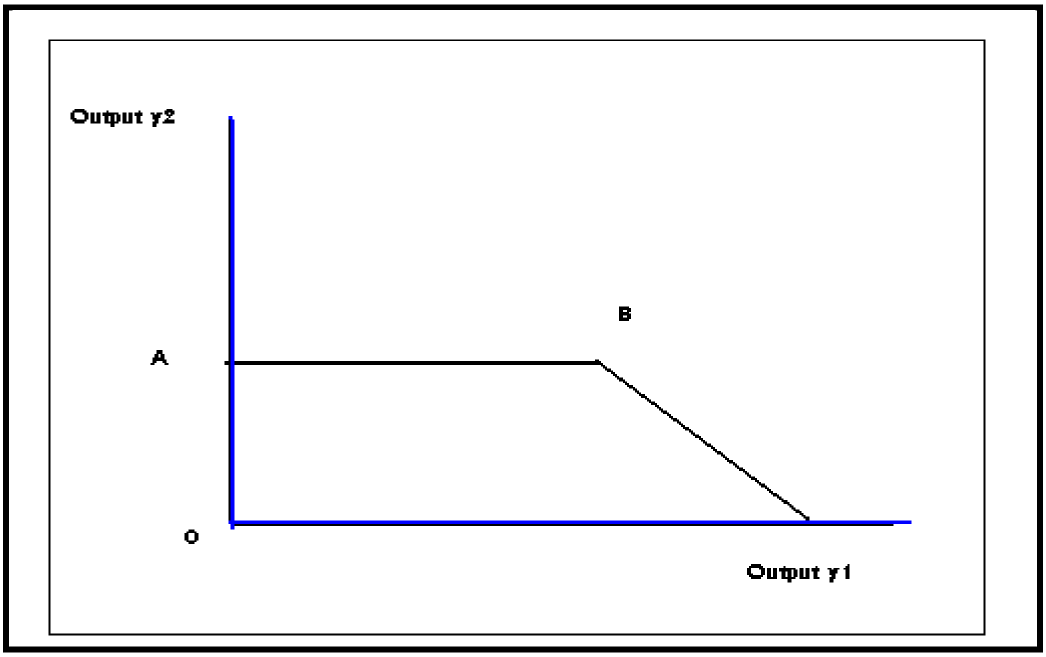


Figure 4. 7 Efficiency frontier (output maximization)

Output 1; $y_{1A} + s_1 *= y_{1B}.\lambda_B$
Output 2; $y_{2A} + 0 *= y_{2B}.\lambda_B$

The dummy variable of y_2 is zero, in other words $s_2^* = 0$. However, the dummy variable of y_1 is positive (s1*>0). In Figure 4.7, the decision unit of A can produce y_2 as much as the decision unit of B whereas it can produce y_1 less than B. The dummy variable of y_1 shows the amount of y_1 input that should be increased by the decision making unit of A in order to achieve the standard that is determined by the decision making unit of B. This amount is equal to AB horizontal distance: $AB = s_1^*$

4.3 Data Envelopment Analysis (DEA)

4.3.1 The Purposes of the Use of DEA

DEA can be used for many purposes. For instance,

- determination of resources and amounts of relative inefficiency in any of input-output dimensions for each unit to be compared,
- classifying the units in terms of their effectiveness,
- evaluating the management styles of the compared units,
- evaluating the productivity of programs and policies that are out of control of the units and differentiating the program inefficiency and managerial inefficiency from each other,
- establishing a qualitative basis with the purpose of attaining the resources for reference units (general objectives of these attaining policies are to change the limited resources among the units for more efficient output production),
- determination of relations of efficient units or efficient input-output relations for indirect purposes through comparing the units,
- examination and overview of valid standards in terms of actual performance for specific input-output relations, and
- comparing the results of previous studies.

Furthermore, DEA can be used in performance and efficiency analysis studies for the following purposes (Sözen, 2010).

The use of Pair Groups

DEA defines a set of efficient units for each inefficient unit and these units constitute pair groups with inefficient units. Each unit in a pair group takes input and output orientation of the inefficient unit and enables its efficiency by using the same weights with the efficient unit.

Determination of efficient working applications

Determining and listing good working applications provide the efficiency increase not only for relatively inefficient units but also for relatively efficient units. Relative efficient units are sources for successful working applications.

Target determination

In practical applications, target determination is often demanded for the guidance of enhancing the performances of the relatively inefficient units. By using DEA, it is possible to determine targets for input and output levels.

Determination of efficient strategies

DEA can be easily used to compare policies and programs of the units. Furthermore, management efficiencies and program efficiencies can be evaluated by solving the model appropriately.

Observing efficiency changes through time

An efficient firm which is determined by DEA can lose its efficiency in the following periods and lose its characteristics of being reference for other firms. Such efficiency changes can be followed up by using DEA.

Resource allocation

DEA gives estimations for potentials of resource keeping and/or increasing the output for inefficient units as well as determining relatively efficient and inefficient units. These make the method suitable for attaining the resources to units. Determining relatively efficient and inefficient units show in which direction the resources should be transferred, in principle.

4.3.2 Strong and Weak Sides of Using DEA

Some strong characteristics of DEA can be summarized as follows (Sözen, 2010):

- Productivity analysis is performed according to the frontier function that is constituted with the best observations instead of the average function of statistical frontier estimation methods; therefore, predetermined goals are stated in terms of the best performance units. This strengthens the significance and validity of the efficiency and productivity analysis performed with DEA.
- DEA can handle multiple input and multiple output models. It can analyze such units with multiple inputs (resources) and outputs (results) under one productivity measure.
- Except linear form, DEA doesn't require an assumption of a functional form relating inputs to outputs. In other words, there is no any assumption requirement for the production function.
- Maximizes the objective functions separately while measuring the relative technical productivity for each decision making unit,
- Decision units whose efficiencies are calculated through DEA are compared with the ones with relative efficiency.
- Inputs and outputs are independent from measurement units. Inputs and outputs can have very different units. In this situation, there is no need of any assumption and transformation in order to measure them in a similar way.
- A detailed data set, including data and analysis results that will required in DEA study, can be created. Therefore, documentation regarding to the topic is strengthened.
- Since it derives some parameters to ensure the productivity of each decision unit by realizing the difference of productive-unproductive, it is a guide for managers.

Some advantageous characteristics of DEA are at the same time the sources of weaknesses for DEA. These weaknesses can be summarized as follows (Sözen, 2010):

- The exact reflection of the production period by related inputs and outputs is significant to have healthy solutions from the method. When a critical input or output is kept out of the research, results of that method can be misleading and biased.

- Since DEA is evaluated as the extreme point technique, it is sensitive to any measurement error.
- DEA is sufficient to measure performances of the decision units but this does not give a clue for the absolute efficiency based interpretation of this evaluation.
- Since reference decision units have relative superiority compared to other decision units, this makes it difficult to realize any comment in terms of whether they are indeed productive or not when they are individually evaluated. Therefore, DEA productivity results should be evaluated under the relativity framework.
- Since DEA is a nonparametric technique, statistical hypothesis tests for the results are difficult.
- DEA is a static analytical technique and performs cross section analysis among the data set of decision units for one period.
- Since each decision unit requires the solution of a different linear programming model, solving of huge dimension problems with DEA can take time to calculate.

4.3.3 Application Processes of DEA

Some required steps to perform DEA are illustrated in Figure 4.8, and basic headings are summarized as in the following Sözen, 2010).

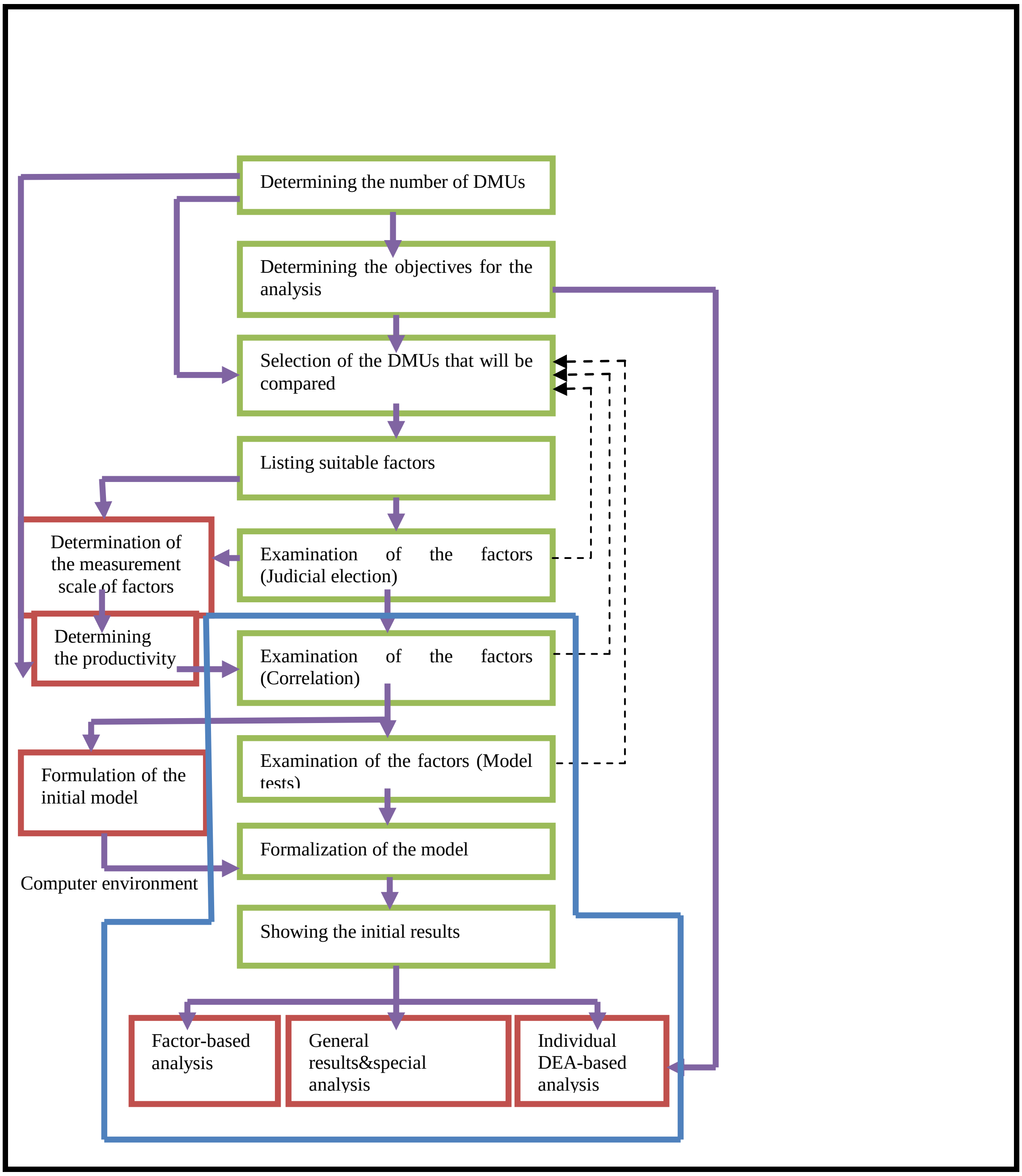


Figure 4. 8 The application model of DEA

Selection of decision units

Finding which of the decision unit is suitable for this study depends on which topic constitutes the main theme of this study. Based on the observed inputs and outputs, DEA calculates relative efficiency values of the decision making units that are included in the sample or in the observation set. Decision units can be any economic units that are responsible for transforming inputs into outputs. However, decision units that will be analyzed should have similar functions intended to same target, should work under the same market conditions and the factors specifying the productivity of all units in the group should be same except their differences in terms of density and size. Two selection principles can be specified (Sözen, 2010):

- Each decision unit should be defined as responsible for its used resources and its produced outputs;
- In order to have a significant production possibility in frontier estimation, the number of the decision units that are included in the sample should be in sufficient amounts. These decision units should be similar enough in terms of their production patterns; they should transform same inputs into same outputs and should be located in similar environments.

To compare their productivity levels through the DEA, the number of DMUs should be above a certain level in order to obtain significant and correct results. In order to have healthy calculation of productivity levels with DEA, Vassiloglou and Giokas (1990) state that the number of decision units should be at least three times the input and output total and Bowlin (1987, 1999) states that at least three decision units should be selected per each input and output; therefore, both of them assert the same view. Based on their own experiences, Norman and Stoker (1991) emphasize that this number should be at least 20 as it depends redundancy of input and output number.

Boussofiane on the other hand (1991) states that if the input number is “s” and output number is “m”, having at least “m+s+1” decision units is a necessary condition for reliability of the research results.

Selection of inputs and outputs

Since inputs and outputs that are used in DEA constitute the basis for comparing the decision units in this study, they should be carefully selected. Adding a lot of inputs and outputs to the model reduces the ability of DEA to decompose efficient and inefficient units from each other.

To increase the number of inputs and outputs, the number of the decision units should also be increased ($n > m+p$, while n = number of observations, m = number of inputs, p = number of outputs) (Boussofiane, 1991).

By separating the variables as input and output, DEA examines their effects on DMU. Retzlaff-Roberts (1997) state that using the concepts of positive and negative affective variables on units instead of using input and output variables is more accurate and suggest if an increase in the variables that make the unit to be evaluated better, these variables should be called "positive affected" and if a reduction in the variables that make the unit to be evaluated better these variables should be called "negative affected".

Data confidentiality

After the identification of inputs and outputs for DEA, it is required to obtain the input and output variables for all decision units. If confidential data cannot be obtained for any unit, productivity value of the related unit and because of the relative productivity calculation the productivity values of all units become problematic, therefore this unit is not included in the study.

Productivity values

As formulated by Charnes and Cooper (1962, 1973), 100% productivity for a decision unit is valid in the following conditions:

a) None of its outputs can be increased except the following situations:

  i) increase in the amount of one or more inputs or

  ii) reduction in some of its other outputs.

b) None of its inputs can be decreased except the following situations:

i) reduction in some of the outputs or

ii) increase in some other inputs

As a result of the productivity calculations, a productivity value between 0 and 1 (or between 0 and 100 in terms of %) is found for each decision unit. The units with the productivity value of 1 (or 100%) constitute "the best observation" set. The decision units with the productivity levels less than 1 (or 100%) are relatively inefficient. The deviation ratio of the relatively inefficient decision units gives the size of the inefficiency.

Target determination for unproductive decision units

The most significant advantage that is obtained by applying DEA is determination of achievable targets to improve performances of the decision units. Since through calculations it is assumed that efficient units use acquirable technologies, it is assumed that technology levels of the efficient units are also attainable for the inefficient units.

Another significant point that should be taken into the consideration for the predetermined targets is that while the efficiency analysis is performed, and hence targets are determined at time "t", in order to achieve these targets the improvement studies will be possibly performed at time "t+1". Therefore, abiding the targets at time "t" means to assume that the efficiency is constant through time.

Evaluation of the results

After a detailed examination of the decision units, a general evaluation takes all inputs and outputs into account for each decision unit. Even the predetermined goals (reduction in the usage of the unproductive resources, etc.) cannot be achieved through DEA as a result of various preferences that belong to the decision units; DEA has significance evaluating the obtained information in following studies and opening the way to improvements.

4.3.4 Theory of Data Envelopment Analysis

Data Envelopment Analysis is a nonparametric method based on the principles of the theory of linear programming, and is specifically designed for the estimation of relative productivity and efficiency of decision making units. As seen from literature, in the management science, it has started to be used as a new method in the comparative analysis of technical productivity of the decision units in the public sector.

When DEA over 25 years is considered, it is seen that as being a nonparametric measurement technique it has a rapid development both theoretically and methodologically. In its early applications, DEA was used in the deterministic form and it was only used in order to determine general technical productivities of service units in the public sector under the assumption of constant returns to scale. Various assumptions regarding to the methodology and significant studies to examine the concepts have started in the 1980s.

DEA ensures the totality in order to evaluate multiple inputs and outputs through the total factor productivity, and DEA performs an efficiency measurement since the difference between the obtained result and expected result is presented. In the production environments of using multiple inputs to produce multiple outputs, DEA can perform the measurement without requiring any estimation for the existence of a predetermined analytical production function as in the parametric methods. (Boussofiane, 1991)

DEA is used in order to evaluate the efficiency of similar units that produce the same outputs with the same inputs and it compares each unit with "the most efficient" unit. "The most efficient unit" that is formed by combining the best areas of each unit is principally a virtual unit. The basis of this method aims to find the best virtual unit for each actual unit. If this virtual unit can produce more output with the inputs of the actual unit, or if it can produce the exact amount or more amount of output of the actual unit with fewer inputs, it can be stated that the actual unit is inefficient. The method of finding the best virtual unit is formulated by a linear program.

In this situation, "n" linear program is required to analyze the efficiency of "n" DMUs. DEA is the sum of these linear programs and enables one productivity score for each observation by using multiple input and output variables in a linear programming model. Evaluation of relative technical productivities is included in the basis of DEA based upon the inputs and outputs observed in similar decision units.

In DEA, correct definition of inputs and outputs is significant. The decision making units (DMUs) that will be compared should have similar inputs and outputs, in other words, there should be similarities among the units.

Linear programming is widely used to solve the optimum resource allocation problems. As a result of the linear programming, the DMUs with an objective function value equal to 1 are classified as “efficient” whereas the DMUs with an objective function value less than 1 are classified as “inefficient”.

Being an alternative method for the parametric methods, DEA does not assume the existence of any analytical form behind the production function as in the regression analysis. Therefore, it is a suitable form for productivity measurement in the flexible production units with multiple inputs and outputs.

“Decision Making Units” in DEA are enterprises or economic institutions that transform inputs into outputs or are the units whose performances are to be compared.

One of the most significant characteristics of the DEA method is that it can define the inefficiency amount and resources in each DMU. With this feature, the method can help problem solvers show how much an input reduction and/or increase in output is required in inefficient units. The most significant innovation of this method is that the measurement can be performed in the environments multiple outputs are produced with multiple inputs in without requiring the existence of any pre-determined analytical production function as in the parametric methods (Boussofiane, 1991). Besides that, inputs and outputs are independent from the measurement units. Therefore, there exists the possibility of assessing various dimensions of an enterprise.

Various inputs are used in the operations (number of employees, salaries, working hours, number of equipments, etc.). Similarly, various outputs also exist (profitability, market share, growth rate, etc.). As a result of the various inputs that are used for the decision units, from the transformation operation of the obtained outputs through transforming the inputs it is difficult to decide which units have low productivity levels. At that point, to determine relative efficiencies, DEA provides an adjunct tool for the decision making units. While forming a hypothetical efficiency frontier based on all units of the reference groups, the DEA approach utilizes from linear programming. The output of the hypothetical unit is calculated by the weighted averages of all outputs in the reference group. The input of the hypothetical unit is calculated by the weighted averages of all inputs in the reference group. Constraints in the linear programming model requires the output levels of the hypothetical unit to be more than or equal to the output levels of the observed units. If the input levels of the hypothetical unit are less than the inputs of the observed unit, this indicates that the hypothetical unit obtains the same level or more output level by using less input.

Since it uses techniques such as "mathematical programming" it evaluates the relations (constraints) with multiple variables and enables the user to study more comfortable compared to other methods that do not evaluate multiple input and output together. Real life problems such as creating policies and making managerial decisions have complicated structures that require the evaluation of several factors at the same time. In addition to this, DEA enables one to perform leading analysis and interpretations with a wide theory and methodology allocation owned by mathematical programming.

The mathematical expression of the output/input ratio that will be maximized for 'n' DMU with 'm' inputs and 't' outputs is given as in the following:

$$\mathrm{Max}h_k = \frac{\sum_{r=1}^{t}(U_{rk}Y_{rk})}{\sum_{i=1}^{\mathrm{m}}(V_{ik}\mathrm{X}_{ik})} \tag{4.3}$$

In this expression, the parameter of $X_{ij} > 0$ indicates the amount of 'i-th' input that is used by the j-th decision unit whereas the parameter of $Y_{rj} > 0$ indicates the amount of 'j-th' output that is used by the 'r-th' decision unit. For this decision problem, variables are the weights given by the decision unit 'k' for input 'i' and output 'r'. These weights are shown as 'v_{ik}' and 'u_{rk}', respectively.

When the weights of the 'k-th' DMU are also used by other decision units, the constraint which does not allow that time efficiencies to be more than 100% is

$$\frac{\sum_{r=1}^{s}\left(U_{rk}Y_{rj}\right)}{\sum_{i=1}^{s}\left(V_{ik}X_{ij}\right)} \leq 1; \qquad j = 1, \dots, n. \qquad \textbf{(4.4)}$$

The constraints which enable the positive weights for outputs and inputs that are to be used are;

$$U_{rk} \geq 0; r = 1, \dots, t$$

$$V_{ik} \geq 0; i = 1, \dots, m \qquad \textbf{(4.5)}$$

It is sufficient to equalize the denominator of the objection function in the maximization form to '1' to obtain the solution through simplex and similar algorithms and to have a constraint by transforming this inequality set into linear programming form.

4.3.5 Linear Data Envelopment Analysis Program

Primary Formulation

In order to calculate the efficiency ratios, the fractional formulation as given in equation 4.3 and equation 4.4 is used. This formulation has some dimensions that do not meet the requirements of being linear and convex. Charnes and Cooper (1962, 1973) have tried to use a transformation in order to transform this fractional formulation to an ordinary linear program.

According to this, the fractional program in equation 4.5 is transformed in order to imply the linear programming methods. Instead of the individual values of numerator and denominator, the proportion of their values is significant in order to maximize the fraction in the objective function. To have the same impact is possible by equating the denominator to a constant value and by maximizing the numerator only.

A linear program for the decision unit of ‘p’ is obtained by equating the denominator of the objective function of the fractional function to ‘1’:

$$MAX\ u_i v_k \sum_{i=1}^{t} u_i y_{ip} \qquad \textbf{(4.6)}$$

Under the following constraints:

$$(x+a)^n = \sum_{k=0}^{n} \binom{n}{k} x^k a^{n-k}$$

$$\sum_{i=1}^{t} u_i y_{ic} \leq \sum_{k=1}^{m} v_k x_{kc}$$

$$c = 1, \ldots, N.$$

$$\sum_{i=1}^{t} V_k X_{kp} = 1$$

(4.7)

$u_i.\, v_k > 0$, for all i and k.

u_i .v_k in the model are the weights on inputs and outputs and constitute the variables of the problem.

The model given above is linear and it maximizes the sum of weighted output of the decision unit ‘p’ by restricting the weighted sum of inputs with ‘1’ and choosing suitable values for u_i and v_k. The productivity value cannot exceed ‘1’, since the less than ‘1’ constraints in the fractional function also exist in primal linear program.

A similar linear program is obtained by minimizing the weighted inputs for the decision unit of ‘p’ and equalizing the weighted outputs to ‘1’:

$$MIN\ v_k u_i \sum_{k=1}^{m} v_k x_{kp} \qquad \textbf{(4.8)}$$

Under the following constraints:

$$\sum_{k=1}^{m} v_k x_{kc} \geq \sum_{i=1}^{t} u_i y_{ic}$$

$c = 1, \ldots, N.$

$$\sum_{i=1}^{t} u_i y_{ic} = 1 \qquad \textbf{(4.9)}$$

$u_i . v_k > 0,$ for all i and k

As seen above, while the input and output weights (u_i and v_k) in the primal formulation are under positivity constraints, they only have the constraint of not being negative in the ordinary linear programs. This solid positivity constraint in DEA is inserted to the model by Charnes, Cooper and Rhodes (1978, 1979). Hence they restrict input and output weights as in the following way:

$v_k > \varepsilon, k = 1, \ldots, m$

$u_i > \varepsilon, i = 1, \ldots, t$

(4.10)

Here, "ε" is an ignorable small value or it is referred as non-Archimedian constant and is generally used in 10^{-5} or 10^{-6} levels. Lewin and Morey (1981) denominate positivity constraint on weights as "lower boundary constraints"

Dual Formulation

It is possible to formulate a common linear program which uses the same data sets for any linear program. The results of primal program or dual program give the same information about the modeled problem, and DEA linear program does not create an exception for that. Formulations in equation 4.6 and equation 4.8 are linear programs and DEA uses the dual of these linear programs in order to calculate the efficiency ratio. The dual of the equation in equation 4.6 establishes a segmented linear approach by minimizing the amounts of m inputs to meet the amount of t output. In other words:

$$Min\ \lambda_c\, h_p - \varepsilon \left(\sum_{k=1}^{m} s_k + \sum_{i=1}^{t} s_i\right)$$

(4.11)

under the following constraints:

$$x_{kp}u - h_p - s_k = \sum_{c=1}^{N} x_{kc}\, \lambda_c \qquad k = 1, \dots, m$$

$$y_{ip}s_i = \sum_{c=1}^{N} y_{ic}\, \lambda_c \qquad i = 1, \dots, t$$

$\lambda_c \geq 0$ $\quad i = 1, \dots, t$ c = 1,..,N (weights in units)

$s_k \geq 0$ $\quad k = 1, \dots, m$ (input dummy variables) **(4.12)**

$s_i \geq 0$ $\quad i = 1, \dots, t$ (output dummy variables)

h_p is unrestricted in terms of its sign and ε is a constant that can be ignored. This number is similar to the constant that is used in the primal equation by Charnes and Cooper (1962, 1973).

Even the dual program does not seem pure and regular as the primal program its interpretation is rather simple: the decision unit of 'p' is relatively productive if and only if the productivity ratio of hp* is equal to "1" and all dummy variables are equal to zero.

$$h_p *= 1\ ve\ s_k *= s_i *= 0 \qquad \textbf{(4.13)}$$

for all k and i.

The star sign in the above indicates the optimum amounts of the variables in the dual program. When the efficiency conditions in equation 4.13 are realized, subjected DMU should be on the efficiency frontier. These DMUs should be considered as the definition of "dominant" or "the best observation". As dual program calculates the weights on DMUs (λ_c) instead of the weights on input and output, the weights of the dual program should be more than, or equal to, zero. In the calculation, the dual program can be implemented more easily than the primal program and constraints in the primal program focus on all 'N' DMUs. On the contrary, constraints in the dual program are on inputs, outputs and on DMU totals, and the number of inputs and outputs does not exceed the number of DMUs. Calculation productivity of the Simplex method decreases as the constraint set increases. For more basic calculation, the dual program is preferred to the program that has N constraints on ‘N’ DMUs with (m+t) constraints on inputs and outputs.

Output maximization dual of the equation 4.8 is;

$$Max\ \lambda_c f_p + \varepsilon \left(\sum_{k=1}^{m} s_k + \sum_{i=1}^{t} s_i\right) \qquad \textbf{(4.14)}$$

Under the following constraints:

$$f_p y_{ip} + s_i = \sum_{c=1}^{N} \lambda_c y_{ic} \qquad i = 1, \dots, t$$

$$x_{kp} - s_k = \sum_{c=1}^{N} \lambda_c x_{kc} \qquad k = 1, \dots, m$$

$\lambda_c \geq 0$ $\qquad c = 1, \dots, N$ (weights in units)

$s_k \geq 0$ $\qquad k = 1, \dots, m$ (input dummy variables) **(4.15)**

$s_i \geq 0$ $\qquad i = 1, \dots, t$ (output dummy variables)

Here, fp is unrestricted in terms of its sign and the output efficiency of the decision unit of ‘p’ is calculated for a given input set. As seen, the linear formulation which is obtained as a result of the transformation can be used for “input minimization” or “output maximization”. The first one calculates the output productivity for a decision unit, while the second one calculates the input productivity. As in all linear programs, both formulas have two components as primal and dual.

4.3.6 Models of Data Envelopment Analysis

DEA models are classified under two main groups as CCR (or Constant Return to Scale – CRS) and BCC (or Variable Return to Scale-VRS).

In their own theoretical and methodological development process, each group is divided into three groups as input oriented, non-oriented and output oriented. Distributions of DEA models according to their tendencies are shown in Figure 4.9.

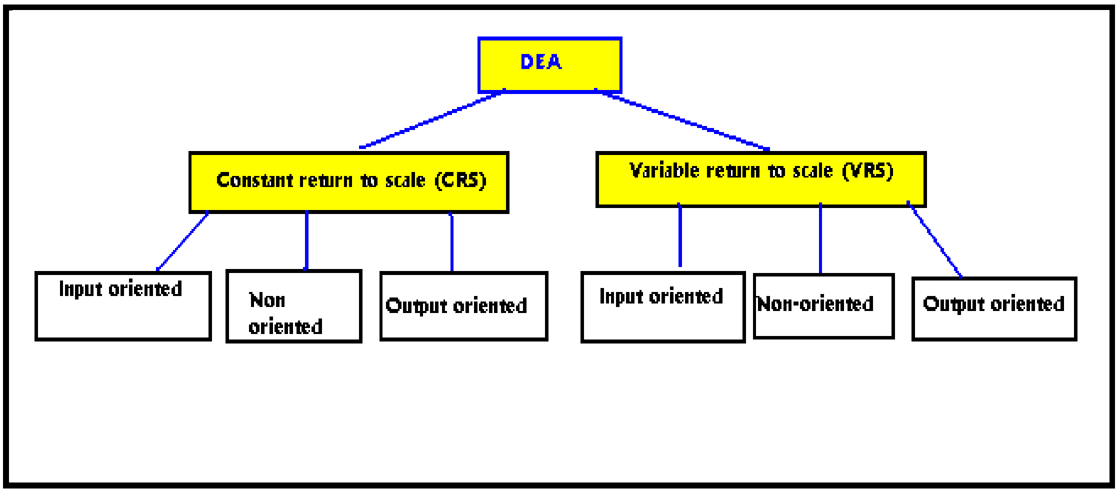


Figure 4. 9 Models of Data Envelopment Analysis

Input oriented models examine in what amounts inputs should be deducted by the decision units that are inefficient for any output level and try to minimize the inputs amount that is used in these models (Figure 4.10).

The objective of input oriented DEA is to provide the input minimization with the constant output condition, output maximization and to examine how much inputs should be deducted by the inefficient decision units in order to be efficient.

Output oriented models examine in what amounts outputs should be increased by the decision units that are inefficient for any input component in order to make efficient units. In the output oriented models, input minimization and maximization of output to input ratio are aimed for and the main objective is to determine the production of the most output level with a certain input combination (Figure 4.10).

Generally, as the scale changes (as the factor amount increases) the firm reaches firstly to increasing returns, then to constant returns and at last decreasing returns phases. However, the production technology does not change but only the scale changes in each of these three conditions.

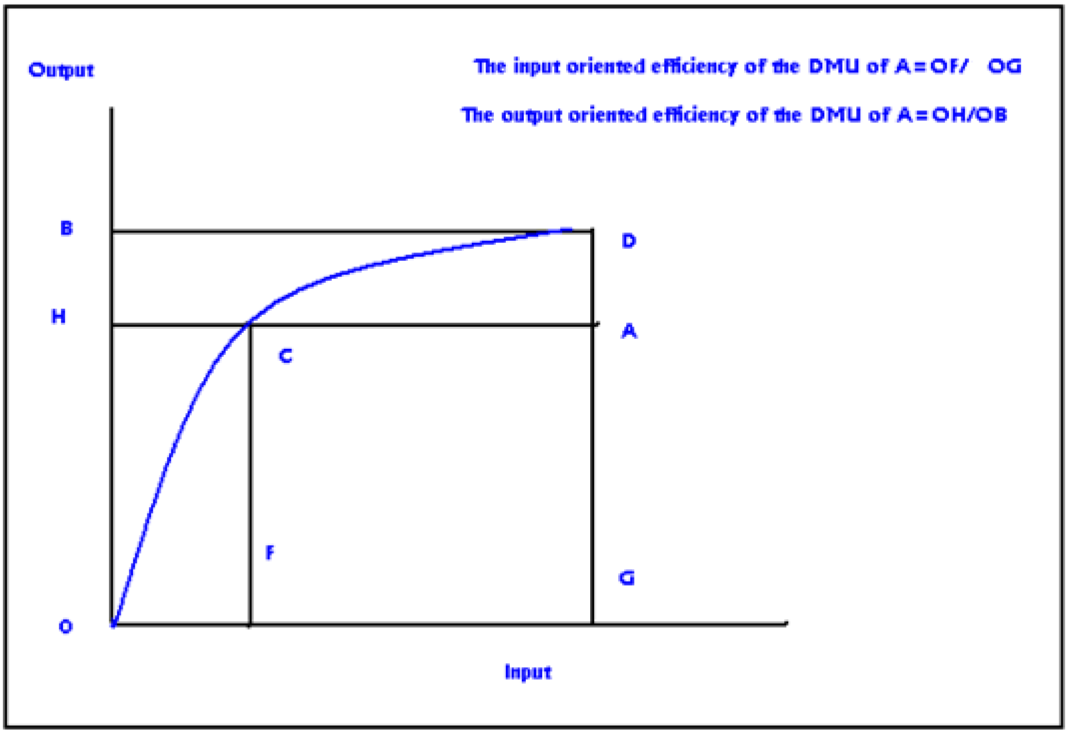


Figure 4. 10 Productivity in terms of inputs and outputs

Scale efficiency

Another performance evaluation concept is the distance to the most productive scale size. This is called as scale efficiency. As Figure 4.5 is recalled here, decision units of C and D are scale efficient; however C is technically efficient while D is technically inefficient.

Even the DMUs of E and F are efficient with the same productivity level and being technically efficient; if the DMU of F increases its scale to keep its technical efficiency, its productivity increases. This is called Increasing Return to Scale. Production frontier (b) in Figure 4.11 indicates an increasing return to scale.

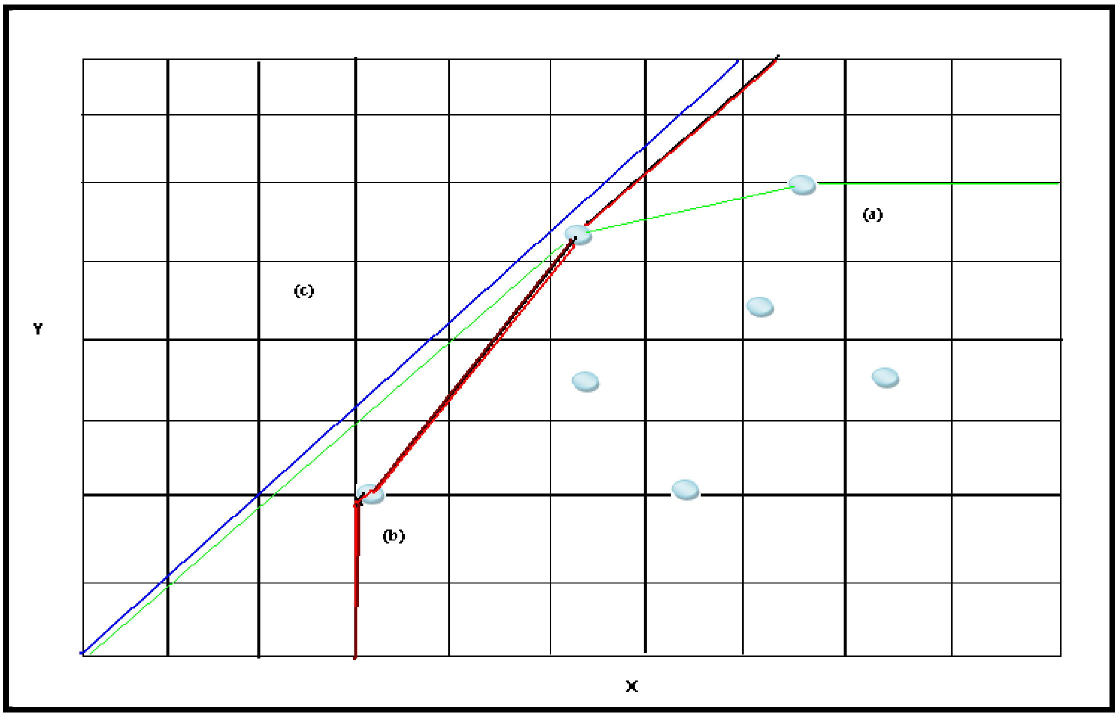


Figure 4. 11 Increasing returns to scale

When decision unit E it decreases its scale by keeping its technical efficiency in the same level, it observes an increase in its productivity. This is called as Decreasing Return to Scale. Production frontier (a) in Figure 4.11 indicates decreasing return to scale. Variable Return to Scale is defined as decreasing, increasing and constant return to scales included together on the production frontier.

The early applications of nonparametric approach become linear programming with the assumption of production with constant returns to scale. The studies of Banker and Thrall (1992); Fare, Grosskopf and Lovell (1983); Banker (1984); Banker, Charnes and Cooper (1984) and Banker, Charnes, Cooper and Schinnar (1981) bring a wider application area by improving this linear programming approach to comprehend wider reference efficiency, and if the sum of weights are constrained by equalizing to ‘1’ (λ_c^*=1), it can have a variable returns to scale including decreasing/increasing returns to scale and constant returns to scale.

Accordingly, it can be said that under the condition of maintaining its technical efficiency if a scale increase of a decision unit increases its total efficiency, this gives us increasing returns to scale, and if a scale increase of a decision unit decreases its total efficiency, this gives us decreasing returns to scale, and if a scale increase of a decision unit does not lead any change in its total efficiency it gives constant returns to scale. Since increasing and decreasing returns to scale are possible in Figure 4.12, decision units that do not have any scale efficiency can also exist on the efficiency frontier.

For instance, even the decision unit of B (with the increasing returns to scale) and the decision units of D and E (with the decreasing returns to scale) do not have any scale efficiency; they have technical efficiency according to the given scale. Consequently, obtained efficiency frontier is the ABCDE frontier with fragmented linear property.

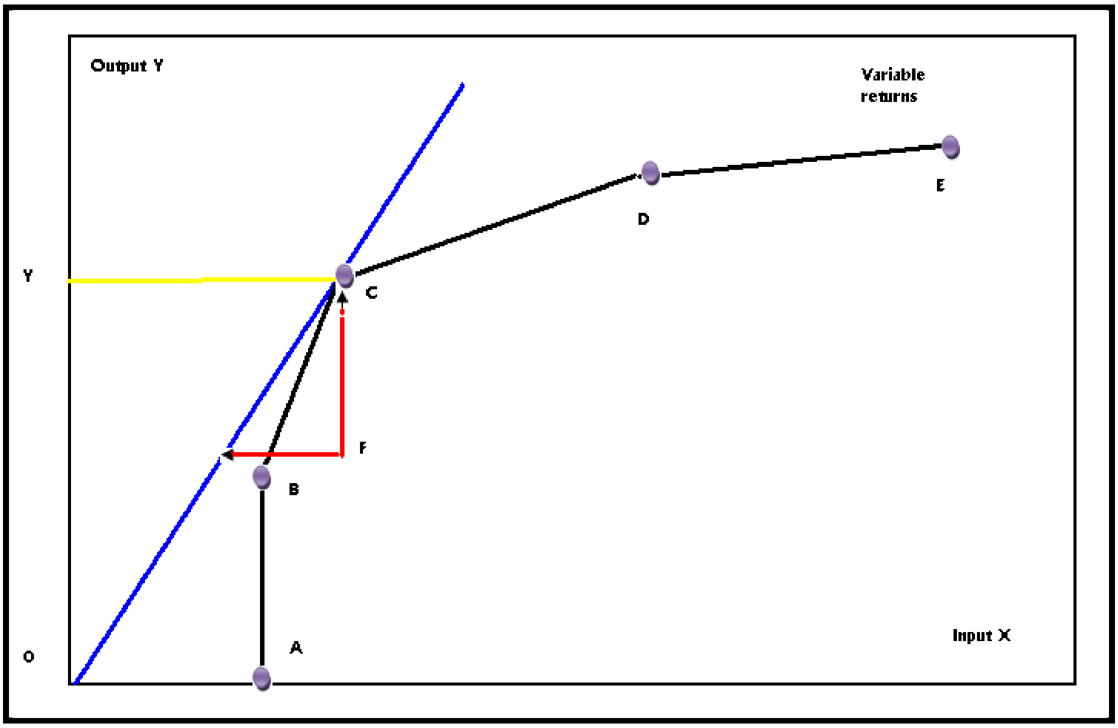


Figure 4. 12 Variable returns to scale

Each part changes according to the scale and each part is solved with one of the constraints of the dual program. According to the decision unit with scale efficiency (C), there is an increasing return to scale in the lower level of input-output combinations, in other words throughout the BC line. A decreasing return to scale is observed in the upper level of input-output combinations. The decision unit of C with scale efficiency lies on both efficiency frontiers with variable returns and constant returns and lies on the intersection of these frontiers.

If the constant returns to scale is assumed considering the observation set in Figure 4.12, the line through 0 and C constitutes the technical efficiency frontier. According to this, even the points B and D that lie on the efficiency frontier seem efficient under the assumption of variable returns to scale; these points seem inefficient under the assumption of constant returns to scale.

Scale efficiency measures the difference between the CRS efficiency score and VRS efficiency score. For any DMU, the scale efficiency is calculated through dividing the efficiency score obtained by VRS assumptions to CRS efficiency score. A scale efficiency score with less than 1 shows scale inefficiency, a scale efficiency score equal to 1 with CRS efficiency score and VRS efficiency score equal to 1 indicate that this decision unit has scale efficiency. Therefore, decision units of B and D from the Figure 4.12 above are technically efficient, but they are scale inefficient. In this figure, only the decision unit of C has scale efficiency. In the linear programming model, the constraint that equates the weights on decision units to 1 enables that "the best observation" of the efficiency frontier to be constituted by multiple linear combinations and relative efficiency to be defined in a less strict way. Since conditions with decreasing returns to scale and increasing returns to scale are included in the model, they are included on the efficiency frontier. To attain the efficiency ratio of '1', a decision unit should have both technical efficiency and scale efficiency. However, in the variable constant returns to scale, if a decision unit with inefficient scale has technical efficiency, it can lie on the frontier as "the best observation". Therefore, it can be stated that in the constant returns to scale, the technical efficiency measure of a decision unit is lower than the variable returns to scale.

Some characteristics of CRS and VRS models are summarized below (Coelli, 1996):

Constant returns to scale (CRS) model

- A radial increase in input vector causes the same proportion of increase in the output vector.
- Radial increase means an equal proportion of increase in each of the input components

Variable/Decreasing/Increasing Returns to Scale models (VRS, DRS, IRS)

- Variable Returns to Scale

This means both increasing and/or decreasing returns to scale are possible.

  - Decreasing Returns to Scale:

    A radial increase in input vector causes a smaller proportion of radial increase in output vector.

  - Increasing Returns to Scale:

    A radial increase in input vector causes a larger proportion of radial increase in output vector.

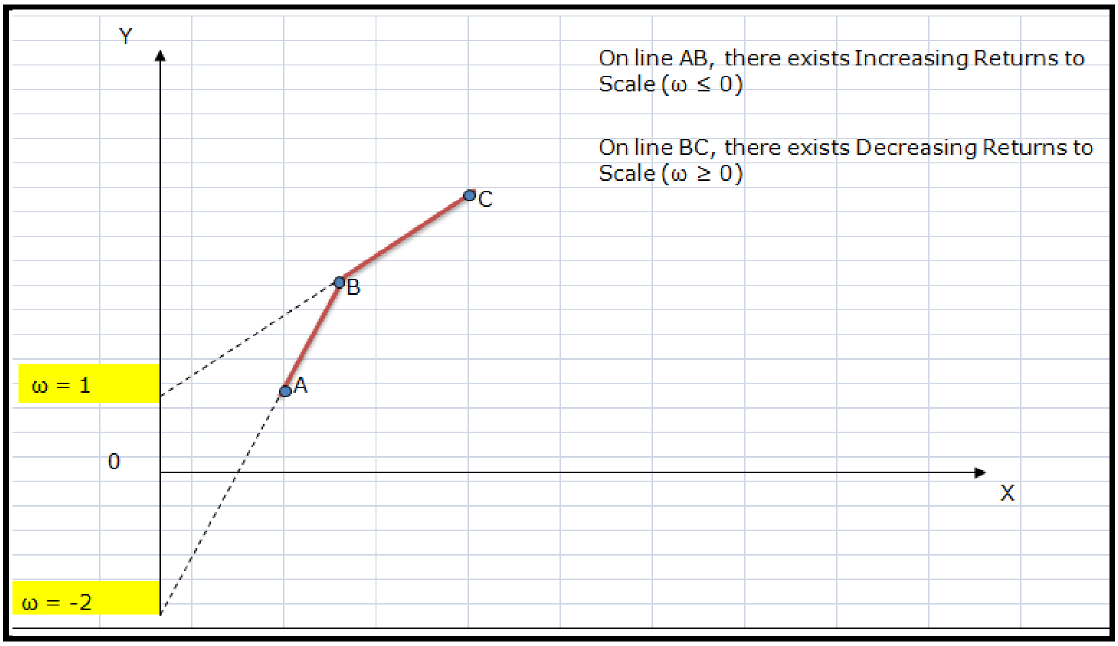


Figure 4. 13 Variable returns to scale model

4.4 Super Efficiency

In output oriented CRS and VRS analyses, the efficient DMUs have an efficiency score of 100. In most of the cases, the number of efficient DMUs with efficiency score of 100 is more than 1. In such cases, to distinct among these efficient DMUs or to rank the best performers is called the super efficiency problem, and many researchers have attempted to develop a solution to this.

One of the approach developed by Andersen and Petersen (1993) is called as AP method. In AP method, a comparison is made between DMU being evaluated and a linear combination of other DMUs of the sample while excluding the observations of the DMU being evaluated. This comparison process affects only the efficiency scores of extremely efficient DMUs, and these DMUs can obtain an efficiency score which is greater than zero. When this process is completed, efficiency ranking of efficient DMUs among themselves is obtained (Andersen and Petersen, 1993).

The mathematical formulation of the AP model can be defined as follow:

$$Max\ h_0 = \emptyset + \varepsilon . \sum_{r=1}^{s} s_r^{\ +} + \varepsilon . \sum_{i=1}^{m} s_i - \qquad \textbf{(4.16)}$$

Subject to

$$\emptyset . y_{ro} - \sum_{j=1, j\neq 0}^{n} \lambda_j y_{rj} + s_r^{\ +} = 0 \qquad \textbf{(4.17)}$$

$$\sum_{j=1, j\neq 0}^{n} \lambda_j x_{ij} + s_i^{\ -} = x_{io} \qquad \textbf{(4.18)}$$

$$\lambda_{j,}\ s_r^{\ +} s_{i-} \geq 0$$

$$j = 1, \dots, n,\ i = 1, \dots, m\ \ r = 1, \dots, s$$

4.5 Malmquist Total Factor Productivity Index

The technique used in order to observe the efficiency changes through time is Malmquist Total Factor Productivity Index (TFP). In order to perform the Malmquist TFP index, there is no need for the assumption of that related decision making units have profit maximization and cost minimization objectives. Time dimension is not evaluated as a strong method to be taken into the consideration particularly assessing the performances of public sector and non-profit organizations (Caves, Christensen and Diewert, 1982; Fare, Grosskoph, Norrys and Zhang, 1994)

In addition to its stated advantages, Malmquist TFP index can clearly define two components that constitute the index. These are technical efficiency change which is the evaluation of approaching to the efficiency frontier for a DMU and technological change which is created to determine the variation of the efficiency frontier in time.

Malmquist TFP index enables both parametric and nonparametric approaches. For this study, nonparametric DEA-based approach is the suitable one. Therefore, only the nonparametric Malmquist index approach is defined here.

The Malmquist TFP index measures the change in the total factor productivity of two observations as the ratio between two distance functions to a common technology and uses the distance function for this. It is developed by Caves et al (1982). and named as Malmquist after the idea of Sten Malmquist to establish an index by using distance functions. When input distance function and output vector are given, based on proportionally the most contracted input vector it defines the production technology.

This index measures the total change in TFP that is between two data units involved in different time periods by calculating the ratio of differences (distances) of each data units to a common technology. When there are multiple inputs and outputs, the distance function can define the production technology without requiring any behavioral assumption as profit maximization or cost minimization. Distance functions reflect multiple input and multiple output technologies that are only based on input and output amounts and do not require to know cost and return shares of inputs and outputs. At least two time periods are required in order to calculate the TFP change and distance functions are used to calculate the deviations from the average maximum output (Cave et al, 1982).

In this regard, the Malmquist TFP index enables to evaluate the efficiency changes of a Decision Making Unit (DMU) between two time periods, and the contributions of technical efficiency change and technological change in TFP can be defined through this. Here, technical efficiency is defined as the catch-up effect for the production frontier while technological change is defined as the frontier-shift of the production frontier curve. Technical efficiency change and technological change constitute the main elements in the TFP change. In other words, multiplication of both of these changes gives TFP change.

Based on improvements and contractions in the frontier technology, Malmquist Index (MI) reflects improvements and contractions in TFP of DMUs. MI>1 defines the improvement in TFP of a DMU from one period to other while MI=1 and MI<1 define the not change and contraction in TFP from one period to other, respectively. Technical efficiency change and technological change values with more than 1 define the improvements in technical efficiency and technology whereas technical efficiency change and technological change values with less than 1 define the contractions in in technical efficiency and technology. Dividing the Malmquist TFP index to these elements is significant to find the main reasons behind the TFP increase. In other words, multiplication of technical efficiency change and technological change gives the change in total factor productivity (Cave et al., 1982).

Traditionally, efficiency and productivity measurements are performed with the following assumptions: reducing the input amount while holding the output amount constant (input oriented) or increasing the output amount while holding the input amount constant (output oriented). Here, the output oriented model is used.

For each time period (t = 1,…,T), the output oriented Malmquist index production technology is defined as the positiveness of transforming inputs (xt) into output (yt). This technology is shown in Figure 4.14 (for time periods of t and t+1). The technological change at time t is,

$$p_t(x) = \{\text{transformation of } y_t, x_t \text{ to } y_t\}$$

To measure the technical efficiency of decision making units at time t, the output function is:

$$d_t(x_t, y_t) = \min\{\theta : (x_t, y_t/\theta)\ p_t(x)\}$$

defined as in the above.

The possibility of maximum output with the given input is measured with this function. The transformation of an input into an output by the Malmquist index with the acceptance of CRS is given in Figure 4.14 (Cave et al., 1982).

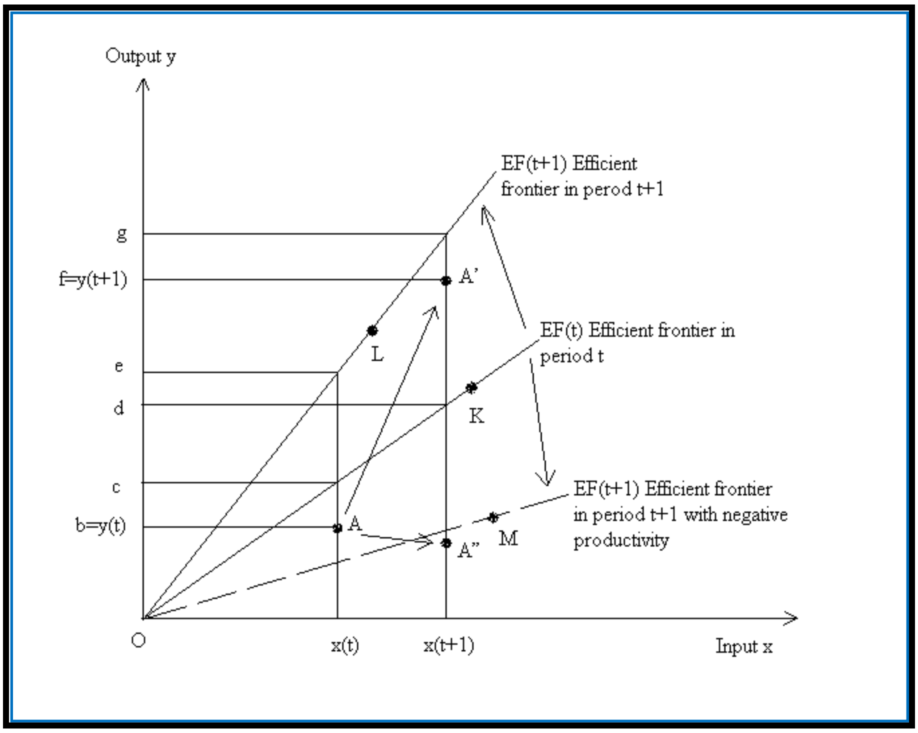


Figure 4. 14 Efficiency change through Malmquist Index analysis

The points of A and A' indicate input-output combinations of decision making units at time t and t+1. At the same time, it indicates the transformation of points of K (L or M) into the best performance at t and (t+1).

Output efficiency of decision making units is measured through Oc/Ob (Efficiency A< 1, DEA CRS (CCR) not efficient). If Decision Making Units are on EF (t) line, score is equal to 1 (in other words, DEA CRS are efficient). Decision Making Unit moves to A in t+1 and comes on EF (t+1) line.

Here; for the time change at t and t+1, DEA CCR output oriented Malmquist Total Factor Productivity is:

$$MI_0(x_t,\ y_t,\ x_{t+1},\ y_{t+1}) = \sqrt{\frac{d^\circ{}_t\,(x_{t+1},y_{t+1})}{d^\circ{}_t\,(x_t,y_t)}\,x\,\frac{d^\circ{}_{t+1}\,(x_{t+1},y_{t+1})}{d^\circ{}_{t+1}\,(x_t,y_t)}}$$ or graphically,

(4.19)

$$MI_0(t, t+1) = \sqrt{\frac{Of/Od}{Of/Og}\,x\,\frac{Ob/Oc}{Ob/Oe}}$$

(4.20)

defined as in the above.

However, the suggested definition of Fare et al. (1994) is:

$$MI_0(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{d^\circ{}_{t+1}\,(x_{t+1},y_{t+1})}{d^\circ{}_t\,(x_t,y_t)}\ \sqrt{\frac{d^\circ{}_t\,(x_{t+1},y_{t+1})}{d^\circ{}_{t+1}\,(x_{t+1},y_{t+1})}\,x\,\frac{d^\circ{}_{t+1}\,(x_t,y_t)}{d^\circ{}_{t+1}\,(x_t,y_t)}}$$

(4.21)

defined as in the above.

According to Figure 4.14, definitions for efficiency change:

Efficiency change (EFFCH) = $\frac{Of/Od}{Ob/Oc}$

(4.22)

Technical change (TECCH) = $\sqrt{\frac{Of/Od}{Of/Og}\,x\,\frac{Ob/Oc}{Ob/Oe}}$

(4.23)

can be shown as in the above.

Pure efficiency changes (PECH) and scale efficiency change (SECH):

PECH= $\frac{d_{t+1}\,(x_{t+1},y_{t+1})}{d_t o\,(x_t,y_t)}$

(4.24)

SECH= $\frac{d^c{}_{t+1}\,(x_{t+1},y_{t+1})}{d^v{}_{t+1}\,(x_{t+1},y_{t+1})}\,x\,\frac{d^c{}_t\,(x_t,y_t)}{d^v{}_t\,(x_t,y_t)}$

(4.25)

can be defined as in the above.

CHAPTER 5

ANALYSES AND RESULTS

5.1 Introduction

In this Chapter, efficiencies and total factor productivities of the establishments of Turkish Coal Enterprises (TKİ) which carry out the whole lignite production of TKİ are analyzed by using the methodologies introduced in Chapter 4.

For the efficiency analysis of the establishments, three distinct models are constructed:

- Model 1: Production Efficiency,
- Model 2: Revenue Efficiency,
- Model 3: Work Safety Efficiency

The analysis of the production efficiency of establishments is useful to understand how an establishment uses its resources in the production process with respect to others. Such a measure is a very useful tool for the management of the establishments and for the mother enterprise (TKİ) in taking managerial decisions.

The determination of the efficiency of an establishment in transforming the inputs to outputs or the determination of whether an establishment uses its resources efficiently or not in the production process is very critical for managerial decisions. In the same manner, knowing the benchmarks in the sector and having an idea how to reorganize its inputs and outputs in order to reach an efficient level is very critical in developing business policies, plans and strategies for the establishments.

Having a competitive advantage relative to its competitors in the market is important for the companies. In addition to the analysis of production efficiency, the analysis of revenues efficiency of the establishments is important to get insight regarding the pricing efficiency and market efficiency of that establishment. For instance, an establishment might be efficient in production phase but may not be efficient in the market, or an establishment may not be efficient in the production process but might be efficient in the marketing phase. When many other possible combinations are considered, the comparisons of the production and sales revenue efficiencies of the establishments will provide the managements with very vital insights to understand the focal point in determining the sources of efficiency or inefficiency. In turn, this will increase the probability of success of the policies and strategies to be developed for the establishments.

Due to its nature, the safety of employees is an important item in the agenda of mining operations throughout the world. One of the problem areas of the mining industry is mine accidents. Therefore, the analysis of work safety efficiency of mining establishments by means of the methodologies described in Chapter 4 of this study is an attempt of a new approach in this field.

In this Chapter, two of the three models (production and revenue efficiency models) constructed in this study are analyzed by using Data Envelopment Analysis (DEA), Super Efficiency (SE) and Malmquist Index (MI) methodologies. In the analysis of the Work Safety efficiency, only the MI is used.

For the DEA and SE analysis, EMP 1.30 (Scheel, 2000) and for the MI analysis DEAP 2.1 (Coelli, 1996) software are used.

Selection of Inputs and Outputs

In deciding the inputs and outputs which should be used in the efficiency and total factor productivity analyses of the establishments of TKİ, it was benefited from previous studies searched in the literature, basic knowledge of business and economics and the opinions of an expert panel. The results of literature survey is already summarized in Chapter 4.

Expert panel consisted of 10 participants who were the high level managers of public coal mining enterprises, selected private mining companies and Ministry of Energy and Natural Resources. Almost all actors playing in Turkish coal mining sector were represented in the panel. The participants were at the responsibility and position of assessing the efficiencies and productivities of their companies.

The composition of the Expert Panel was as follow:

- 2 Representatives of Turkish Coal Enterprises (TKİ)
  - Deputy General Director
  - Head of Department of Operations
- 2 Representatives of Turkish Hard Coal Enterprises (TTK)
  - Deputy General Director
  - Head of Department of Operations
- 2 Representatives of Turkish Electricity Generation Company (EÜAŞ)
  - Deputy General Director
  - Head of Department of Mine Sites
- 2 Representatives of Ministry of Energy and Natural Resources (ETKB)
  - Deputy General Director of Mining Affairs
  - Head of Department at Strategy Development Department of ETKB
- 2 Representatives of Selected Private Companies
  - General Director of a company
  - High level representative of another company

The expert panel was asked which inputs and outputs are necessary and useful in assessing the Production, Revenue and Work Safety efficiencies and productivities of mining establishments taking the nature of the methodologies used in this study into consideration. The expert panel was enlightened on the purpose of study first, then the methodologies to be used in the study, and then the results of the preliminary literature survey showing the inputs and outputs used in other similar studies.

Opinions of the experts were gathered through brainstorming sessions, and the list of inputs and outputs used in this study was finalized taking those opinions into consideration (Table 5.1).

Table 5. 1 Input and output variables of the models used in the analyses

Variables	MODEL 1 (Production Efficiency)	MODEL 2 (Revenue Efficiency)	MODEL 3 (Work Safety Efficiency)
(NE) Number of employees (number)	**I**	**I**	**I**
(ETP) Work safety and security training period (hours)			**I**
(WSI) Work safety and security investments (TL)			**I**
(TA) Total number of accidents (number)			**O (1/TA as output)**
(IE) Investment expenses (TL)	**I**	**I**	
(OE) Operating expenses (TL)	**I**	**I**	
(SP) Saleable production amount (Tons)	**O**		**I (1/SP as input)**
(SR) Sales revenue (TL)		**O**	

In the analysis of work safety efficiency, to be explained later in this section, as input "1/SP" and "1/WSI", and as output "1/TA" values are used. Those values are too small and the EMP 1.30 software is sensitive to small (much less than 1) values. Therefore, in the analysis of work safety efficiency, DEA and SE methodologies are not preferred. When taking into consideration that CRS and VRS analyses are also included in the stages of the MI methodology, it can be said that this will not create problem in terms of efficiency analyses and their interpretation.

Giving the definitions of the terminology and abbreviations which will be used throughout the rest of the study here is useful to follow up the graphs, tables and explanations, even before the explanations regarding the 3 models' construction.

In using DEA, SE and MI methodologies, the establishment whose efficiency and total factor productivity analyses will be performed are called as Decision Making Unit (DMU). Therefore from this point further the terms "DMU" and "establishment" will be used interchangeably.

Other necessary abbreviations are given below:

Abbreviations:

- M 1 : Model 1 (Production Efficiency Model)
- M 2 : Model 2 (Revenue Efficiency Model)
- M 3 : Model 3 (Work Safety Efficiency Model)
- DEA : Data Envelopment Analysis
- SE : Super Efficiency
- MI : Malmquist Total Factor Productivity Index
- CRS : Constant Return to Scale
- VRS : Variable Return to Scale
- DMU : Decision Making Unit (TKİ establishments in this study)
- **DMUs:**
  - EGESOMA : EGE Lignite Establishment
  - ÇAN : ÇAN Lignite Establishment
  - YATAĞAN : GÜNEY EGE Lignite Establishment
  - YENİKÖY : YENİKÖY Lignite Establishment
  - GARP : GARP Lignite Establishment
  - ILGIN : ILGIN Lignite Establishment
  - SEYİTÖMER : SEYİTÖMER Lignite Establishment
  - BURSA : BURSA Lignite Establishment
- **Data:**
  - NE : Total number of Employees (Number)
  - IE : Investment Expenses (TL)
  - OE : Operating Expenses (TL)
  - SP : Saleable Production (Tons)
  - SR : Sales revenue (TL)
  - TA : Total number of Accidents (Number)
  - ETP : Work safety Education Period (Hours)
  - WSI : Work Safety Expenses (TL)

5.2 Models Constructed

Models constructed for the efficiency analysis of the establishments are described below.

5.2.1 Production Efficiency Model

In the analysis of production efficiency of the establishments NE, IE and OE are taken as input, and SP is taken as output.

In the theory of Economics land, labor and capital are known as the factors of production (Nicholson, 1989; Schiller, 1991). In this respect those inputs are enough to cover all the factors necessary for the production process.

Output oriented models are used in CRS, VRS, SE and MI analysis. As explained in Chapter 4 of this study, in the output oriented models the methodologies are trying to maximize the outputs while keeping inputs constant. By doing this, the methodologies are trying to minimize the inputs/output ratio in the optimization process.

The data corresponding to the inputs and outputs used in the analyses of Model 1 for the years 2006 to 2009 are given in Table 5.2 (TKİ, 2011a; TKİ, 2011b; TKİ, 2011c; TKİ, 2011d; TKİ, 2011e; 2011f).

Table 5. 2 Input and output data used in the analyses of Model 1

ESTABLISHMENTS (2006)	O	I_1	I_2	I_3
	SP (tons)	NE (Number)	IE (TL)	OE (TL)
EGESOMA	7788116	3158	44481099	657472023
ÇAN	1340701	532	16560690	161199588
YATAĞAN	4005317	1089	12688793	122227776
YENİKÖY	6718621	631	9472837	105474283
GARP	3414978	2933	31348409	352838084
ILGIN	211566	182	5028356	14742819
SEYİTÖMER	4602873	1086	16439673	102561475
BURSA	1218771	687	17793126	78944449
ESTABLISHMENTS (2007)	**O**	**I_1**	**I_2**	**I_3**
	SP (tons)	**NE (Number)**	**IE (TL)**	**OE (TL)**
EGESOMA	8690564	2920	43715531	593134460
ÇAN	1932801	492	17658272	158411527
YATAĞAN	4033727	1027	13065011	130826143
YENİKÖY	6424363	598	11298434	133140120
GARP	3371692	2835	33588990	371554000
ILGIN	76560	155	6551951	20821661
SEYİTÖMER	4891348	1020	15998154	94396721
BURSA	1468941	611	16845340	88008820
ESTABLISHMENTS (2008)	**O**	**I_1**	**I_2**	**I_3**
	SP (tons)	**NE (Number)**	**IE (TL)**	**OE (TL)**
EGESOMA	10096626	2452	46660144	651383233
ÇAN	1930330	440	15925609	142975257
YATAĞAN	5076815	909	13503150	150075743
YENİKÖY	6962156	488	12083334	124696780
GARP	3801379	2382	40073209	402589705
ILGIN	139387	147	6150239	14717284
SEYİTÖMER	6140686	812	15629575	103555534
BURSA	1495976	534	16547802	71329693
ESTABLISHMENTS (2009)	**O**	**I_1**	**I_2**	**I_3**
	SP (tons)	**NE (Number)**	**IE (TL)**	**OE (TL)**
EGESOMA	8852555	2298	51852888	731149343
ÇAN	1694648	462	15115809	122571715
YATAĞAN	4255164	869	13837037	148495572
YENİKÖY	5689927	478	11888905	105567379
GARP	3398862	2243	50908148	324111850
ILGIN	260796	148	5761733	23649900
SEYİTÖMER	6597124	875	13462794	105598067
BURSA	1470955	574	16577917	87014310

5.2.2 Revenue Efficiency Model

An output oriented is also used in the Revenue efficiency model. Taking into consideration that sales revenue is equal to the “price*SP”, the explanations given in the section 5.2.2 is also valid for this section.

The data corresponding to the inputs and outputs used in the analyses of Model 2 for the years 2006 to 2009 are given in Table 5.3 (TKİ, 2011a; TKİ, 2011b; TKİ, 2011c; TKİ, 2011d; TKİ, 2011e; 2011f).

Table 5. 3 Input and output data used in the analyses of Model 2

ESTABLISHMENTS (2006)	O	I_1	I_2	I_3
	SR (TL)	NE (Number)	IE (TL)	OE (TL)
EGESOMA	495183466	3158	44481099	657472023
ÇAN	83352050	532	16560690	161199588
YATAĞAN	110794635	1089	12688793	122227776
YENİKÖY	152765713	631	9472837	105474283
GARP	285886309	2933	31348409	352838084
ILGIN	9298097	182	5028356	14742819
SEYİTÖMER	123898005	1086	16439673	102561475
BURSA	51407504	687	17793126	78944449
ESTABLISHMENTS (2007)	**O**	I_1	I_2	I_3
	SR (TL)	**NE (Number)**	**IE (TL)**	**OE (TL)**
EGESOMA	600792258	2920	43715531	593134460
ÇAN	108852927	492	17658272	158411527
YATAĞAN	141981295	1027	13065011	130826143
YENİKÖY	174385439	598	11298434	133140120
GARP	306559167	2835	33588990	371554000
ILGIN	8782479	155	6551951	20821661
SEYİTÖMER	144912386	1020	15998154	94396721
BURSA	62400880	611	16845340	88008820
ESTABLISHMENTS (2008)	**O**	I_1	I_2	I_3
	SR (TL)	**NE (Number)**	**IE (TL)**	**OE (TL)**
EGESOMA	789008529	2452	46660144	651383233
ÇAN	108471678	440	15925609	142975257
YATAĞAN	183853991	909	13503150	150075743
YENİKÖY	199429859	488	12083334	124696780
GARP	391692960	2382	40073209	402589705
ILGIN	9891407	147	6150239	14717284
SEYİTÖMER	192615404	812	15629575	103555534
BURSA	69572656	534	16547802	71329693
ESTABLISHMENTS (2009)	**O**	I_1	I_2	I_3
	SR (TL)	**NE (Number)**	**IE (TL)**	**OE (TL)**
EGESOMA	826489437	2298	51852888	731149343
ÇAN	113757532	462	15115809	122571715
YATAĞAN	177200521	869	13837037	148495572
YENİKÖY	187792690	478	11888905	105567379
GARP	417461635	2243	50908148	324111850
ILGIN	21855839	148	5761733	23649900
SEYİTÖMER	232610388	875	13462794	105598067
BURSA	79919993	574	16577917	87014310

5.2.3 Work Safety Efficiency Model

In the analyses of work safety efficiency of the establishments NE, ETP, WSI and SP (in the form of 1/SP) are taken as input and TA (in the form of 1/TA) is used as output. This model is also an output oriented model. In running the software, the methodologies will try to minimize "1/SP" and maximize "1/TA" values. By this, in turn, SP will be maximized and TA will be minimized in practice.

The data corresponding to the inputs and outputs used in the analyses of Model 3 for the years 2006 to 2009 are given in Table 5.4 (TKİ, 2011a; TKİ, 2011b; TKİ, 2011c; TKİ, 2011d; TKİ, 2011e; 2011f).

Table 5. 4 Input and output data used in the analyses of Model 3

ESTABLISHMENTS (2006)	O	I_1	I_2	I_3	I_4
	TA (Number)	NE (Number)	SP (tons)	ETP (Hours)	WSI (TL)
EGESOMA	75	3158	7788116	4132	1654792
ÇAN	5	532	1340701	626	278768
YATAĞAN	23	1089	4005317	2058	17627
YENİKÖY	15	631	6718621	1062	16832
GARP	47	2933	3414978	4582	874162
ILGIN	2	182	211566	221	5000
SEYİTÖMER	25	1086	4602873	1555	229754
BURSA	6	687	1218771	932	4776
ESTABLISHMENTS (2007)	**O**	I_1	I_2	I_3	I_4
	TA (Number)	**NE (Number)**	**SP (tons)**	**ETP (Hours)**	**WSI (TL)**
EGESOMA	46	2920	8690564	2646	1830840
ÇAN	4	492	1932801	525	308484
YATAĞAN	10	1027	4033727	754	26448
YENİKÖY	14	598	6424363	330	24297
GARP	57	2835	3371692	2990	587841
ILGIN	1	155	76560	336	3750
SEYİTÖMER	13	1020	4891348	525	217816
BURSA	4	611	1468941	1205	3847
ESTABLISHMENTS (2008)	**O**	I_1	I_2	I_3	I_4
	TA (Number)	**NE (Number)**	**SP (tons)**	**ETP (Hours)**	**WSI (TL)**
EGESOMA	35	2452	10096626	2644	2135692
ÇAN	10	440	1930330	765	383240
YATAĞAN	6	909	5076815	1489	18334
YENİKÖY	13	488	6962156	774	21717
GARP	69	2382	3801379	2053	415371
ILGIN	1	147	139387	182	4000
SEYİTÖMER	13	812	6140686	1756	183935
BURSA	3	534	1495976	662	6200
ESTABLISHMENTS (2009)	**O**	I_1	I_2	I_3	I_4
	TA (Number)	**NE (Number)**	**SP (tons)**	**ETP (Hours)**	**WSI (TL)**
EGESOMA	32	2298	8852555	3818	2449668
ÇAN	1	462	1694648	451	492492
YATAĞAN	12	869	4255164	1286	13415
YENİKÖY	15	478	5689927	759	29516
GARP	32	2243	3398862	3540	390149
ILGIN	1	148	260796	206	3750
SEYİTÖMER	16	875	6597124	2663	135014
BURSA	3	574	1470955	242	14054

5.3 DEA and Super Efficiency Analyses

In the CRS and VRS analysis of output oriented models the efficient DMUs have the efficiency scores of 100, and the higher the efficiency score the less the efficiency level of an DMU. It must be kept in mind that DEA (CRS, VRS and SE) efficiency scores are not a measure of absolute efficiencies of DMUs. They are relative efficiency measures of DMUs within the group in a given time. For this study, this means that, efficiency scores show the relative efficiencies of establishments within 8 establishments for the years 2006, 2007, 2008 and 2009 individually. In another study using different methods or for different set of DMUs, the results might be different.

In the tables and graphs which show DEA (CRS, VRS) and SE analyses results, efficient DMUs with 100 efficiency scores are marked with bold character, and the most inefficient DMUs with higher scores are marked with red color. Additionally, efficient DMUs are ranked in accordance with their efficiency scores in SE analysis results.

VRS analysis excludes the scale efficiency in determining the efficient establishments compared to CRS analysis which requires scale and pure technical efficiencies together. Inclusion of CRS and VRS analyses together into the study was beneficial in seeing how the list of efficient establishments were changing when the scale efficiency condition is ignored.

In the VRS Super Efficiency analyses results, the efficiency scores of some efficienct DMUs appearing as “BIG” in the tables and graphs mean that the DMU remains efficient under arbitrary large decreased outputs (for output oriented models) Scheel (2000) .

Benchmarks are produced by EMP 1.30 software as a result of CRS and VRS analyses. In the benchmarks tables, in rows where inefficient DMUs are placed under first column, the name or the order number of efficient DMUs and a coefficient in the parenthesis (for example YENİKÖY (4,70) or 4 (4,70)) are found for every year under the columns of years. Coefficients are generated by the software as a result of the analyses, and used in calculating the target values and improvement potentials for the inefficient establishments to move to becoming efficient. In rows where efficient DMUs are placed under first column, numbers are found for every year under the columns of years. Those numbers show how many inefficient DMUs take this efficient DMU as reference to move to becoming efficient.

5.3.1 DEA Analyses of Production Efficiency Model (Model 1)

Model 1 CRS Analysis

CRS efficiency scores of the DMUs for Model 1 between 2006 to 2009 are given in Table 5.5 and shown in Figure 5.1.

Table 5. 5 CRS efficiency scores of DMUs for Model 1

		Efficiency Scores				
M1 CRS	**DMUs**	**2006**	**2007**	**2008**	**2009**	**2006-2009 Average**
1	EGESOMA	405,08	286,02	266,27	281,44	309,70
2	ÇAN	422,50	273,47	325,20	324,52	336,42
3	YATAĞAN	194,39	158,55	153,25	159,02	166,30
4	YENİKÖY	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
5	GARP	651,07	534,31	593,09	566,03	586,13
6	ILGIN	443,88	1357,64	626,11	524,57	738,05
7	SEYİTÖMER	141,93	**100,00**	**100,00**	**100,00**	110,48
8	BURSA	412,60	297,39	281,25	346,76	334,50

According to the Model 1 CRS analysis results; in 2006 YENİKÖY, in 2007, 2008 and 2009 YENİKÖY and SEYİTÖMER were efficient. While YENİKÖY was efficient in all years between 2006 to 2009, SEYİTÖMER was efficient in 2007, 2008 and 2009, but not 2006.

In those years, the DMUs which were most inefficient were GARP in 2006 and 2009, and Ilgın in 2007 and 2008.

The Benchmarks and references for inefficient DMUs based on CRS analysis for Model 1 are given in Table 5.6. In the table, for efficient DMUs (4 in 2006; 4 and 7 in 2007, 2008, 2009), number of being reference to inefficient DMUs are shown at the intersection of the row of the efficient DMU and the column of the analysis year. For inefficient DMUs (1, 2, 3, 5, 6, 7 and 8 in 2006; 1, 2, 3, 5, 6, and 8 in 2007, 2008, 2009), efficient DMUs which were taken reference by the inefficient DMU to move to becoming efficient are shown at the intersection of the row of the inefficient DMU and the column of the analysis year. Coefficients generated by the software and used in calculating target values for inefficient DMUs are shown in the parenthesis beside the efficient DMUs taken as reference.

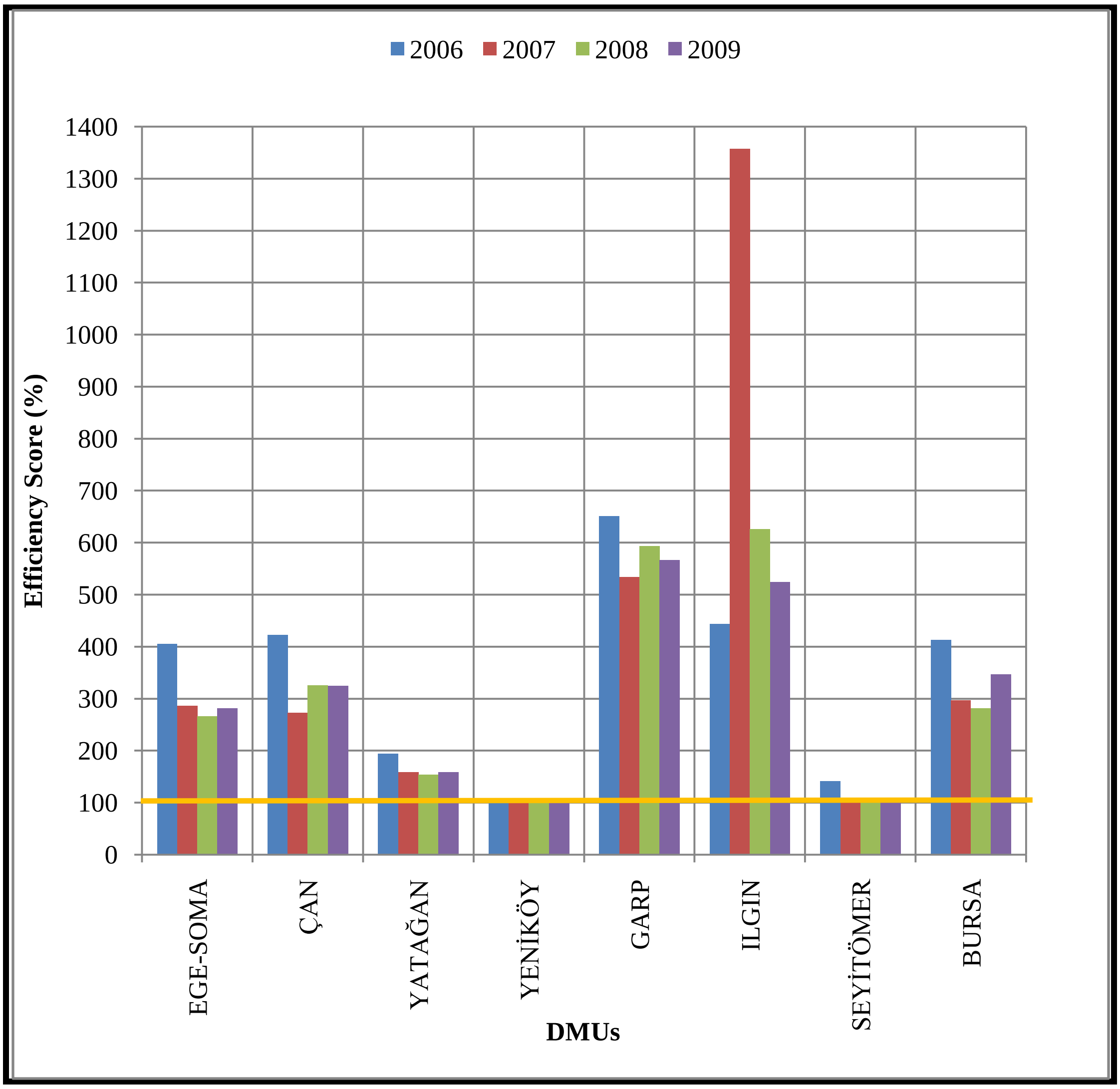


Figure 5. 1 CRS efficiency scores of DMUs for Model 1

Table 5. 6 Benchmarks and references for inefficient DMUs for Model 1 CRS analysis

M1 CRS	DMUs	Benchmarks			
		2006	**2007**	**2008**	**2009**
1	EGESOMA	YENİKÖY (4,70)	YENİKÖY (3,87)	YENİKÖY (3,86)	YENİKÖY (3,64) SEYİTÖMER (0,64)
2	ÇAN	YENİKÖY (0,84)	YENİKÖY (0,82)	YENİKÖY (0,90)	YENİKÖY (0,97)
3	YATAĞAN	YENİKÖY (1,16)	YENİKÖY (0,81) SEYİTÖMER (0,25)	YENİKÖY (1,12)	YENİKÖY (0,10) SEYİTÖMER (0,94)
4	**YENİKÖY**	**7**	**6**	**5**	**6**
5	GARP	YENİKÖY (3,31)	YENİKÖY (2,61) SEYİTÖMER (0,26)	YENİKÖY (3,07) SEYİTÖMER (0,19)	YENİKÖY (1,12) SEYİTÖMER (1,95)
6	ILGIN	YENİKÖY (0,14)	YENİKÖY (0,08) SEYİTÖMER (0,10)	SEYİTÖMER (0,14)	YENİKÖY (0,12) SEYİTÖMER (0,10)
7	**SEYİTÖMER**	YENİKÖY (0,97)	**4**	**3**	**5**
8	BURSA	YENİKÖY (0,75)	YENİKÖY (0,40) SEYİTÖMER (0,36)	YENİKÖY (0,05) SEYİTÖMER (0,63)	YENİKÖY (0,37) SEYİTÖMER (0,45)

Model 1 CRS Super Efficiency (SE) analysis

Model 1 CRS-SE analysis is performed to rank the DMUs which are efficient in CRS analysis among themselves.

According to CRS-SE analysis for Model 1, the efficiency ranking of efficient DMUs in CRS analysis is given in Table 5.7, and the efficiency ranking of all DMUs is given in Table 5.8 and Figure 5.2 for the years between 2006 to 2009.

Table 5. 7 SE scores of efficient DMUs for Model 1 CRS analysis

M1 CRS SE	DMUs	2006	2007	2008	2009
4	YENİKÖY	**39,62**	**44,64**	**53,01**	**63,34**
7	SEYİTÖMER		**93,12**	**94,16**	**86,27**

Table 5. 8 Ranking of DMUs on CRS and CRS-SE efficiency scores

DMUs	2006	DMUs	2007	DMUs	2008	DMUs	2009
YENİKÖY	**39,62**	YENİKÖY	**44,64**	YENİKÖY	**53,01**	YENİKÖY	**63,34**
SEYİTÖMER	141,93	SEYİTÖMER	**93,12**	SEYİTÖMER	**94,16**	SEYİTÖMER	**86,27**
YATAĞAN	194,39	YATAĞAN	158,55	YATAĞAN	153,25	YATAĞAN	159,02
EGESOMA	405,08	ÇAN	273,47	EGESOMA	266,27	EGESOMA	281,44
BURSA	412,60	EGESOMA	286,02	BURSA	281,25	ÇAN	324,52
ÇAN	422,50	BURSA	297,39	ÇAN	325,20	BURSA	346,76
ILGIN	443,88	GARP	534,31	GARP	593,09	ILGIN	524,57
GARP	651,07	ILGIN	1357,64	ILGIN	626,11	GARP	566,03

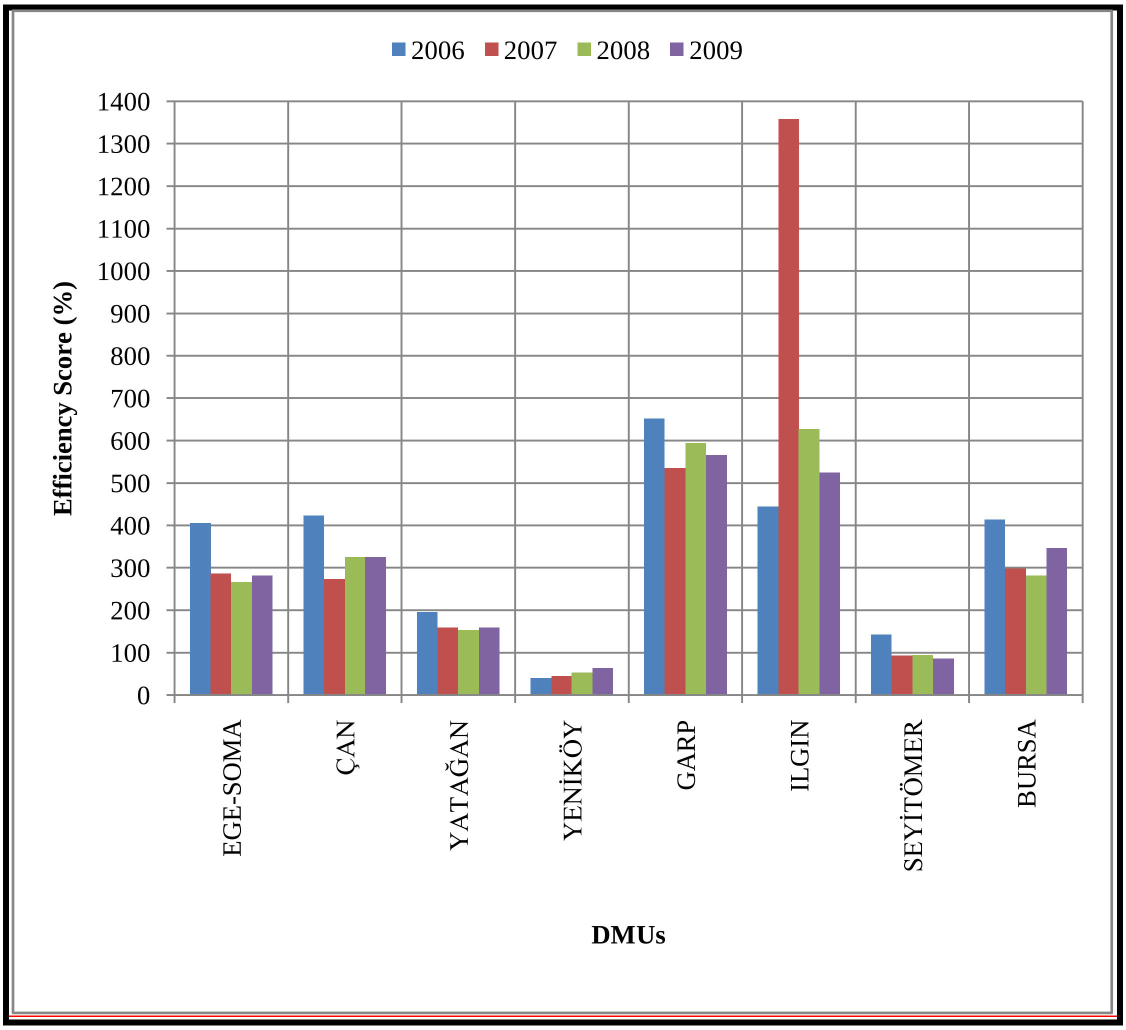


Figure 5. 2 CRS and CRS SE efficiency scores of DMUs for Model 1

Model 1 VRS Analysis

VRS Efficiency scores of DMUs for Model 1 are given in Table 5.9 and Figure 5.3.

Table 5. 9 VRS efficiency scores of DMUs for Model 1

		Efficiency Scores				
M1 VRS	**DMUs**	**2006**	**2007**	**2008**	**2009**	**2006-2009 Average**
1	**EGESOMA**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
2	ÇAN	394,11	253,80	310,92	320,23	319,77
3	YATAĞAN	168,55	157,00	139,67	154,72	154,99
4	**YENİKÖY**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
5	GARP	210,77	225,37	226,65	217,28	220,02
6	**ILGIN**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
7	**SEYİTÖMER**	141,43	**100,00**	**100,00**	**100,00**	110,36
8	BURSA	395,15	278,56	261,87	329,70	316,32

According to the VRS analysis, in 2006 EGESOMA, YENİKÖY and ILGIN, in 2007, 2008 and 2009 EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient. EGESOMA, YENİKÖY and ILGIN were efficient in all the years between 2006 to 2009.

Among the most inefficient DMUs, ÇAN was for 2008, and Bursa was for 2006, 2007 and 2009.

Benchmarks and references for the inefficient DMUs in VRS efficiency analysis for Model 1 are given in Table 5.10. In the table, for efficient DMUs (1, 4 and 6 in 2006; 1, 4, 6 and 7 in 2007, 2008, 2009), number of being reference to inefficient DMUs are shown at the intersection of the row of the efficient DMU and the column of the analysis year. For inefficient DMUs (2, 3, 5, 7 and 8 in 2006; 2, 3, 5 and 8 in 2007, 2008, 2009), efficient DMUs which were taken reference by the inefficient DMU to move to becoming efficient are shown at the intersection of the row of the inefficient DMU and the column of the analysis year. Coefficients generated by the software and used in calculating target values for inefficient DMUs are shown in the parenthesis beside the efficient DMUs taken as reference.

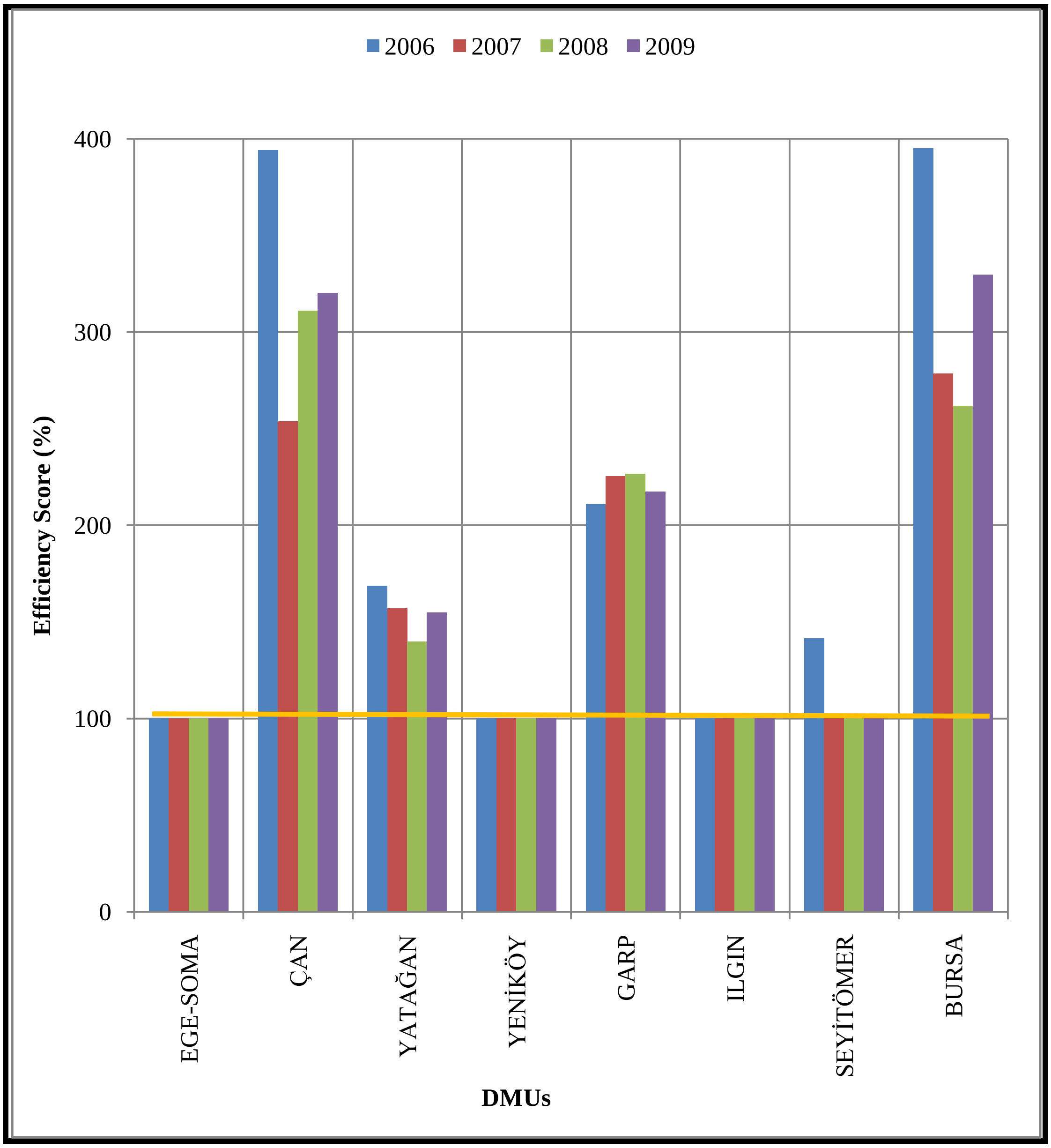


Figure 5. 3 VRS efficiency scores of DMUs for Model 1

Table 5. 10 Benchmarks and references for inefficient DMUs for Model 1 VRS analysis

M1 VRS	**DMUs**	**Benchmarks**			
		2006	**2007**	**2008**	**2009**
1	**EGESOMA**	**2**	**1**	**2**	**1**
2	ÇAN	YENİKÖY (0,78) ILGIN (0,22)	YENİKÖY (0,76) ILGIN (0,24)	YENİKÖY (0,86) ILGIN (0,14)	YENİKÖY (0,95) ILGIN (0,05)
3	YATAĞAN	EGESOMA (0,03) YENİKÖY (0,97)	YENİKÖY (0,94) SEYİTÖMER (0,06)	EGESOMA (0,04) YENİKÖY (0,96)	YENİKÖY (0,02) SEYİTÖMER (0,98)
4	**YENİKÖY**	**5**	**4**	**4**	**3**
5	GARP	EGESOMA (0,45) YENİKÖY (0,55)	EGESOMA (0,52) YENİKÖY (0,48)	EGESOMA (0,53) YENİKÖY (0,47)	EGESOMA (0,35) SEYİTÖMER (0,65)
6	**ILGIN**	**3**	**2**	**2**	**2**
7	**SEYİTÖMER**	YENİKÖY (0,97) ILGIN (0,03)	**2**	**1**	**3**
8	BURSA	YENİKÖY (0,71) ILGIN (0,29)	YENİKÖY (0,38) ILGIN (0,29) SEYİTÖMER (0,33)	YENİKÖY (0,08) ILGIN (0,38) SEYİTÖMER (0,54)	YENİKÖY (0,34) ILGIN (0,23) SEYİTÖMER (0,43)

Model 1 VRS Super Efficiency Analysis

Model 1 VRS Super Efficiency (SE) analysis is performed to rank DMUs which are efficient in VRS analysis among themselves.

According to VRS SE analysis, the efficiency ranking of efficient DMUs in VRS analysis is given in Table 5.11, and efficiency ranking of all DMUs based on VRS and VRS-SE analysis is given in Table 5.12 and Figure 5.4 for the years between 2006 to 2009.

Table 5. 11 SE scores of efficient DMUs for Model 1 VRS analysis

		Efficiency Scores			
M1 VRS SE	**DMUs**	**2006**	**2007**	**2008**	**2009**
1	EGESOMA	**86,27**	**73,92**	**68,96**	**74,52**
4	YENİKÖY	**32,67**	**39,15**	**46,20**	**55,13**
6	ILGIN	**BIG**	**BIG**	**BIG**	**BIG**
7	SEYİTÖMER		**86,58**	**92,02**	**86,25**

Table 5. 12 Efficiency ranking of DMUs for Model 1 VRS and SE analysis

DMUs	2006	DMUs	2007	DMUs	2008	DMUs	2009
ILGIN	**BIG**	ILGIN	**BIG**	ILGIN	**BIG**	ILGIN	**BIG**
YENİKÖY	**32,67**	YENİKÖY	**39,15**	YENİKÖY	**46,20**	YENİKÖY	**55,13**
EGESOMA	**86,27**	EGESOMA	**73,92**	EGESOMA	**68,96**	EGESOMA	**74,52**
SEYİTÖMER	141,43	SEYİTÖMER	**86,58**	SEYİTÖMER	**92,02**	SEYİTÖMER	**86,25**
YATAĞAN	168,55	YATAĞAN	157,00	YATAĞAN	139,67	YATAĞAN	154,72
GARP	210,77	GARP	225,37	GARP	226,65	GARP	217,28
ÇAN	394,11	ÇAN	253,80	BURSA	261,87	ÇAN	320,23
BURSA	395,15	BURSA	278,56	ÇAN	310,92	BURSA	329,70

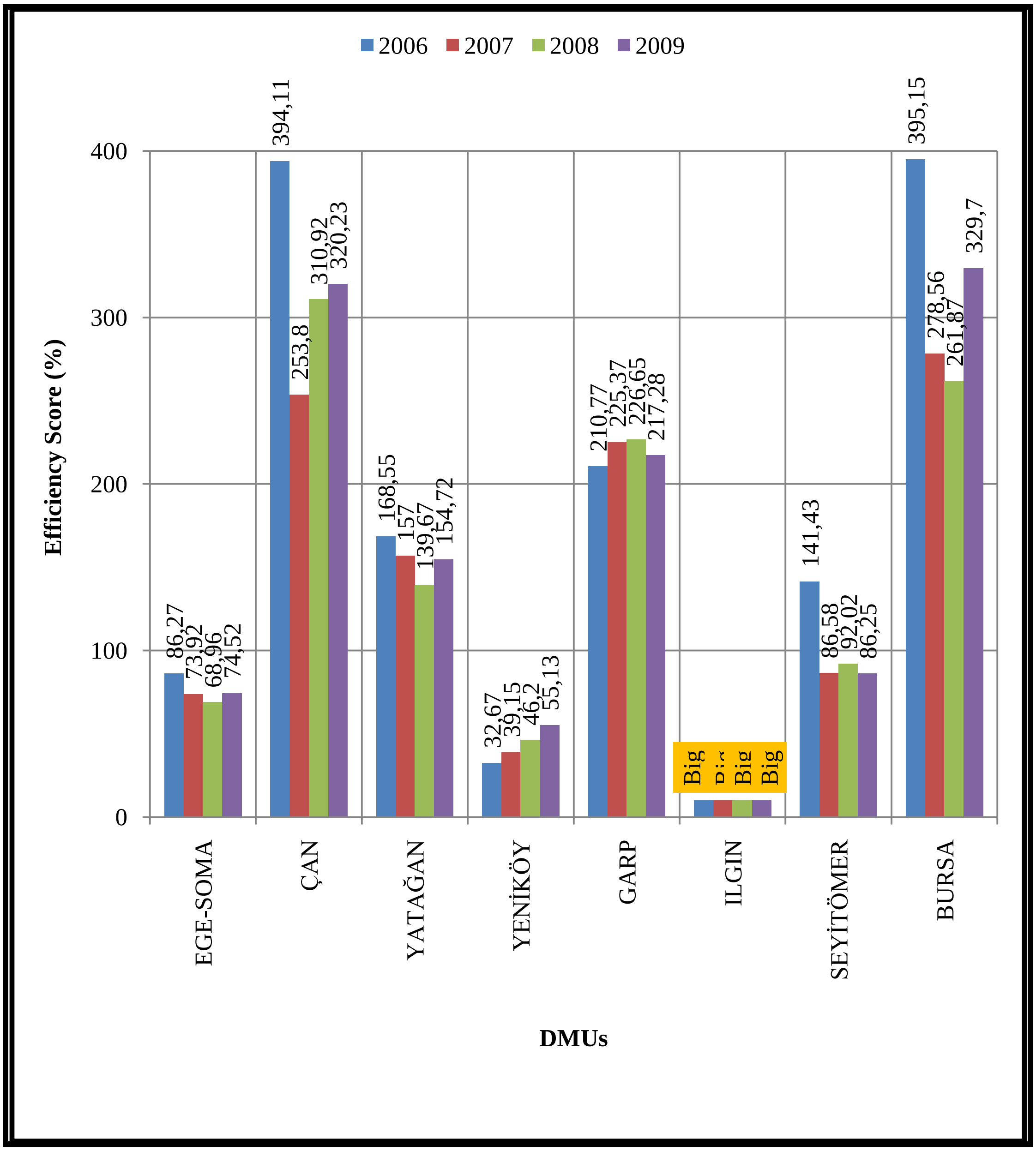


Figure 5. 4 VRS and VRS SE efficiency scores of DMUs for Model 1

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 1 in 2006 is given in Table 5.13.

Table 5. 13 CRS, VRS and SE efficiency scores of DMUs for Model 1 in 2006

		Efficiency Scores			
2006 M1	**DMU**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	EGESOMA	405,08	405,08	**100,00**	**86,27**
2	ÇAN	422,50	422,50	394,11	394,11
3	YATAĞAN	194,39	194,39	168,55	168,55
4	YENİKÖY	**100,00**	**39,62**	**100,00**	**32,67**
5	GARP	651,07	651,07	210,77	210,77
6	ILGIN	443,88	443,88	**100,00**	**BIG**
7	SEYİTÖMER	141,93	141,93	141,43	141,43
8	BURSA	412,60	412,60	395,15	395,15

For Model 1, Yeniköy was efficient in all types of analysis in 2006.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2006, the efficiency ranking of DMUs for Model 1 is given in Table 5.14.

Table 5. 14 CRS, VRS and SE efficiency rankings of DMUs for Model 1 in 2006

DMU	**CRS**	**DMU**	**CRS SE**	**DMU**	**VRS**	**DMU**	**VRS SE**
YENİKÖY	**100,00**	YENİKÖY	**39,62**	EGESOMA	**100,00**	ILGIN	**BIG**
SEYİTÖMER	141,93	SEYİTÖMER	141,93	YENİKÖY	**100,00**	YENİKÖY	**32,67**
YATAĞAN	194,39	YATAĞAN	194,39	ILGIN	**100,00**	EGESOMA	**86,27**
EGESOMA	405,08	EGESOMA	405,08	SEYİTÖMER	141,43	SEYİTÖMER	141,43
BURSA	412,60	BURSA	412,60	YATAĞAN	168,55	YATAĞAN	168,55
ÇAN	422,50	ÇAN	422,50	GARP	210,77	GARP	210,77
ILGIN	443,88	ILGIN	443,88	ÇAN	394,11	ÇAN	394,11
GARP	651,07	GARP	651,07	BURSA	395,15	BURSA	395,15

Efficiency scores of DMUs in all types of efficiency analyses for Model 1 in 2006 are shown in Figure 5.5.

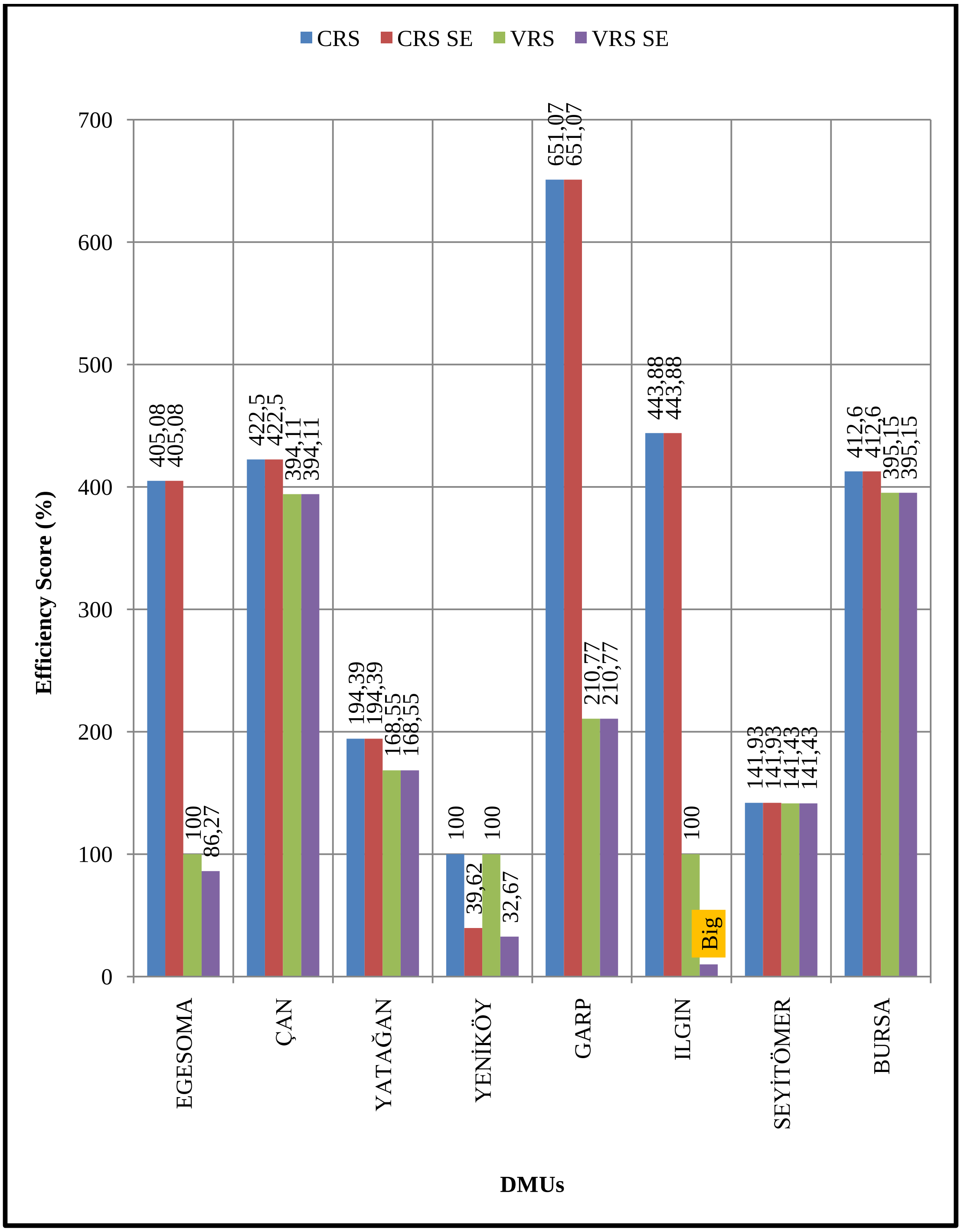


Figure 5. 5 Model 1 CRS, VRS and SE efficiency scores of DMUs (2006)

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 1 in 2007 is given in Table 5.15.

Table 5. 15 CRS, VRS and SE efficiency scores of DMUs for Model 1 in 2007

		Efficiency Scores			
2007 M1	**DMU**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	EGESOMA	286,02	286,02	**100,00**	**73,92**
2	ÇAN	273,47	273,47	253,80	253,80
3	YATAĞAN	158,55	158,55	157,00	157,00
4	YENİKÖY	**100,00**	**44,64**	**100,00**	**39,15**
5	GARP	534,31	534,31	225,37	225,37
6	ILGIN	1357,64	1357,64	**100,00**	**BIG**
7	SEYİTÖMER	**100,00**	**93,12**	**100,00**	**86,58**
8	BURSA	297,39	297,39	278,56	278,56

According to the analyses results of 2007, EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient in VRS and VRS-SE analyses, YENİKÖY and SEYİTÖMER were efficient in all CRS, CRS-SE, VRS and VRS-SE analyses. ÇAN, YATAĞAN, GARP and BURSA were not efficient in all CRS, CRS-SE, VRS and VRS-SE analyses.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2007, the efficiency ranking of DMUs for Model 1 is given in Table 5.16.

Table 5. 16 CRS, VRS and SE efficiency rankings of DMUs for Model 1 in 2007

DMU	**CRS**	**DMU**	**CRS SE**	**DMU**	**VRS**	**DMU**	**VRS SE**
YENİKÖY	**100,00**	YENİKÖY	**44,64**	EGESOMA	**100,00**	ILGIN	**BIG**
SEYİTÖMER	**100,00**	SEYİTÖMER	**93,12**	YENİKÖY	**100,00**	YENİKÖY	**39,15**
YATAĞAN	158,55	YATAĞAN	158,55	ILGIN	**100,00**	EGESOMA	**73,92**
ÇAN	273,47	ÇAN	273,47	SEYİTÖMER	**100,00**	SEYİTÖMER	**86,58**
EGESOMA	286,02	EGESOMA	286,02	YATAĞAN	157,00	YATAĞAN	157,00
BURSA	297,39	BURSA	297,39	GARP	225,37	GARP	225,37
GARP	534,31	GARP	534,31	ÇAN	253,80	ÇAN	253,80
ILGIN	1357,64	ILGIN	1357,64	BURSA	278,56	BURSA	278,56

Efficiency scores of all efficiency analyses in 2007 are shown in Figure 5.6.

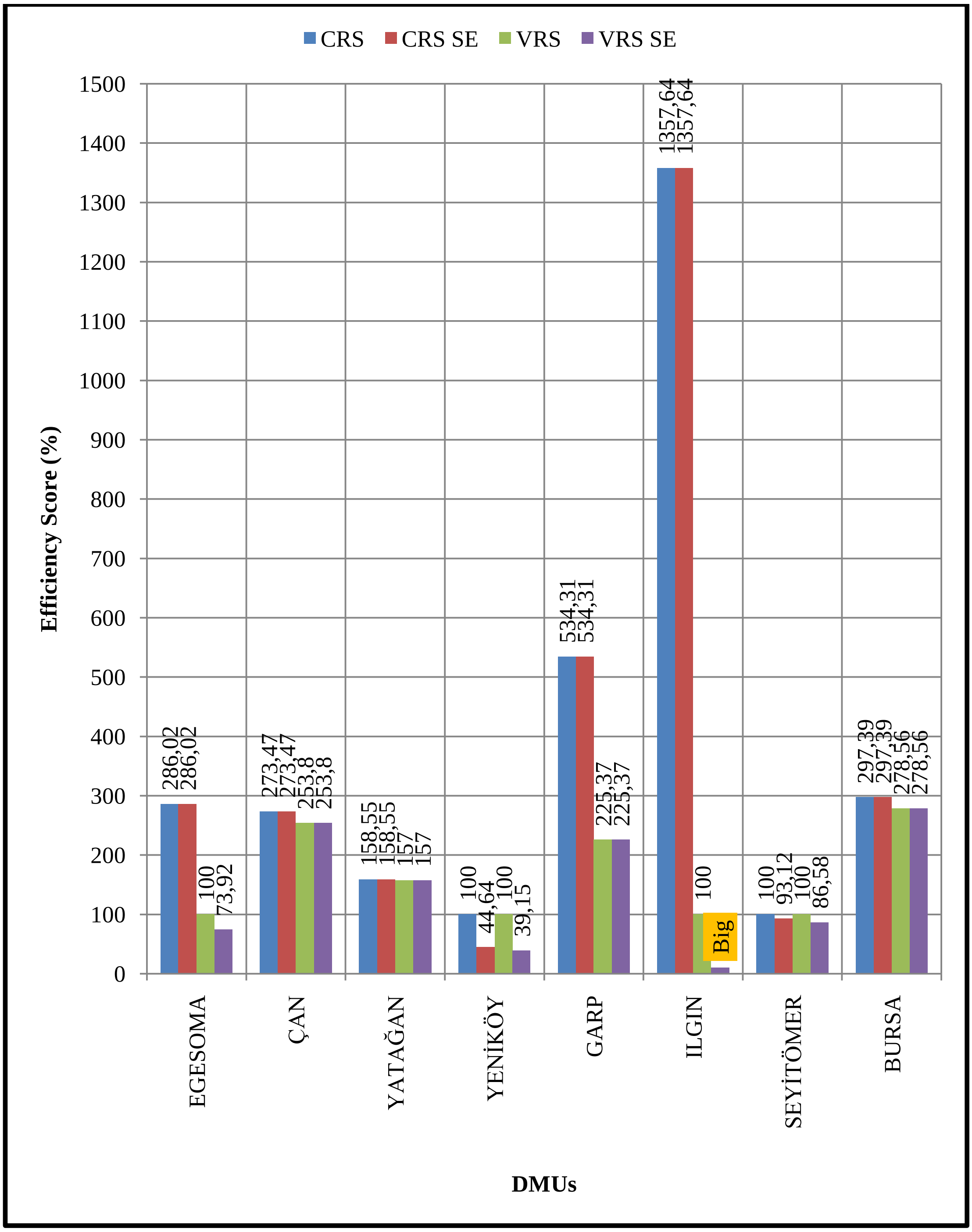


Figure 5. 6 Model 1 CRS, VRS and SE efficiency scores of DMUs for Model 1 (2007)

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 1 in 2008 is given in Table 5.17.

Table 5. 17 CRS, VRS and SE efficiency scores of DMUs for Model 1 in 2008

		Efficiency Scores			
2008 M1	**DMU**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	EGESOMA	266,27	266,27	**100,00**	**68,96**
2	ÇAN	325,20	325,20	310,92	310,92
3	YATAĞAN	153,25	153,25	139,67	139,67
4	YENİKÖY	**100,00**	**53,01**	**100,00**	**46,2**
5	GARP	593,09	593,09	226,65	226,65
6	ILGIN	626,11	626,11	**100,00**	**BIG**
7	SEYİTÖMER	**100,00**	**94,16**	**100,00**	**92,02**
8	BURSA	281,25	281,25	261,87	261,87

According to 2008 analyses results for Model 1 EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient in VRS and VRS-SE analyses, and YENİKÖY and SEYİTÖMER were efficient in all CRS, CRS SE, VRS and VRS SE analysis. ÇAN, YATAĞAN, GARP and BURSA were not efficient an all types of analysis.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2008, the efficiency ranking of DMUs for Model 2 is given in Table 5.18.

Table 5. 18 CRS, VRS and SE efficiency rankings of DMUs for Model 1 in 2008

DMU	**CRS**	**DMU**	**CRS SE**	**DMU**	**VRS**	**DMU**	**VRS SE**
YENİKÖY	**100,00**	YENİKÖY	**53,01**	EGESOMA	**100,00**	ILGIN	**BIG**
SEYİTÖMER	**100,00**	SEYİTÖMER	**94,16**	YENİKÖY	**100,00**	YENİKÖY	**46,20**
YATAĞAN	153,25	YATAĞAN	153,25	ILGIN	**100,00**	EGESOMA	**68,96**
EGESOMA	266,27	EGESOMA	266,27	SEYİTÖMER	**100,00**	SEYİTÖMER	**92,02**
BURSA	281,25	BURSA	281,25	YATAĞAN	139,67	YATAĞAN	139,67
ÇAN	325,20	ÇAN	325,20	GARP	226,65	GARP	226,65
GARP	593,09	GARP	593,09	BURSA	261,87	BURSA	261,87
ILGIN	626,11	ILGIN	626,11	ÇAN	310,92	ÇAN	310,92

Efficiency scores of DMUs in all types of efficiency analysis in 2008 are shown in Figure 5.7.

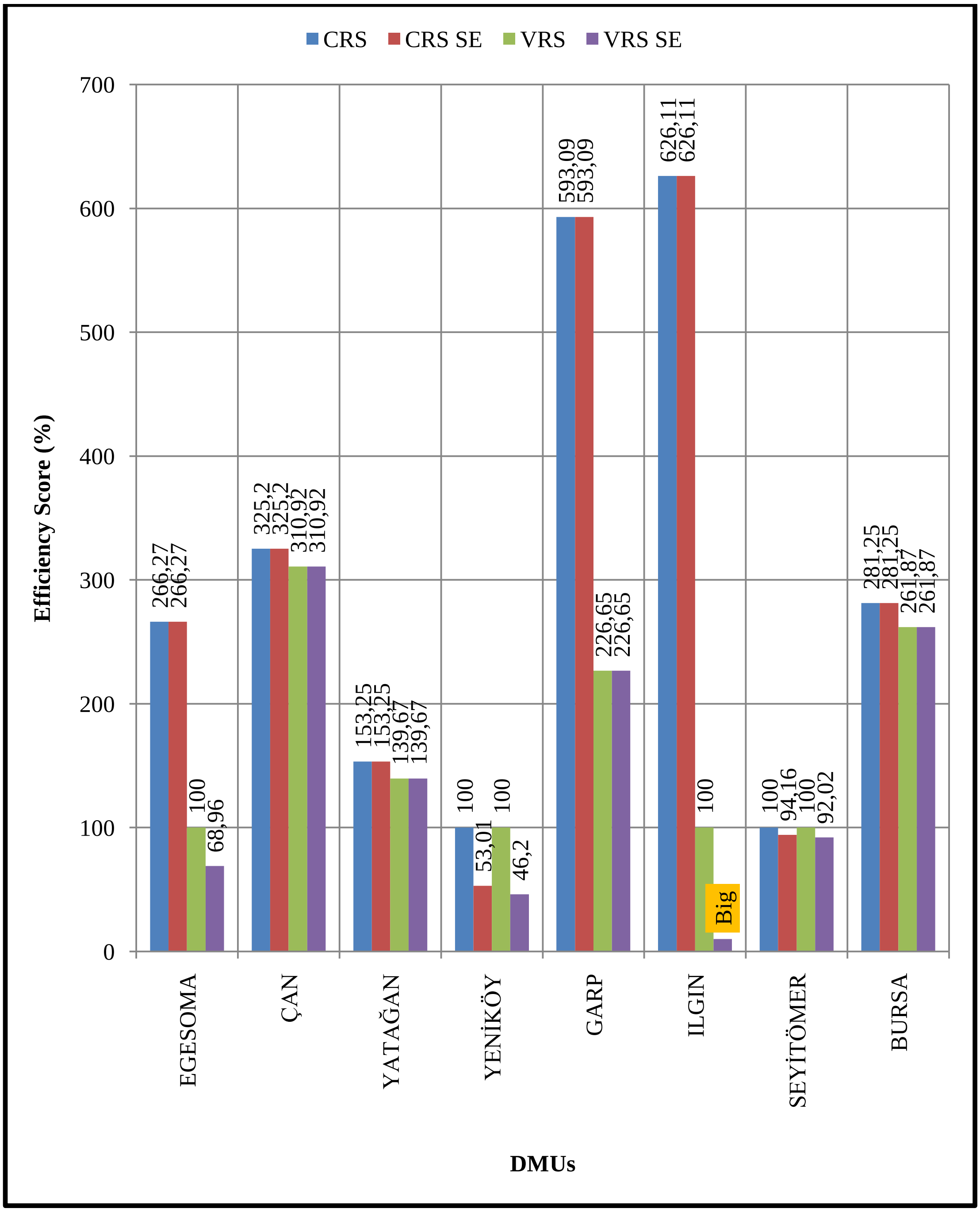


Figure 5. 7 Model 1 CRS, VRS and SE efficiency scores of DMUs for Model 1 (2008)

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 1 in 2009 are given in Table 5.19.

Table 5. 19 CRS, VRS and SE efficiency scores of DMUs for Model 1 in 2009

		Efficiency Scores			
2009 M1	**DMU**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	EGESOMA	281,44	281,44	**100,00**	**74,52**
2	ÇAN	324,52	324,52	320,23	320,23
3	YATAĞAN	159,02	159,02	154,72	154,72
4	YENİKÖY	**100,00**	**63,34**	**100,00**	**55,13**
5	GARP	566,03	566,03	217,28	217,28
6	ILGIN	524,57	524,57	**100,00**	**BIG**
7	SEYİTÖMER	**100,00**	**86,27**	**100,00**	**86,25**
8	BURSA	346,76	346,76	329,70	329,70

According to the analyses results for Model 1 in 2009 EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient in VRS and VRS-SE analyses, and YENİKÖY and SEYİTÖMER were efficient in all of CRS, CR- SE, VRS and VRS-SE analyses. ÇAN, YATAĞAN, GARP and BURSA were not efficient in all efficiency analyses.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2009, the efficiency ranking of DMUs for Model 1 is given in Table 5.20.

Table 5. 20 CRS, VRS and SE efficiency rankings of DMUs for Model 1 in 2009

DMU	**CRS**	**DMU**	**CRS SE**	**DMU**	**VRS**	**DMU**	**VRS SE**
YENİKÖY	**100,00**	YENİKÖY	**63,34**	EGESOMA	**100,00**	ILGIN	**BIG**
SEYİTÖMER	**100,00**	SEYİTÖMER	**86,27**	YENİKÖY	**100,00**	YENİKÖY	**55,13**
YATAĞAN	159,02	YATAĞAN	159,02	ILGIN	**100,00**	EGESOMA	**74,52**
EGESOMA	281,44	EGESOMA	281,44	SEYİTÖMER	**100,00**	SEYİTÖMER	**86,25**
ÇAN	324,52	ÇAN	324,52	YATAĞAN	154,72	YATAĞAN	154,72
BURSA	346,76	BURSA	346,76	GARP	217,28	GARP	217,28
ILGIN	524,57	ILGIN	524,57	ÇAN	320,23	ÇAN	320,23
GARP	566,03	GARP	566,03	BURSA	329,70	BURSA	329,70

Efficiency scores of DMUs in all types of efficiency analyses in 2009 are shown in Figure 5.8.

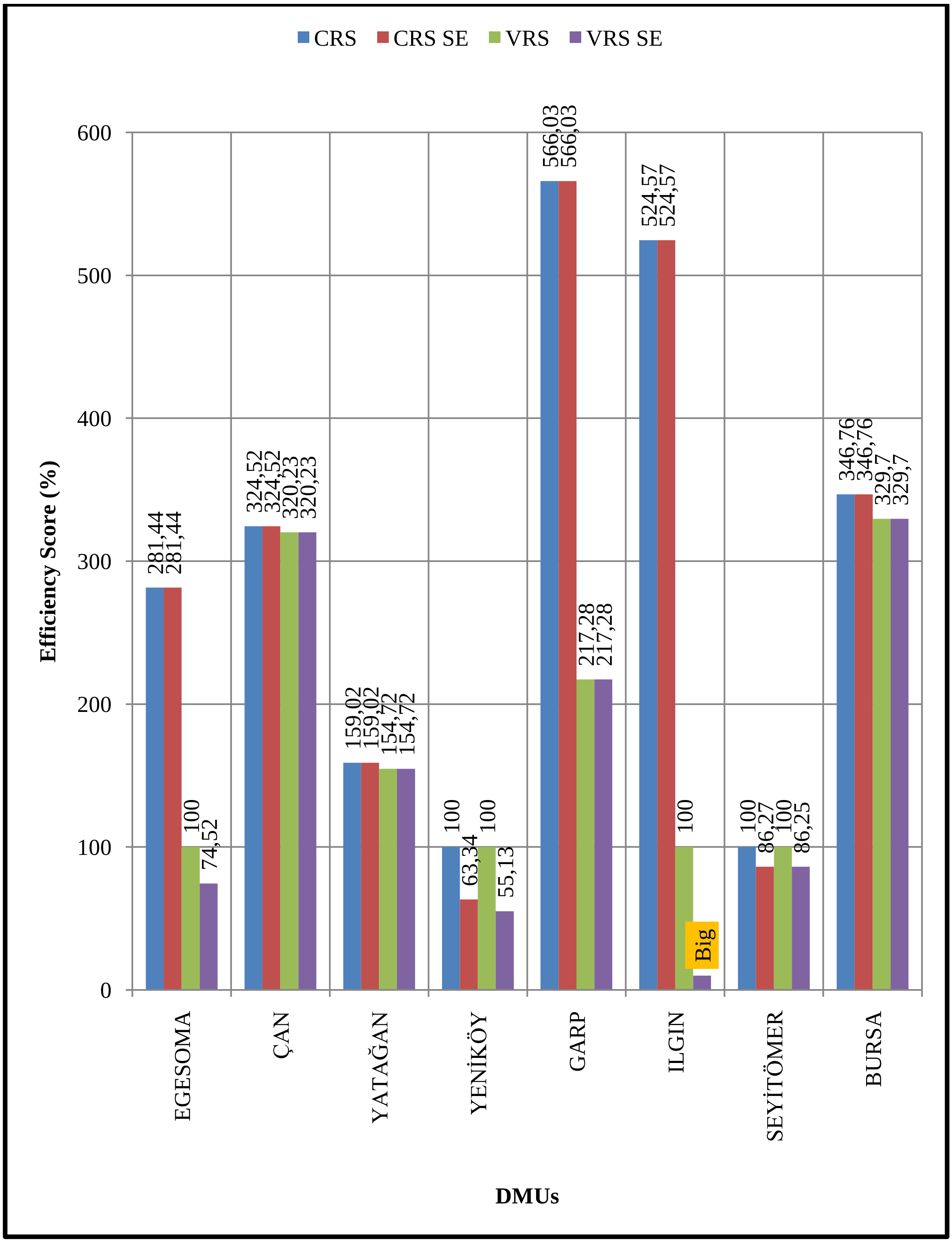


Figure 5. 8 CRS, VRS and SE efficiency scores of DMUs for Model 1 (2009)

5.3.2 DEA Analyses of Revenue Efficiency Model (Model 2)

Model 2 CRS Analysis

CRS efficiency scores of DMUs for Model 2 between 2006-2009 are calculated and given in Table 5.21 and Figure 5.9.

Table 5. 21 CRS efficiency scores of DMUs for Model 2

		Efficiency Scores				
M2 CRS	DMUs	2006	2007	2008	2009	2006-2009 Average
1	EGESOMA	144,86	112,31	**100,00**	100,64	114,45
2	ÇAN	154,52	131,81	165,77	159,56	152,92
3	YATAĞAN	159,78	124,37	121,87	133,90	134,98
4	YENİKÖY	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
5	GARP	176,83	160,54	165,69	159,06	165,53
6	ILGIN	229,65	335,51	276,75	213,61	263,88
7	SEYİTÖMER	119,89	**100,00**	**100,00**	**100,00**	104,97
8	BURSA	222,42	197,07	188,28	219,08	206,71

According to the results in 2006 YENİKÖY, in 2007 YENİKÖY and SEYİTÖMER, in 2008 EGESOMA, YENİKÖY and SEYİTÖMER, and in 2009 YENİKÖY and SEYİTÖMER were efficient. YENİKÖY were efficient in all of 4 years. The DMUs with highest inefficiencies were ILGIN in 2006, 2007 and 2008, and BURSA in 2009.

The benchmarks and references for inefficient DMUs based on CRS analysis for Model 2 are given in Table 5.22. In the table, for efficient DMUs (4 in 2006; 4 and 7 in 2007, 2009; 1, 4 and 7 in 2008), number of being reference to inefficient DMUs are shown at the intersection of the row of the efficient DMU and the column of the analysis year. For inefficient DMUs (1, 2, 3, 5, 6, 7 and 8 in 2006; 1, 2, 3, 5, 6 and 8 in 2007, 2009; 2, 3, 5, 6, and 8 in 2008), efficient DMUs which were taken reference by the inefficient DMU to move to becoming efficient are shown at the intersection of the row of the inefficient DMU and the column of the analysis year. Coefficients generated by the software and used in calculating target values for inefficient DMUs are shown in the parenthesis beside the efficient DMUs taken as reference.

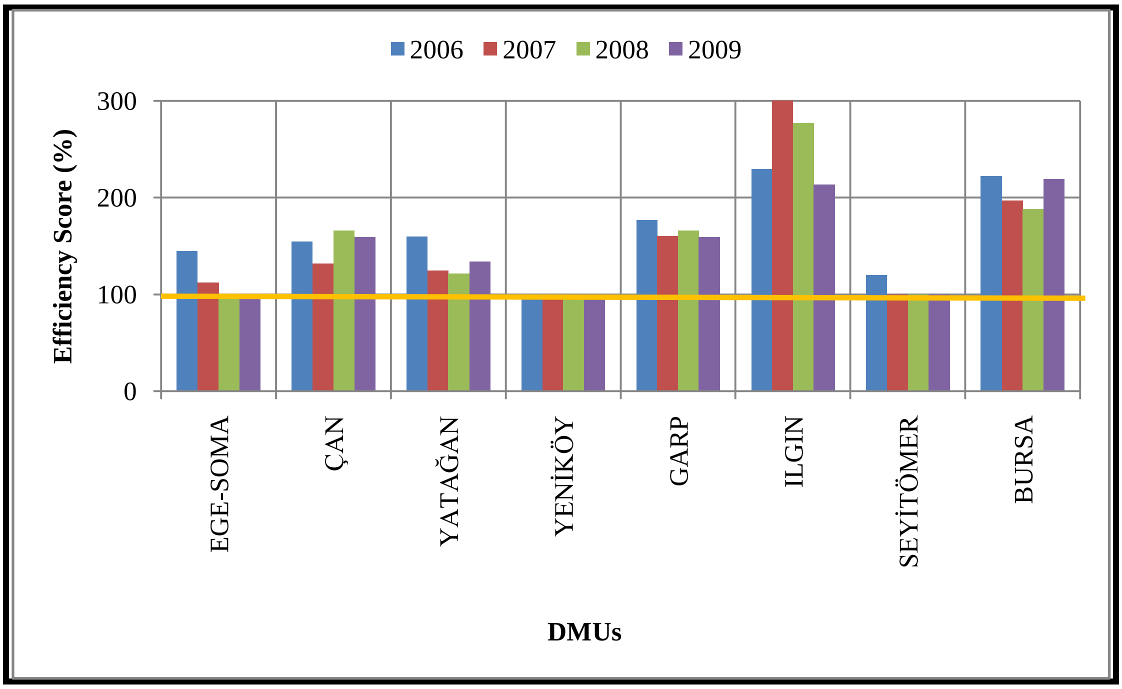


Figure 5. 9 CRS efficiency scores of DMUs for Model 2

Table 5. 22 Benchmarks and references for inefficient DMUs for Model 2 CRS analysis

M2 CRS	**DMUs**	**Benchmarks**			
		2006	**2007**	**2008**	**2009**
1	**EGESOMA**	YENİKÖY (4,70)	YENİKÖY (3,87)	**1**	YENİKÖY (3,64) SEYİTÖMER (0,64)
2	ÇAN	YENİKÖY (0,84)	YENİKÖY (0,82)	YENİKÖY (0,90)	YENİKÖY (0,97)
3	YATAĞAN	YENİKÖY (1,16)	YENİKÖY (0,81) SEYİTÖMER (0,25)	EGE-SOMA (0,06) YENİKÖY (0,87)	YENİKÖY (0,10) SEYİTÖMER (0,94)
4	**YENİKÖY**	**7**	**6**	**4**	**6**
5	GARP	YENİKÖY (3,31)	YENİKÖY (2,61) SEYİTÖMER (0,26)	YENİKÖY (3,07) SEYİTÖMER (0,19)	YENİKÖY (1,12) SEYİTÖMER (1,95)
6	ILGIN	YENİKÖY (0,14)	YENİKÖY (0,08) SEYİTÖMER (0,10)	SEYİTÖMER (0,14)	YENİKÖY (0,12) SEYİTÖMER (0,10)
7	**SEYİTÖMER**	YENİKÖY (0,97)	**4**	**3**	**5**
8	BURSA	YENİKÖY (0,75)	YENİKÖY (0,40) SEYİTÖMER (0,36)	YENİKÖY (0,05) SEYİTÖMER (0,63)	YENİKÖY (0,37) SEYİTÖMER (0,45)

Model 2 CRS Super efficiency (SE) analysis

CRS-SE analysis is performed to rank DMUs, which are efficient in CRS analysis, among themselves. The ranking of efficient DMUs in CRS-SE analysis for Model 2 is given in Table 5.23 and the ranking of all DMUs in CRS and CRS-SE analysis is given in Table 5.24 and Figure 5.10 for the years 2006-2009.

Table 5. 23 CRS SE scores of efficient DMUs for Model 2

		Efficiency Scores			
M2 CRS SE	**DMUs**	**2006**	**2007**	**2008**	**2009**
1	EGESOMA			**97,60**	
4	YENİKÖY	**58,40**	**71,43**	**77,22**	**79,78**
7	SEYİTÖMER		**85,32**	**85,98**	**80,76**

Table 5. 24 CRS and CRS SE efficiency ranking of DMUs

DMUs	2006	DMUs	2007	DMUs	2008	DMUs	2009
YENİKÖY	**58,40**	YENİKÖY	**71,43**	YENİKÖY	**77,22**	YENİKÖY	**79,78**
SEYİTÖMER	119,89	SEYİTÖMER	**85,32**	SEYİTÖMER	**85,98**	SEYİTÖMER	**80,76**
EGESOMA	144,86	EGESOMA	112,31	EGESOMA	**97,60**	EGESOMA	100,64
ÇAN	154,52	YATAĞAN	124,37	YATAĞAN	121,87	YATAĞAN	133,90
YATAĞAN	159,78	ÇAN	131,81	GARP	165,69	GARP	159,06
GARP	176,83	GARP	160,54	ÇAN	165,77	ÇAN	159,56
BURSA	222,42	BURSA	197,07	BURSA	188,28	ILGIN	213,61
ILGIN	229,65	ILGIN	335,51	ILGIN	276,75	BURSA	219,08

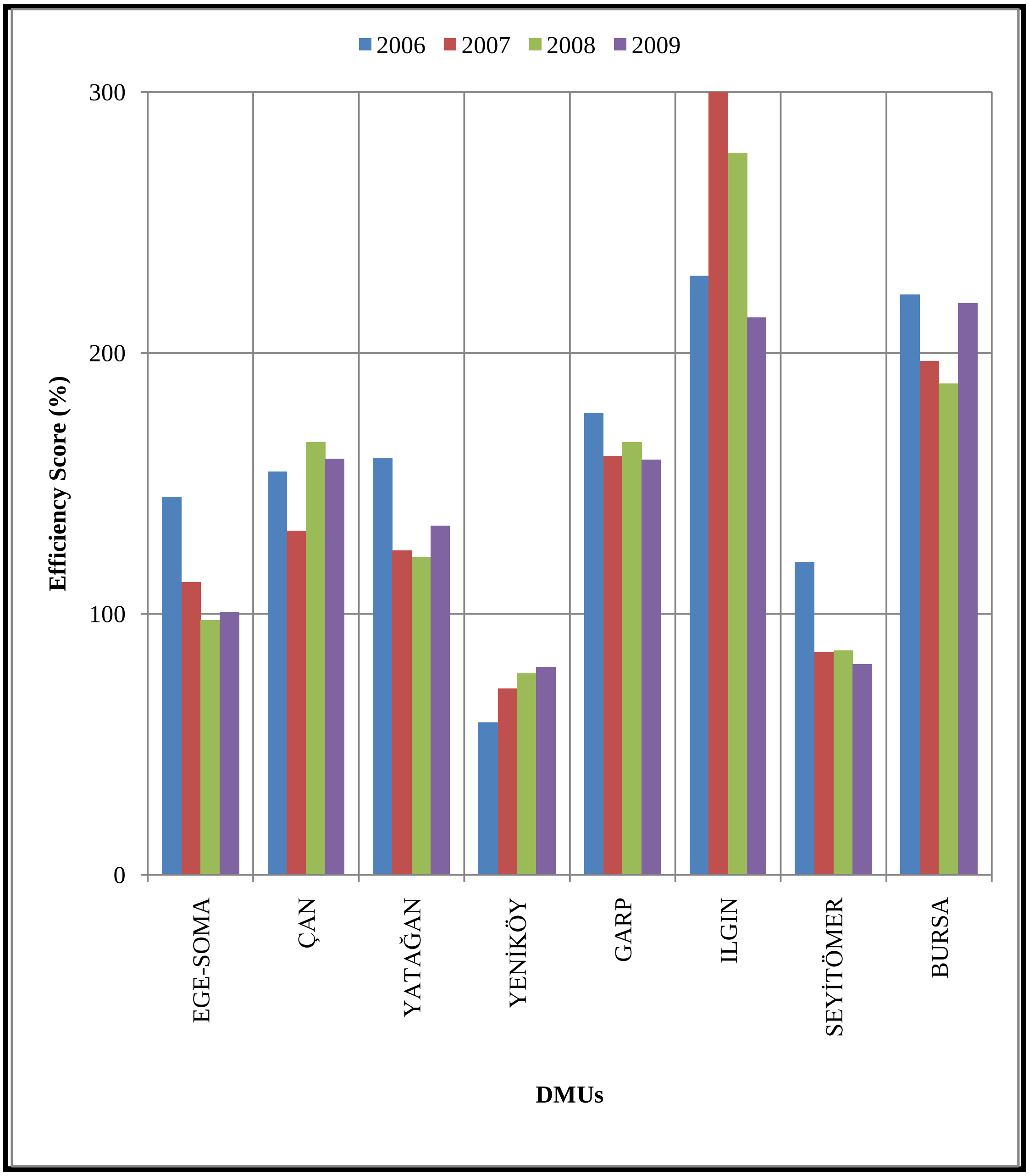


Figure 5. 10 CRS and CRS-SE efficiency scores of DMUs for Model 2

Model 2 VRS Analysis

VRS Efficiency Scores of DMUs for Model 2 are given in Table 5.25 and shown in Figure 5.11.

Table 5. 25 VRS efficiency scores of DMUs for Model 2

		Efficiency Scores				
M2 VRS	**DMUs**	**2006**	**2007**	**2008**	**2009**	**2006-2009 Average**
1	**EGESOMA**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
2	ÇAN	145,33	123,80	159,26	158,01	146,60
3	YATAĞAN	147,26	122,49	121,64	133,86	131,31
4	**YENİKÖY**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
5	GARP	107,11	129,91	132,29	105,41	118,68
6	**ILGIN**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**
7	**SEYİTÖMER**	119,58	**100,00**	**100,00**	**100,00**	104,90
8	BURSA	215,56	187,55	177,56	212,04	198,18

According to the VRS analysis, in 2006 EGESOMA, YENİKÖY and ILGIN, in 2007, 2008 and 2009 EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient. EGESOMA, YENİKÖY and ILGIN were efficient all 4 years. BURSA was the most inefficient DMU in 2006, 2007, 2008 and 2009.

Benchmarks and references for inefficient DMUs in VRS analysis for Model 2 are given in Table 5.26. In the table, for efficient DMUs (1, 4 and 6 in 2006; 1, 4, 6 and 7 in 2007, 2008, 2009), number of being reference to inefficient DMUs are shown at the intersection of the row of the efficient DMU and the column of the analysis year. For inefficient DMUs (2, 3, 5, 7 and 8 in 2006; 2, 3, 5 and 8 in 2007, 2008, 2009), efficient DMUs which were taken reference by the inefficient DMU to move to becoming efficient are shown at the intersection of the row of the inefficient DMU and the column of the analysis year. Coefficients generated by the software and used in calculating target values for inefficient DMUs are shown in the parenthesis beside the efficient DMUs taken as reference.

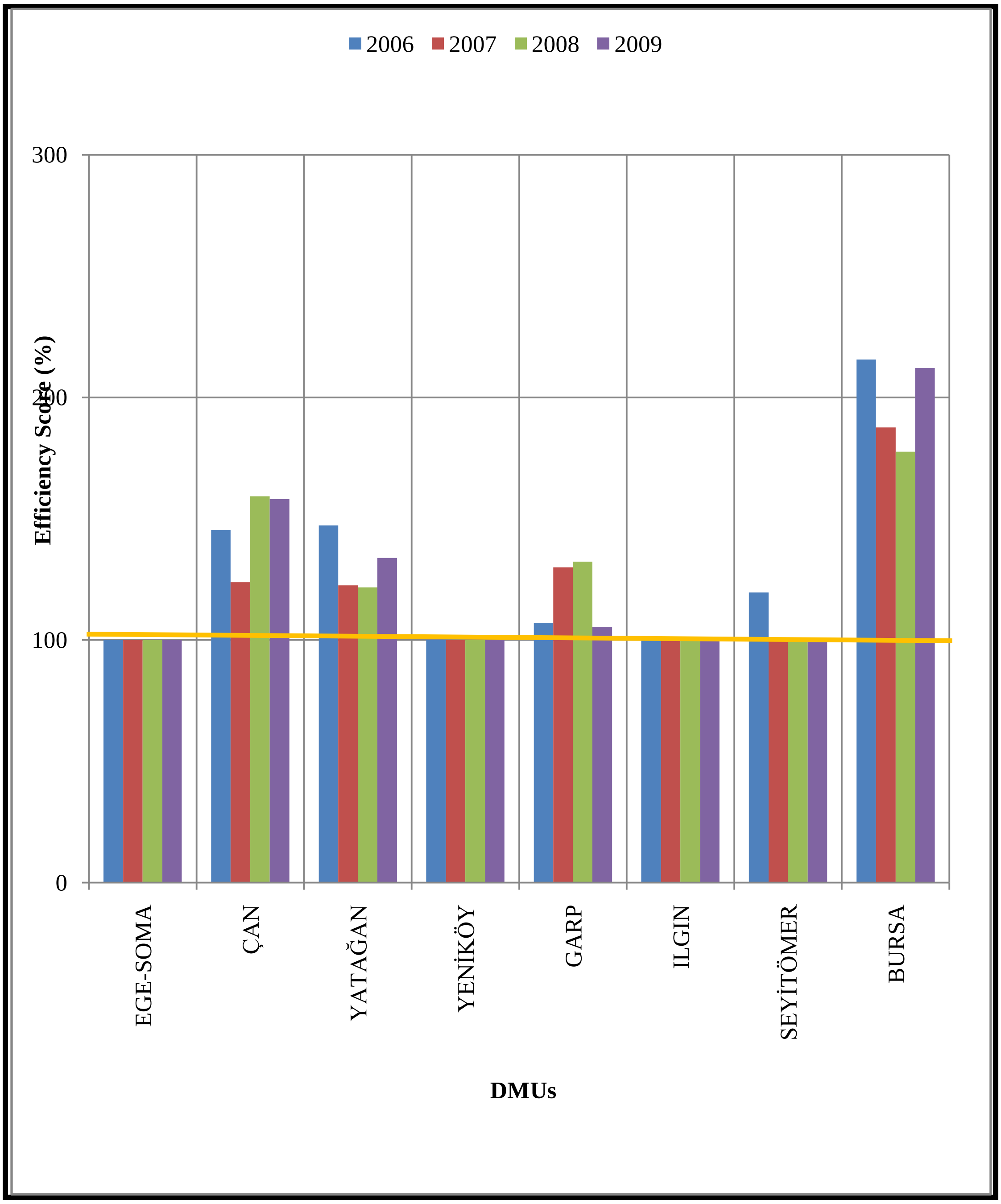


Figure 5. 11 VRS efficiency scores of DMUs for Model 2

Table 5. 26 Benchmarks and references for inefficient DMUs for Model 2 VRS analysis

M2 VRS	**DMUs**	**Benchmarks**			
		2006	**2007**	**2008**	**2009**
1	**EGESOMA**	**2**	**2**	**2**	**2**
2	ÇAN	YENİKÖY (0,78) ILGIN (0,22)	YENİKÖY (0,76) ILGIN (0,24)	YENİKÖY (0,86) ILGIN (0,14)	YENİKÖY (0,95) ILGIN (0,05)
3	YATAĞAN	EGESOMA (0,03) YENİKÖY (0,97)	EGESOMA (0,02) YENİKÖY (0,72) SEYİTÖMER (0,26)	EGESOMA (0,04) YENİKÖY (0,96)	EGESOMA (0,01) YENİKÖY (0,06) SEYİTÖMER (0,93)
4	**YENİKÖY**	**5**	**3**	**3**	**3**
5	GARP	EGESOMA (0,45) YENİKÖY (0,55)	EGESOMA (0,56) SEYİTÖMER (0,44)	EGESOMA (0,55) SEYİTÖMER (0,45)	EGESOMA (0,35) SEYİTÖMER (0,65)
6	**ILGIN**	**3**	**2**	**2**	**2**
7	**SEYİTÖMER**	YENİKÖY (0,97) ILGIN (0,03)	**3**	**2**	**3**
8	BURSA	YENİKÖY (0,71) ILGIN (0,29)	YENİKÖY (0,38) ILGIN (0,29) SEYİTÖMER (0,33)	YENİKÖY (0,08) ILGIN (0,38) SEYİTÖMER (0,54)	YENİKÖY (0,34) ILGIN (0,23) SEYİTÖMER (0,43)

Model 2 VRS Super Efficiency Analysis

Model 2 VRS-SE analysis is performed to determine the efficiency ranking of DMUs which are efficient in VRS analysis among themselves.

Efficiency ranking of efficient DMUs for Model 2 based on VRS-SE analysis is given in Table 5.27 and the efficiency ranking of all DMUs for Model 2 based on VRS and VRS-SE analyses is given in Table 5.28 and Figure 5.12 for the years between 2006 to 2009.

Table 5. 27 SE scores of efficient DMUs for Model 2 VRS analysis

		Efficiency Scores			
M2 VRS SE	**DMUs**	**2006**	**2007**	**2008**	**2009**
1	EGESOMA	**57,73**	**51,03**	**49,64**	**50,51**
4	YENİKÖY	**43,54**	**52,31**	**62,34**	**71,87**
6	ILGIN	**BIG**	**BIG**	**BIG**	**BIG**
7	SEYİTÖMER		**80,92**	**84,62**	**80,75**

Table 5. 28 VRS and VRS SE efficiency ranking of DMUs for Model 2

DMUs	2006	DMUs	2007	DMUs	2008	DMUs	2009
ILGIN	**BIG**	ILGIN	**BIG**	ILGIN	**BIG**	ILGIN	**BIG**
YENİKÖY	**43,54**	EGESOMA	**51,03**	EGESOMA	**49,64**	EGESOMA	**50,51**
EGESOMA	**57,73**	YENİKÖY	**52,31**	YENİKÖY	**62,34**	YENİKÖY	**71,87**
GARP	107,11	SEYİTÖMER	**80,92**	SEYİTÖMER	**84,62**	SEYİTÖMER	**80,75**
SEYİTÖMER	119,58	YATAĞAN	122,49	YATAĞAN	121,64	GARP	105,41
ÇAN	145,33	ÇAN	123,80	GARP	132,29	YATAĞAN	133,86
YATAĞAN	147,26	GARP	129,91	ÇAN	159,26	ÇAN	158,01
BURSA	215,56	BURSA	187,55	BURSA	177,56	BURSA	212,04

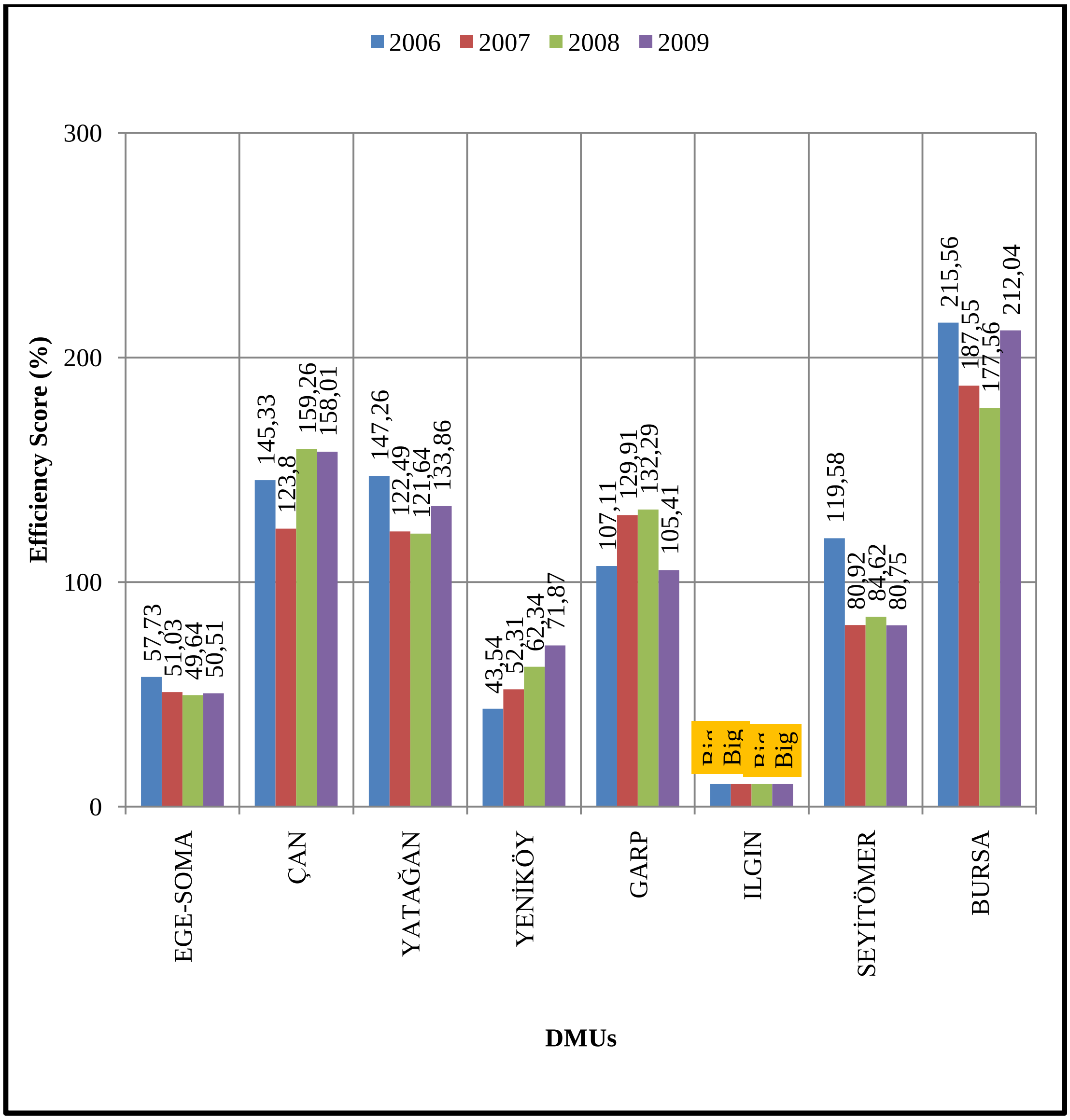


Figure 5. 12 VRS and VRS SE efficiency scores of DMUs for Model 2

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 2 in 2006 is given in Table 5.29.

Table 5. 29 CRS, VRS and SE efficiency scores of DMUs for Model 2 in 2006

		Efficiency Scores			
2006 M2	**DMUs**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	**EGESOMA**	144,86	144,86	**100,00**	**57,73**
2	ÇAN	154,52	154,52	145,33	145,33
3	YATAĞAN	159,78	159,78	147,26	147,26
4	**YENİKÖY**	**100,00**	**58,40**	**100,00**	**43,54**
5	GARP	176,83	176,83	107,11	107,11
6	**ILGIN**	229,65	229,65	**100,00**	**BIG**
7	SEYİTÖMER	119,89	119,89	119,58	119,58
8	BURSA	222,42	222,42	215,56	215,56

According to the analysis results for Model 2 in 2006 EGESOMA, YENİKÖY and ILGIN were efficient in VRS and VRS-SE analyses. YENİKÖY was efficient in all analyses. ÇAN, YATAĞAN, GARP, SEYİTÖMER and BURSA were not efficient in any of the analyses.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2006, the efficiency ranking of DMUs for Model 2 is given in Table 5.30.

Table 5. 30 CRS, VRS and SE efficiency rankings of DMUs for Model 2 in 2006

DMUs	**CRS**	**DMUs**	**CRS SE**	**DMUs**	**VRS**	**DMUs**	**VRS SE**
YENİKÖY	**100,00**	YENİKÖY	**58,40**	EGESOMA	**100,00**	ILGIN	**BIG**
SEYİTÖMER	119,89	SEYİTÖMER	119,89	YENİKÖY	**100,00**	YENİKÖY	**43,54**
EGESOMA	144,86	EGESOMA	144,86	ILGIN	**100,00**	EGESOMA	**57,73**
ÇAN	154,52	ÇAN	154,52	GARP	107,11	GARP	107,11
YATAĞAN	159,78	YATAĞAN	159,78	SEYİTÖMER	119,58	SEYİTÖMER	119,58
GARP	176,83	GARP	176,83	ÇAN	145,33	ÇAN	145,33
BURSA	222,42	BURSA	222,42	YATAĞAN	147,26	YATAĞAN	147,26
ILGIN	229,65	ILGIN	229,65	BURSA	215,56	BURSA	215,56

All analyses results of DMUs for Model 2 in 2006 are shown in Figure 5.13.

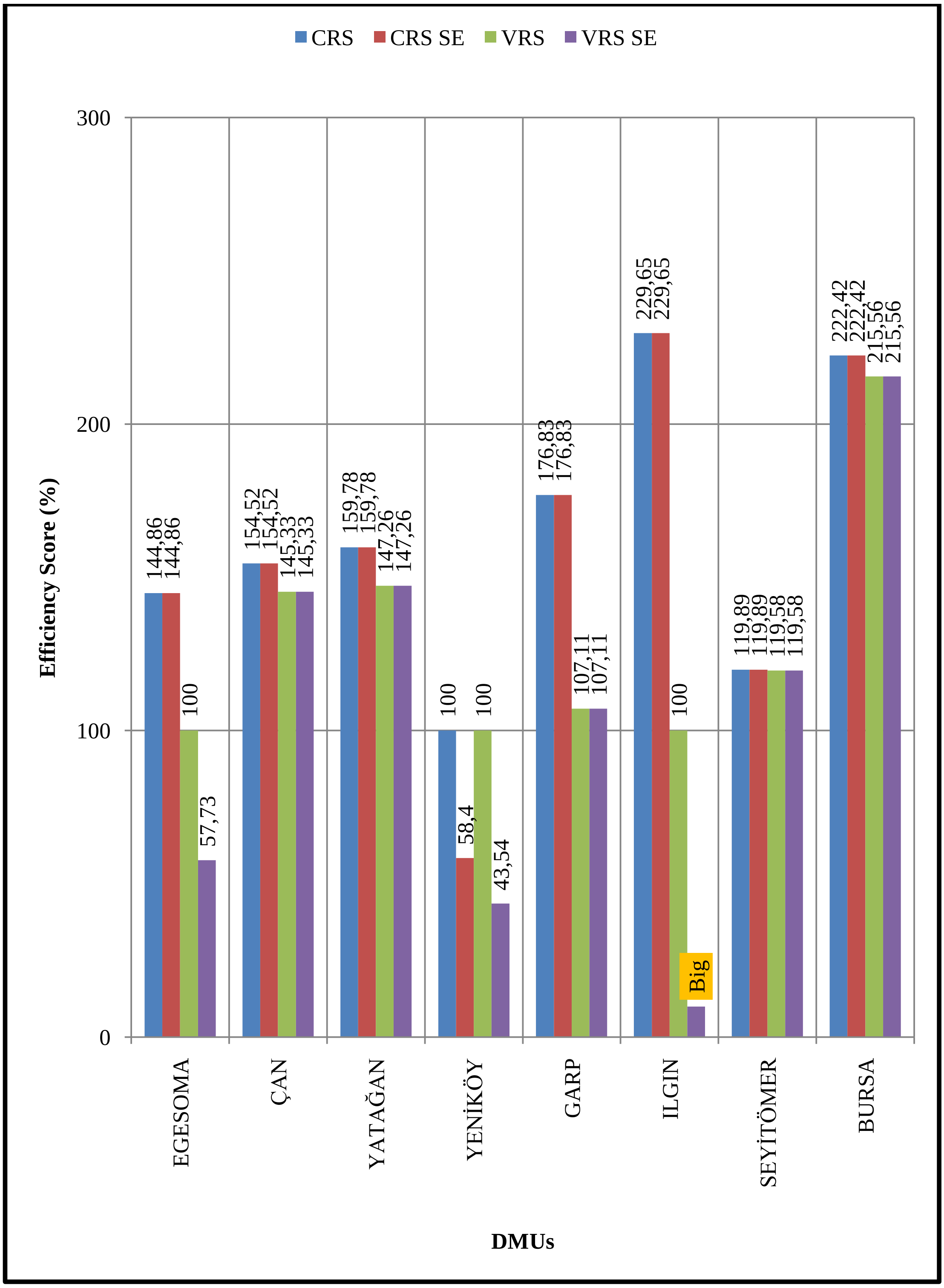


Figure 5. 13 Model 2 CRS, VRS and SE efficiency scores of DMUs (2006)

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 2 in 2007 is given in Table 5.31.

Table 5. 31 CRS, VRS and SE efficiency scores of DMUs for Model 2 in 2007

		Efficiency Scores			
M2	**DMUs**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	**EGESOMA**	112,31	112,31	**100,00**	**51,03**
2	ÇAN	131,81	131,81	123,80	123,80
3	YATAĞAN	124,37	124,37	122,49	122,49
4	**YENİKÖY**	**100,00**	**71,43**	**100,00**	**52,31**
5	GARP	160,54	160,54	129,91	129,91
6	**ILGIN**	335,51	335,51	**100,00**	**BIG**
7	**SEYİTÖMER**	**100,00**	**85,32**	**100,00**	**80,92**
8	BURSA	197,07	197,07	187,55	187,55

According to the results for Model 2 EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient in VRS and VRS-SE analyses. YENİKÖY and SEYİTÖMER were efficient in all analyses. ÇAN, YATAĞAN, GARP and BURSA were not efficient in any of the analyses.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2007, the efficiency ranking of DMUs for Model 2 is given in Table 5.32.

Table 5. 32 CRS, VRS and SE efficiency rankings of DMUs for Model 2 in 2007

DMUs	**CRS**	**DMUs**	**CRS SE**	**DMUs**	**VRS**	**DMUs**	**VRS SE**
YENİKÖY	**100,00**	YENİKÖY	**71,43**	EGESOMA	**100,00**	ILGIN	**BIG**
SEYİTÖMER	**100,00**	SEYİTÖMER	**85,32**	YENİKÖY	**100,00**	EGESOMA	**51,03**
EGESOMA	112,31	EGESOMA	112,31	ILGIN	**100,00**	YENİKÖY	**52,31**
YATAĞAN	124,37	YATAĞAN	124,37	SEYİTÖMER	**100,00**	SEYİTÖMER	**80,92**
ÇAN	131,81	ÇAN	131,81	YATAĞAN	122,49	YATAĞAN	122,49
GARP	160,54	GARP	160,54	ÇAN	123,80	ÇAN	123,80
BURSA	197,07	BURSA	197,07	GARP	129,91	GARP	129,91
ILGIN	335,51	ILGIN	335,51	BURSA	187,55	BURSA	187,55

All the analysis results of DMUs for Model 2 in 2007 are shown in Figure 5.14.

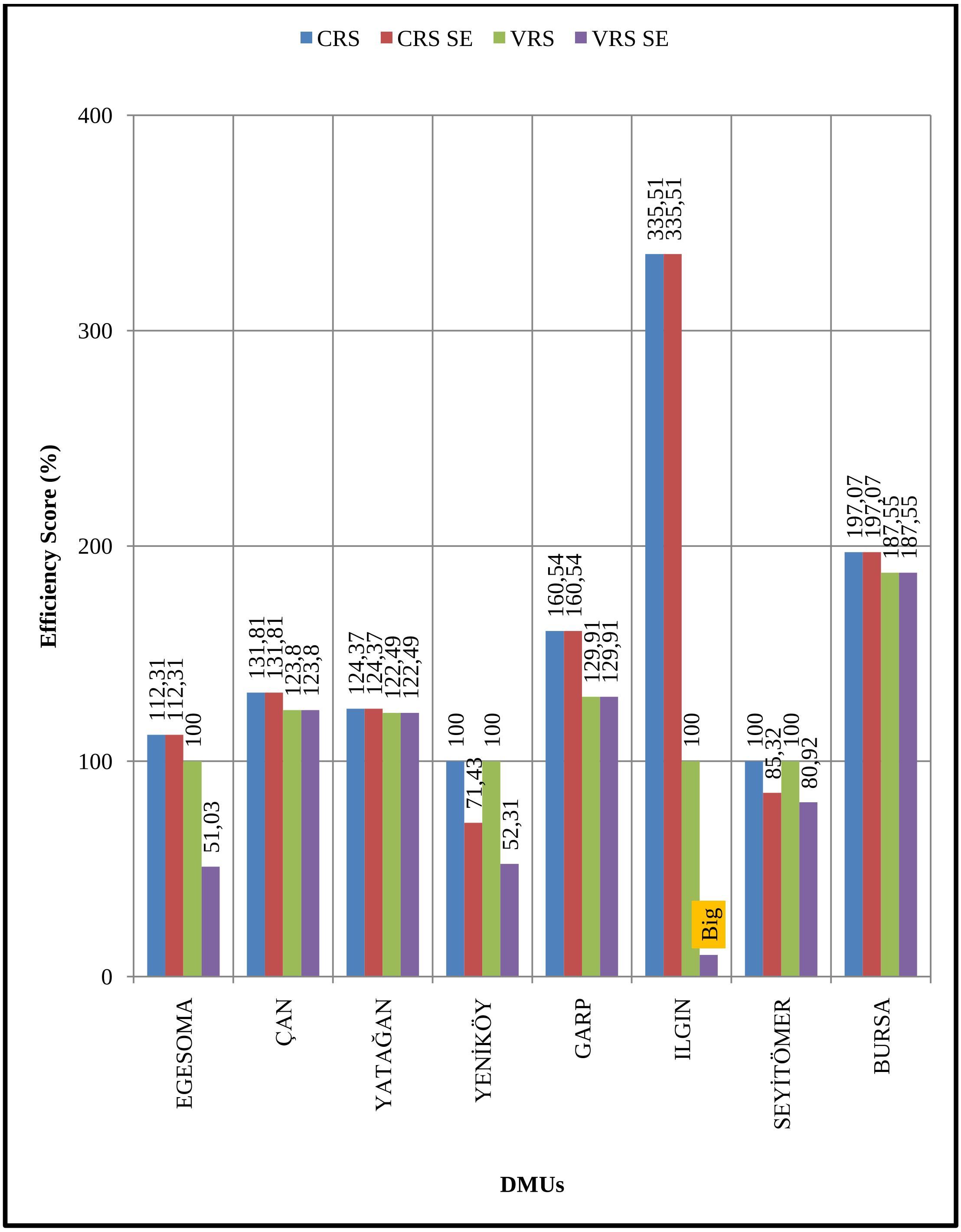


Figure 5. 14 Model 2 CRS, VRS and SE efficiency scores of DMUs (2007)

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 2 in 2008 is given in Table 5.33.

Table 5. 33 CRS, VRS and SE efficiency scores of DMUs for Model 2 in 2008

		Efficiency Scores			
2008 M2	**DMUs**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	**EGESOMA**	**100,00**	**97,60**	**100,00**	**49,64**
2	ÇAN	165,77	165,77	159,26	159,26
3	YATAĞAN	121,87	121,87	121,64	121,64
4	**YENİKÖY**	**100,00**	**77,22**	**100,00**	**62,34**
5	GARP	165,69	165,69	132,29	132,29
6	**ILGIN**	276,75	276,75	**100,00**	**BIG**
7	**SEYİTÖMER**	**100,00**	**85,98**	**100,00**	**84,62**
8	BURSA	188,28	188,28	177,56	177,56

According to the analysis results, EGESOMA, YENİKÖY and SEYİTÖMER were efficient in all types of analyses. ÇAN, YATAĞAN, GARP and BURSA were not efficient in any of the analyses.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2008, the efficiency ranking of DMUs for Model 2 is given in Table 5.34.

Table 5. 34 CRS, VRS and SE efficiency rankings of DMUs for Model 2 in 2008

DMUs	**CRS**	**DMUs**	**CRS SE**	**DMUs**	**VRS**	**DMUs**	**VRS SE**
EGESOMA	**100,00**	YENİKÖY	**77,22**	EGESOMA	**100,00**	ILGIN	**BIG**
YENİKÖY	**100,00**	SEYİTÖMER	**85,98**	YENİKÖY	**100,00**	EGESOMA	**49,64**
SEYİTÖMER	**100,00**	EGESOMA	**97,60**	ILGIN	**100,00**	YENİKÖY	**62,34**
YATAĞAN	121,87	YATAĞAN	121,87	SEYİTÖMER	**100,00**	SEYİTÖMER	**84,62**
GARP	165,69	GARP	165,69	YATAĞAN	121,64	YATAĞAN	121,64
ÇAN	165,77	ÇAN	165,77	GARP	132,29	GARP	132,29
BURSA	188,28	BURSA	188,28	ÇAN	159,26	ÇAN	159,26
ILGIN	276,75	ILGIN	276,75	BURSA	177,56	BURSA	177,56

All analyses results of DMUs for Model 2 in 2008 are shown in Figure 5.15.

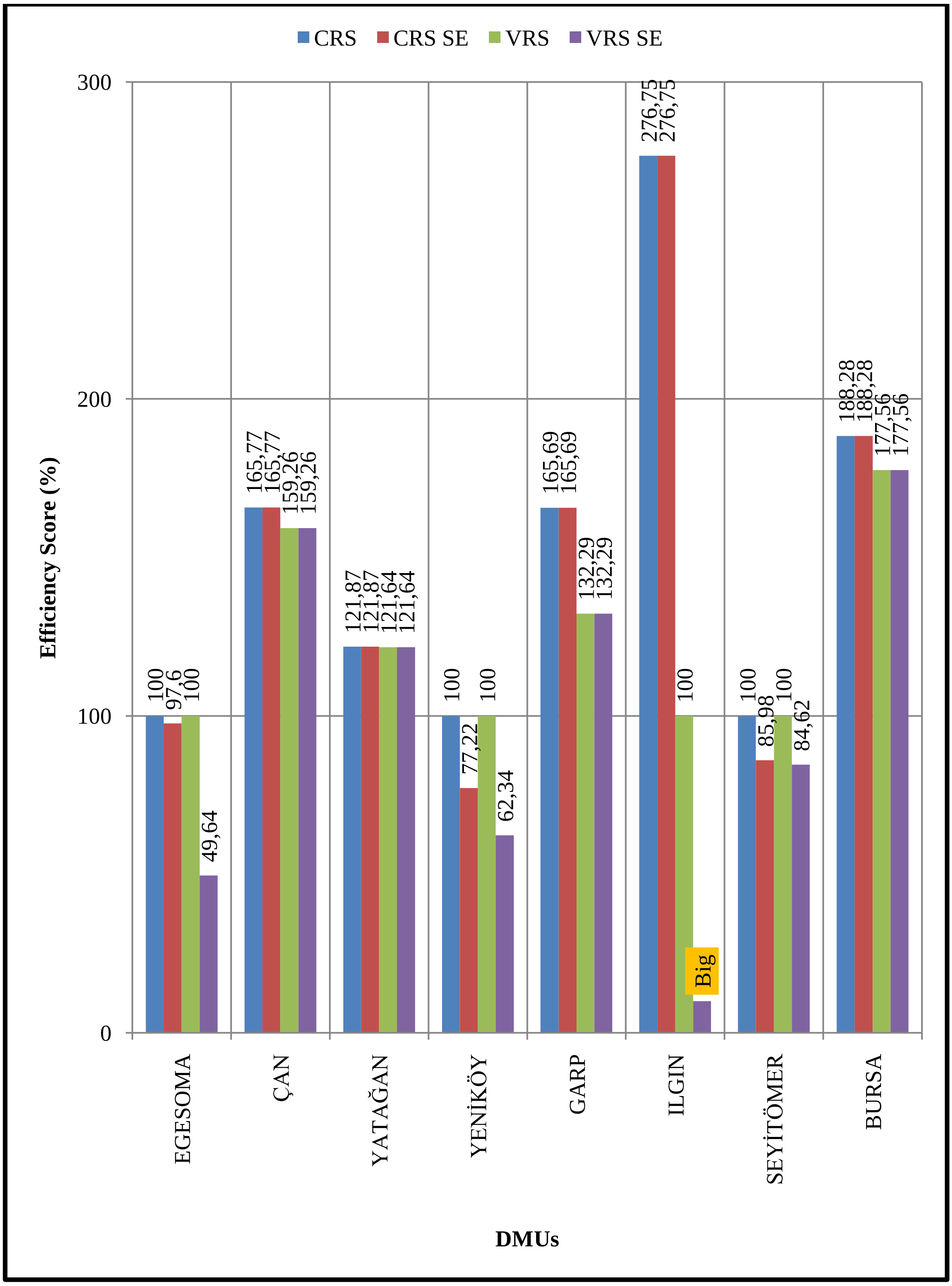


Figure 5. 15 Model 2 CRS, VRS and SE efficiency scores of DMUs (2008)

The summary of CRS, CRS-SE, VRS and VRS-SE analyses results of DMUs for Model 2 in 2009 is given in Table 5.35.

Table 5. 35 CRS, VRS and SE efficiency scores of DMUs for Model 2 in 2009

		Efficiency Scores			
2009 M2	**DMUs**	**CRS**	**CRS SE**	**VRS**	**VRS SE**
1	**EGESOMA**	100,64	100,64	**100,00**	**50,51**
2	ÇAN	159,56	159,56	158,01	158,01
3	YATAĞAN	133,90	133,90	133,86	133,86
4	**YENİKÖY**	**100,00**	**79,78**	**100,00**	**71,87**
5	GARP	159,06	159,06	105,41	105,41
6	ILGIN	213,61	213,61	**100,00**	**BIG**
7	**SEYİTÖMER**	**100,00**	**80,76**	**100,00**	**80,75**
8	BURSA	219,08	219,08	212,04	212,04

According to the analyses results, YENİKÖY and SEYİTÖMER were efficient in all types of the analyses for Model 2 in 2009 while EGESOMA and ILGIN were efficient only in VRS and VRS-SE analyses. ÇAN, YATAĞAN, GARP and BURSA were not efficient in any of the analyses.

Based on the CRS, CRS-SE, VRS and VRS-SE analyses in 2009, the efficiency ranking of DMUs for Model 2 is given in Table 5.36.

Table 5. 36 CRS, VRS and SE efficiency rankings of DMUs for Model 2 in 2009

DMUs	**CRS**	**DMUs**	**CRS SE**	**DMUs**	**VRS**	**DMUs**	**VRS SE**
YENİKÖY	**100,00**	YENİKÖY	**79,78**	EGESOMA	**100,00**	ILGIN	**BIG**
SEYİTÖMER	**100,00**	SEYİTÖMER	**80,76**	YENİKÖY	**100,00**	EGESOMA	**50,51**
EGESOMA	100,64	EGESOMA	100,64	ILGIN	**100,00**	YENİKÖY	**71,87**
YATAĞAN	133,90	YATAĞAN	133,90	SEYİTÖMER	**100,00**	SEYİTÖMER	**80,75**
GARP	159,06	GARP	159,06	GARP	105,41	GARP	105,41
ÇAN	159,56	ÇAN	159,56	YATAĞAN	133,86	YATAĞAN	133,86
ILGIN	213,61	ILGIN	213,61	ÇAN	158,01	ÇAN	158,01
BURSA	219,08	BURSA	219,08	BURSA	212,04	BURSA	212,04

All analysis results of DMUs for Model 2 in 2009 are shown in Figure 5.16.

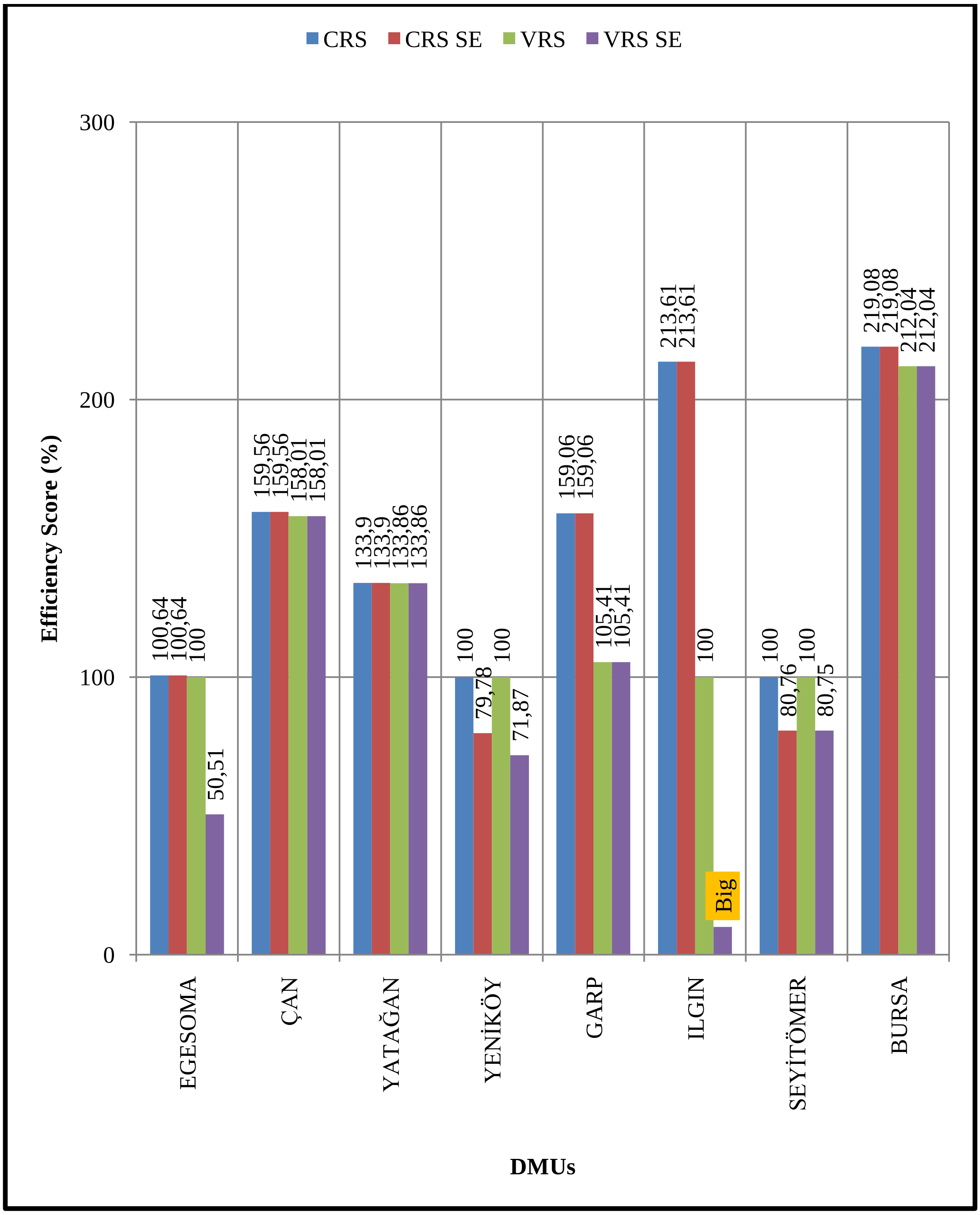


Figure 5. 16 CRS, VRS and SE efficiency scores of DMUs for Model 2 (2009)

5.3.3 Comparisons of Model 1 and Model 2 Analyses Results

Model 1 and Model 2 Comparison for 2006

Comparison of the 2006 CRS and VRS analyses results are given in Table 5.37, Table 5.38, Figure 5.17 and Figure 5.18.

Table 5. 37 CRS efficiencies of DMUs for Model 1 and Model 2 in 2006

2006 CRS	DMUs	M1	M2
1	EGESOMA	405,08	144,86
2	ÇAN	422,50	154,52
3	YATAĞAN	194,39	159,78
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	651,07	176,83
6	ILGIN	443,88	229,65
7	SEYİTÖMER	141,93	119,89
8	BURSA	412,60	222,42

In CRS analysis, only YENİKÖY was efficient for both Model 1 and Model 2 in 2006.

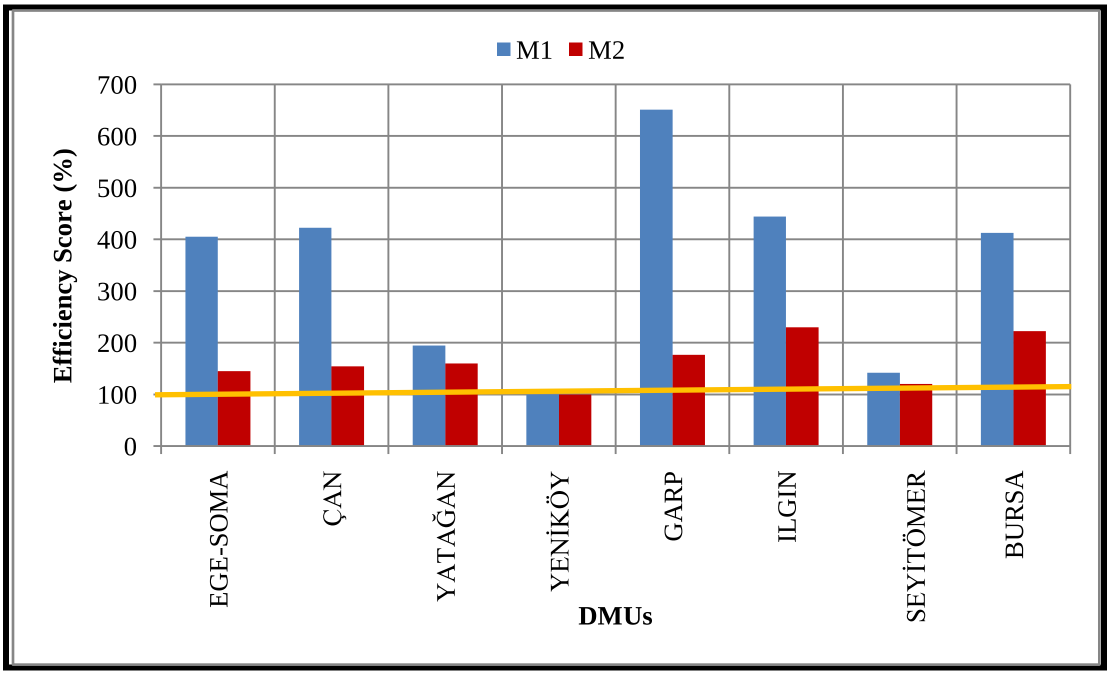


Figure 5. 17 CRS efficiencies of DMUs for Model 1 and Model 2 (2006)

Table 5. 38 VRS efficiencies of DMUs for Model 1 and Model 2 in 2006

2006 VRS	DMUs	M1	M2
1	**EGESOMA**	**100,00**	**100,00**
2	ÇAN	394,11	145,33
3	YATAĞAN	168,55	147,26
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	210,77	107,11
6	ILGIN	**100,00**	**100,00**
7	**SEYİTÖMER**	141,43	119,58
8	BURSA	395,15	215,56

EGESOMA, YENİKÖY and ILGIN were efficient for both Model 1 and Model 2 VRS efficiency analyses in 2006.

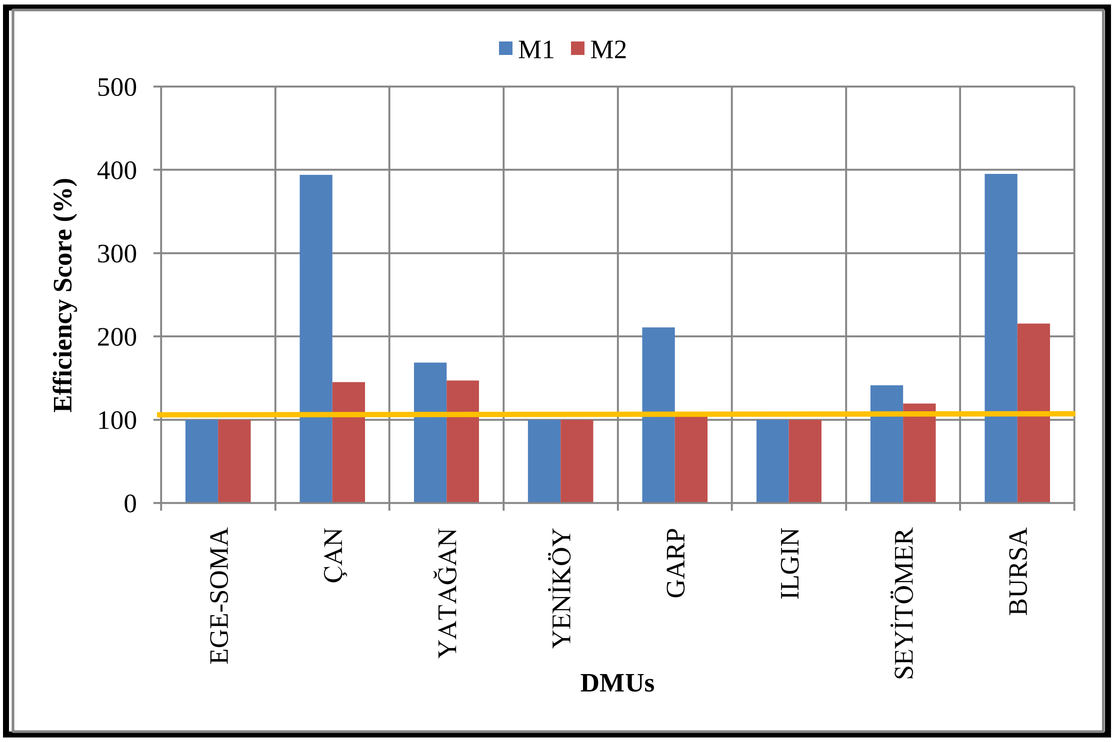


Figure 5. 18 VRS efficiencies of Model 1 and Model 2 (2006)

Model 1 and Model 2 Comparison for 2007

Comparison of the 2007 CRS and VRS analyses results are given in Table 5.39, Table 5.40, Figure 5.19 and Figure 5.20.

Table 5. 39 CRS efficiencies of DMUs for Model 1 and Model 2 in 2007

2007 CRS	DMUs	M1	M2
1	EGESOMA	286,02	112,31
2	ÇAN	273,47	131,81
3	YATAĞAN	158,55	124,37
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	534,31	160,54
6	ILGIN	1357,64	335,51
7	**SEYİTÖMER**	**100,00**	**100,00**
8	BURSA	297,39	197,07

YENİKÖY and SEYİTÖMER were efficient in both Model 1 and Model 2 in CRS efficiency analysis.

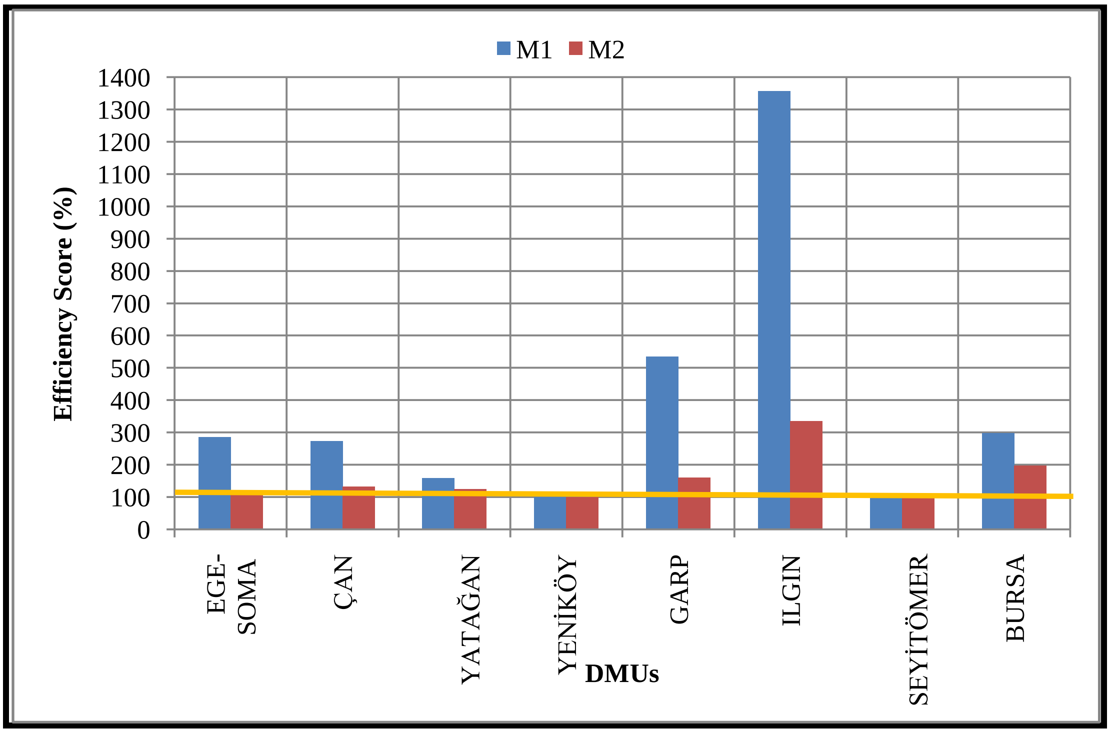


Figure 5. 19 CRS efficiencies of DMUs for Model 1 and Model 2 (2007)

Table 5. 40 VRS efficiencies of DMUs for Model 1 and Model 2 in 2007

2007 VRS	DMUs	M1	M2
1	**EGESOMA**	**100,00**	**100,00**
2	ÇAN	253,80	123,80
3	YATAĞAN	157	122,49
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	225,37	129,91
6	**ILGIN**	**100,00**	**100,00**
7	**SEYİTÖMER**	**100,00**	**100,00**
8	BURSA	278,56	187,55

EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient in both Model 1 and Model 2 in VRS analyses results.

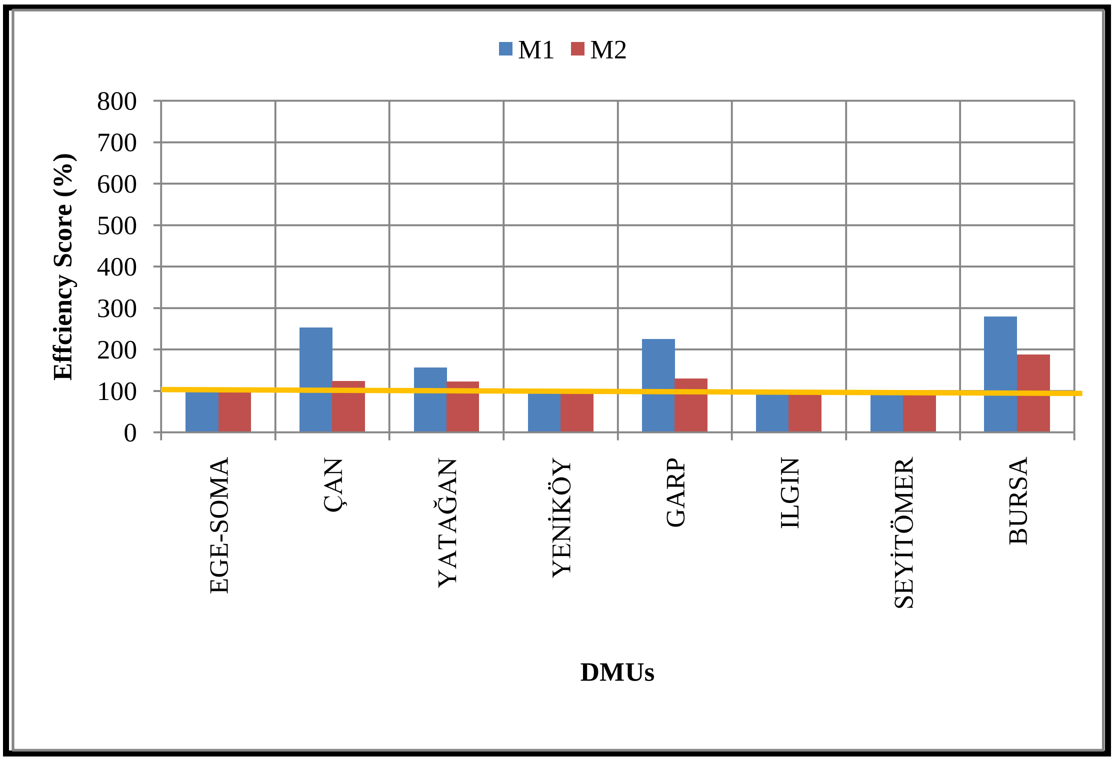


Figure 5. 20 VRS efficiencies of Model 1 and Model 2 (2007)

Model 1 and Model 2 Comparison for 2008

Comparison of the 2008CRS and VRS analyses results are given in Table 5.41, Table 5.42, Figure 5.21 and Figure 5.22.

Table 5. 41 CRS Efficiencies of DMUs for Model 1 and Model 2 in 2008

2008 CRS	DMUs	M1	M2
1	EGESOMA	266,27	100,00
2	ÇAN	325,20	165,77
3	YATAĞAN	153,25	121,87
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	593,09	165,69
6	ILGIN	626,11	276,75
7	**SEYİTÖMER**	**100,00**	**100,00**
8	BURSA	281,25	188,28

YENİKÖY and SEYİTÖMER were efficient in both Model 1 and Model 2 in CRS efficiency analyses in 2008.

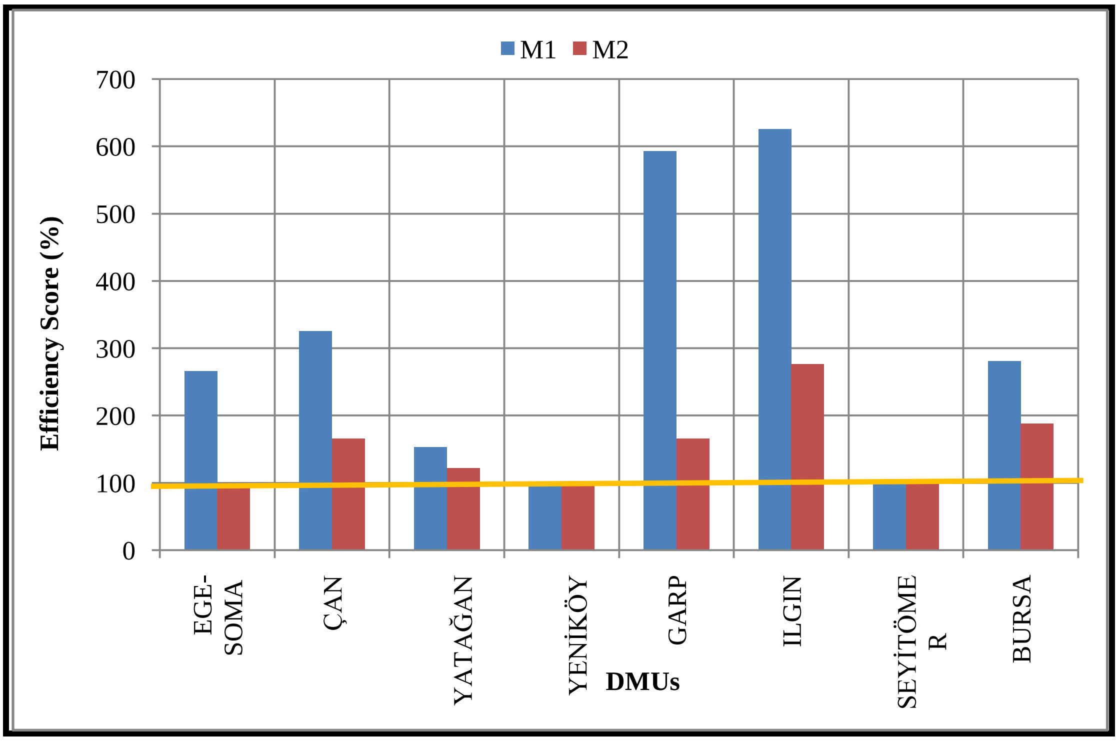


Figure 5. 21 CRS efficiencies of DMUs for Model 1 and Model 2 (2008)

Table 5. 42 VRS efficiencies of DMUs for Model 1 and Model 2 in 2008

2008 VRS	DMUs	M1	M2
1	**EGESOMA**	**100,00**	**100,00**
2	ÇAN	310,92	159,26
3	YATAĞAN	139,67	121,64
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	226,65	132,29
6	**ILGIN**	**100,00**	**100,00**
7	**SEYİTÖMER**	**100,00**	**100,00**
8	BURSA	261,87	177,56

EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient in both Model 1 and Model 2 in 2008.

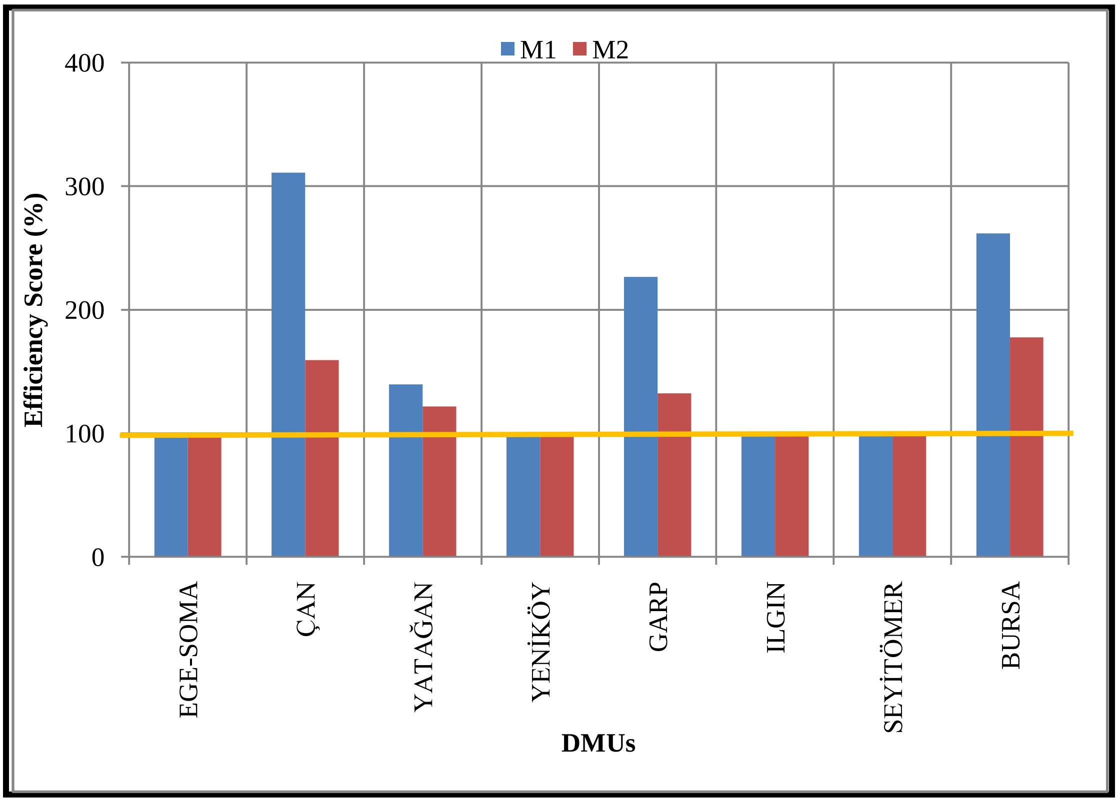


Figure 5. 22 VRS efficiencies of Model 1 and Model 2 (2008)

Model 1 and Model 2 Comparison for 2009

Comparison of the 2009 CRS and VRS analyses results are given in Table 5.43, Table 5.44, Figure 5.23 and Figure 5.24.

Table 5. 43 CRS efficiencies of DMUs for Model 1 and Model 2 in 2009

2009 CRS	DMUs	M1	M2
1	EGESOMA	281,44	100,64
2	ÇAN	324,52	159,56
3	YATAĞAN	159,02	133,90
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	566,03	159,06
6	ILGIN	524,57	213,61
7	**SEYİTÖMER**	**100,00**	**100,00**
8	BURSA	346,76	219,08

YENİKÖY and SEYİTÖMER were efficient in both Model 1 and Model 2 in CRS efficiency analyses in 2009.

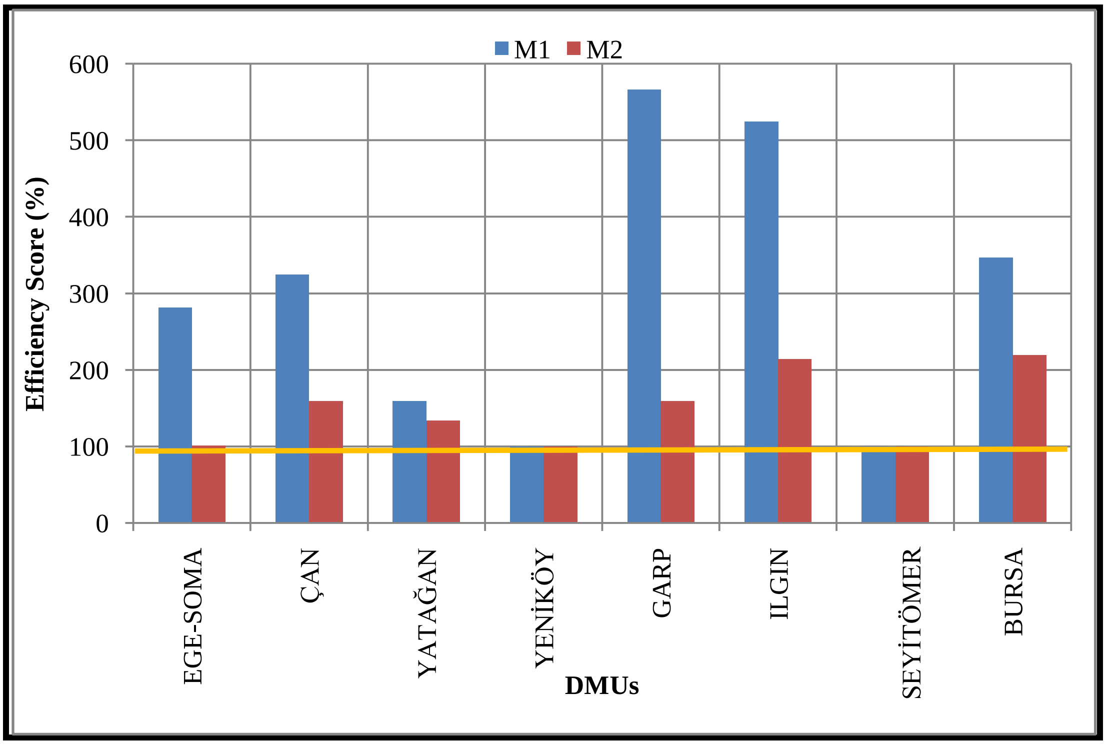


Figure 5. 23 CRS efficiencies of DMUs for Model 1 and Model 2 (2009)

Table 5. 44 VRS efficiencies of DMUs for Model 1 and Model 2 in 2009

2009 VRS	DMUs	M1	M2
1	**EGESOMA**	**100,00**	**100,00**
2	ÇAN	320,23	158,01
3	YATAĞAN	154,72	133,86
4	**YENİKÖY**	**100,00**	**100,00**
5	GARP	217,28	105,41
6	**ILGIN**	**100,00**	**100,00**
7	**SEYİTÖMER**	**100,00**	**100,00**
8	BURSA	329,70	212,04

EGESOMA, YENİKÖY, ILGIN and SEYİTÖMER were efficient in both Model 1 and Model 2 VRS analyses in 2009.

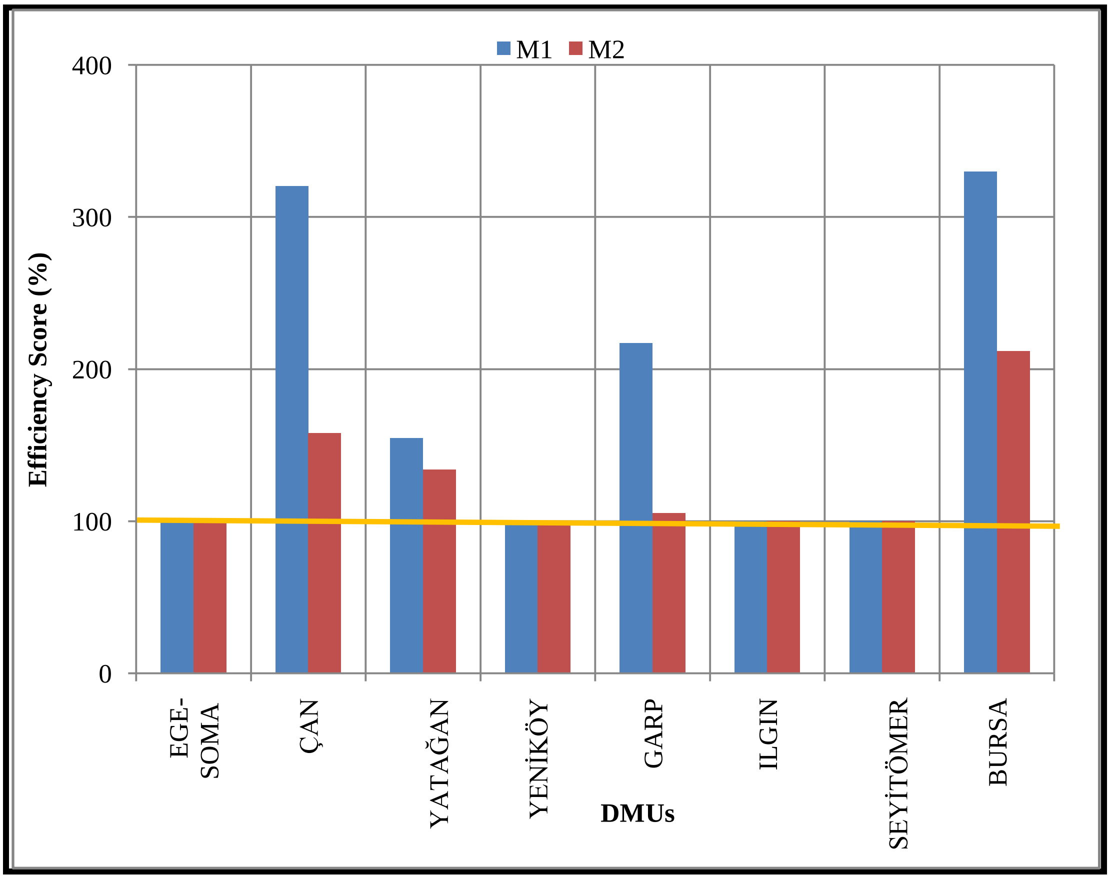


Figure 5. 24 VRS efficiencies of Model 1 and Model 2 (2009)

5.3.4 Target values and improvement potential for inefficient establishments

In this section, the target values and improvement potential of inputs and outputs used in the production process are calculated to provide suggestions and recommendations to the inefficient DMUs regarding how to become efficient.

In calculating the target values and improvement potential of inputs and outputs of the establishments, the 2009 input and output values are taken as references, and CRS analysis results and and the benchmarks stemming from CRS analysis of Model 1 are used in the calculations.

The reason for taking 2009 input and output values as the reference or base is simple. Suggestions should be for the future years which have not been realized yet, and any suggestion to the establishments for future operations should be based on their last available and realized data. In this sense, 2009 is their last year of operation in the analysis period of 2006-2009.

The reason for using CRS analysis results is hidden in the natures of CRS and VRS methodologies. Compared to VRS, CRS is more conservative. In transforming inputs to outputs, depending on the number of inputs and outputs, more than one interrelationship occurs among inputs and outputs in the production process. Based on this, there is more than one condition or criteria to be satisfied for a DMU to become efficient. In VRS analysis, meeting pure technical efficiency condition is enough to assume a DMU as efficient, whereas pure technical and scale efficient together must be satisfied in CRS analysis. In other words, while in VRS analysis scale inefficient DMUs could be efficient, in order to be accepted as efficient DMUs must also be scale efficient in CRS analysis. Operating at appropriate scales are important for TKİ establishments' efficiency assessments, and it should not be ignored. Suggestions to the management of DMUs for further improvements in their operations should be comprehensive, and therefore based on CRS analysis results.

The target values and potential improvements are calculated in an Excel software by using the benchmarks and 2009 values of inputs and outputs of establishments.

Benchmarks are produced by EMP 1.30 software as a result of CRS analyses. In the benchmarks tables, in rows where inefficient DMUs are placed under the first column, the name or the order number of efficient DMUs and a coefficient in the parenthesis (for example YENİKÖY (4,70) or 4 (4,70)) are found for every year under the columns of years. Coefficients are generated by the software as a result of the analyses, and used in calculating the target values and improvement potentials for the inefficient establishments to move to becoming efficient. In rows where efficient DMUs are placed under the first column, numbers (also marked with *) are found for every year under the columns of years. Those numbers show how many inefficient DMUs take this efficient DMU as reference to move to becoming efficient.

The last important note is that some target values calculated may be seen as too big and may not be achievable for some establishments due to the limits in the project implemented in these establishments. Therefore, target values and potential improvement rates should be taken as the sign of improvement magnitude needed for inefficient DMUs to become efficient, and any improvement in the actual values towards the target values will help the establishments to become more efficient that before. In other words, for an inefficient establishment, the more progress it makes towards the target values, the more efficient it will become.

Model 1: Production Efficiency

According to the CRS analysis results of Model 1, the benchmarks for inefficient establishments, and target values and potential improvements of the inputs and outputs of those inefficient establishments are given in Table 5.45.

EGESOMA should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. As seen in Table 5.45, EGESOMA should decrease its operating expenses (up to 38,2%) and increase saleable production (up to 181,6%) while keeping the number of employees and investment expenses at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

ÇAN should take YENİKÖY as a benchmark and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. ÇAN should decrease investment expenses (up to 23,7%) and operating expenses (up to 16,4), and increase saleable production (up to 225,6%) while keeping the number of employees at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

YATAĞAN should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. YATAĞAN should decrease operating expenses (up to 26%) and increase saleable production (up to 59,1%) while keeping the number of employees and investment expenses at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

Because YENİKÖY and SEYİTÖMER were efficient, there are no benchmarks, target values or potential improvements for them.

GARP should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. GARP should decrease investment expenses (up to 22,3%) and increase saleable production (up to 466%) while keeping the number of employees and operating expenses at 2009 levels.

The more it makes progress in this direction, the more it will become efficient.

ILGIN should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. ILGIN should decrease its number of employees (up to 2,1%), operating expenses (up to 1,7%) and investment expenses (up to 51,9%), and increase saleable production (up to 415%). The more it makes progress in this direction, the more it will become efficient.

BURSA should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. BURSA should decrease investment expenses (up to 36,9%), and increase saleable production (up to 245%) while keeping the number of employees and operating expenses at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

Table 5. 45 Target values and improvement potentialS for establishments (Model 1)

	2009	2009 Values					Target Values				Improvement Potentials			
		O	I_1	I_2	I_3		O	I_1	I_2	I_3	Change %			
	DMUs	SP (ton)	NE (Number)	IE (TL)	OE (TL)	Benchmarks	SP (ton)	NE (Number)	IE (TL)	OE (TL)	SP (ton)	NE (Number)	IE (TL)	OE (TL)
1	EGESOMA	8852555	2298	51852888	731149343	YENİKÖY (3,64) SEYİTÖMER (0,64)	24933494	2299,9	51891802	451848022	181,65	0,08	0,08	-38,20
2	ÇAN	1694648	462	15115809	122571715	YENİKÖY (0,97)	5519229	463,6	11532238	102400358	225,69	0,36	-23,71	-16,46
3	YATAĞAN	4255164	869	13837037	148495572	YENİKÖY (0,10) SEYİTÖMER (0,94)	6770289	870,3	13843917	109818921	59,11	0,15	0,05	-26,05
4	YENİKÖY	5689927	478	11888905	105567379	6*								
5	GARP	3398862	2243	50908148	324111850	YENİKÖY (1,12) SEYİTÖMER (1,95)	19237110	2241,6	39568022	324151695	465,99	-0,06	-22,28	0,01
6	ILGIN	260796	148	5761733	23649900	YENİKÖY (0,12) SEYİTÖMER (0,10)	1342504	144,8	2772948	23227892	414,77	-2,12	-51,87	-1,78
7	SEYİTÖMER	6597124	875	13462794	105598067	5*								
8	BURSA	1470955	574	16577917	87014310	YENİKÖY (0,37) SEYİTÖMER (0,45)	5073979	570,6	10457152	86579060	244,94	-0,59	-36,92	-0,5

Model 2: Revenue Efficiency

According to the CRS analysis results of Model 1, the benchmarks for inefficient establishments, and target values and potential improvements of the inputs and outputs of those inefficient establishments are given in Table 5.46.

EGESOMA should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. As seen in Table 5.46, EGESOMA should decrease its operating expenses (up to 38,2) and increase revenues (up to 0,7%) while keeping the number of employees and investment expenses at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

ÇAN should take YENİKÖY as a benchmark and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. ÇAN should decrease investment expenses (up to 23,7%) and operating expenses (up to 16,5), and increase revenues (up to 60%) while keeping the number of employees at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

YATAĞAN should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. YATAĞAN should decrease operating expenses (up to 26%) and increase revenues (up to 34%) while keeping the number of employees and investment expenses at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

Because YENİKÖYand SEYİTÖMER were efficient, there are no benchmarks, target values or potential improvements for them.

GARP should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. GARP should decrease investment expenses (up to 22,3%) and increase revenues (up to 59%) while keeping the number of employees and operating expenses at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

ILGIN should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. ILGIN should decrease the number of employees (up to 2,1%), operating expenses (up to 1,8%) and investment expenses (up to 51,9%), and increase revenues (up to 109,5%). The more it makes progress in this direction, the more it will become efficient.

BURSA should take YENİKÖY and SEYİTÖMER as benchmarks and reorganize its input and output values accordingly in order to reach the efficient frontier and become efficient. BURSA should decrease investment expenses (up to 36,9%), and increase revenues (up to 117,9%) while keeping the number of employees and operating expenses almost at 2009 levels. The more it makes progress in this direction, the more it will become efficient.

Table 5. 46 Target values and improvement potentials for establishments (Model 2)

	2009	2009 Values					Target Values				Improvement Potentials			
		O	I_1	I_2	I_3		O	I_1	I_2	I_3	Change %			
	DMUs	SR (TL)	NE (Number)	IE (TL)	OE (TL)	Benchmarks	SR (TL)	NE (Number)	IE (TL)	OE (TL)	SR (TL)	NE (Number)	IE (TL)	OE (TL)
1	EGESOMA	826489437	2298	51852888	731149343	YENİKÖY (3,64) SEYİTÖMER (0,64)	832436040	2299,9	51891802	451848022	0,7	0,1	0,1	-38,2
2	ÇAN	113757532	462	15115809	122571715	YENİKÖY (0,97)	182158909	463,6	11532238	102400357	60,1	0,4	-23,7	-16,5
3	YATAĞAN	177200521	869	13837037	148495572	YENİKÖY (0,10) SEYİTÖMER (0,94)	237433034	870,3	13843917	109818921	34,0	0,1	0,0	-26,0
4	YENİKÖY	187792690	478	11888905	105567379	6*								
5	GARP	417461635	2243	50908148	324111850	YENİKÖY (1,12) SEYİTÖMER (1,95)	663918069	2241,6	39568022	324151695	59,0	-0,1	-22,3	0,0
6	ILGIN	21855839	148	5761733	23649900	YENİKÖY (0,12) SEYİTÖMER (0,10)	45796162	144,8	2772948	23227892	109,5	-2,1	-51,9	-1,8
7	SEYİTÖMER	232610388	875	13462794	105598067	5*								
8	BURSA	79919993	574	16577917	87014310	YENİKÖY (0,37) SEYİTÖMER (0,45)	174157969	570,6	10457152	86579060	117,9	-0,6	-36,9	-0,5

5.4 MALMQUIST INDEX (MI) ANALYSES

In this section, efficiency and total factor productivity analysis of the 3 models (Production Efficiency, Revenue Efficiency and Work Safety Efficiency Models) are performed by using MI methodology. In the analysis using MI methodology, the changes in Technical Efficiency (EFFCH), Technologic Efficiency (TECHCH), Pure Efficiency (PECH), Scale Efficiency (SECH) and Total Factor Productivity (TFPCH) of eight establishments are calculated for the years 2006 to 2009.

In the tables and graphs showing MI analysis results, yellow shows the DMUs whose efficiencies and/or Total Factor Productivities did not change, and bold character the DMUs whose efficiencies and/or Total Factor Productivities improved. Normal character shows the DMUs whose efficiencies and/or Total Factor Productivities became worst in comparison to the previous year. Light blue is used to mark the geometric means of the values. In the same manner, the value "1" shows no change in the efficiencies and/or Total Factor Productivities of DMUs, while values lower than "1" shows those that became worst, and values greater than "1" showing improvement, again with respect to the previous year.

As explained in Chapter 4, MI methodology produces indexes for measuring the efficiency and/or total factor productivity of DMUs with respect to the previous year. In this study 4 years (2006, 2007, 2008, 2009) are included into the analysis. Therefore, for year 2006, the index values cannot be calculated because there is no any data of previous year. Within this context, there are 3 periods (2007, 2008, and 2009) whose indexes can be calculated by using MI methodology. In other words, the indexes for period 1 (2007) show the changes in efficiencies and TFP between 2006-2007, the indexes for period 2 (2008) show the changes in efficiencies and TFP between 2007-2008, and the indexes for period 3 (2009) show the changes in efficiencies and TFP between 2008-2009.

5.4.1 Malmquist Index Model 1: Production Efficiency Analysis

For Model 1, Technical Efficiency (EFFCH), Technologic Efficiency (TECHCH), Pure Efficiency (PECH), Scale Efficiency (SECH) and Total Factor Productivity (TFPCH) changes of DMUs with respect to previous year and geometric means for each year is given in Table 5.47, Table 5.48 and Table 5.49.

Table 5. 47 Changes of efficiencies and TFP of DMUs for Model 1 in 2007

2007	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**1,42**	0,80	1,00	**1,42**	**1,14**
ÇAN	**1,55**	**1,01**	**1,55**	1,00	**1,56**
YATAĞAN	**1,23**	0,77	**1,07**	**1,14**	0,94
YENİKÖY	1,00	0,88	1,00	1,00	0,88
GARP	**1,22**	0,77	0,94	**1,30**	0,93
ILGIN	0,33	0,80	1,00	0,33	0,26
SEYİTÖMER	**1,42**	0,81	**1,41**	1,00	**1,15**
BURSA	**1,39**	0,79	**1,42**	0,98	**1,09**
Means	**1,10**	**0,82**	**1,15**	**0,95**	**0,94**

Table 5. 48 Changes of efficiencies and TFP of DMUs For Model 1 in 2008

2008	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**1,07**	**1,02**	1,00	**1,07**	**1,09**
ÇAN	0,84	**1,33**	0,82	**1,03**	**1,12**
YATAĞAN	**1,04**	**1,11**	**1,12**	0,92	**1,15**
YENİKÖY	1,00	**1,16**	1,00	1,00	**1,16**
GARP	0,90	**1,11**	0,99	0,91	1,00
ILGIN	**2,17**	**1,17**	1,00	**2,17**	**2,53**
SEYİTÖMER	1,00	**1,16**	1,00	1,00	**1,16**
BURSA	**1,06**	**1,18**	**1,06**	0,99	**1,25**
Means	**1,09**	**1,15**	**1,00**	**1,09**	**1,25**

Table 5. 49 Changes of efficiencies and TFP of DMUs for Model 1 in 2009

2009	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	0,95	0,84	1,00	0,95	0,79
ÇAN	1,00	0,83	0,97	**1,03**	0,84
YATAĞAN	0,96	0,85	0,90	**1,07**	0,82
YENİKÖY	1,00	0,89	1,00	1,00	0,89
GARP	**1,05**	0,94	**1,04**	1,00	0,98
ILGIN	**1,19**	**1,03**	1,00	**1,19**	**1,23**
SEYİTÖMER	1,00	**1,06**	1,00	1,00	**1,06**
BURSA	0,81	**1,02**	0,79	**1,02**	0,83
Means	**0,99**	**0,93**	**0,96**	**1,03**	**0,92**

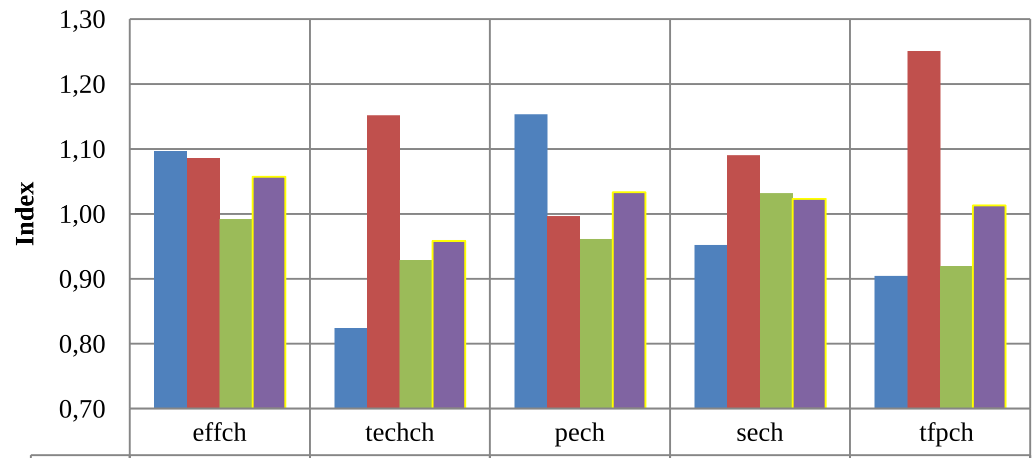
The value lower than 1 for technical and technologic efficiencies which are the components of Total Factor Productivity means getting worst in technical and technologic efficiencies, while the value higher than 1 for Technical and technologic efficiencies means getting better in technical and technologic efficiencies. A technical efficiency value greater than 1 shows that the DMU catches the efficient production frontier, and the technologic efficiency value greater than 1 shows that the efficient production frontier shifts upward. When change in the Pure efficiency and the scale efficiency which are the components of technical efficiency is greater than 1, this shows that the DMU is operating at efficient management and scale.

The means of the efficiency change values of the each DMU in each year (2007, 2008 and 2009) are given in Table 5.47, Table 5.48 and Table 5.49. The geometric means of the efficiency changes of all DMUs in 2007, 2008 and 2009 are given in Table 5.50.

Table 5. 50 Efficiency and TFP Changes of DMUs for Model 1

	EFFCH	TECHCH	PECH	SECH	TFPCH
2007	**1,10**	0,82	**1,15**	0,95	0,90
2008	**1,09**	**1,15**	1,00	**1,09**	**1,25**
2009	0,99	0,93	0,96	**1,03**	0,92
Means	**1,06**	**0,96**	**1,03**	**1,02**	**1,01**

The graphical presentation of the efficiency changes and total factor productivity change with time dimension is shown Figure 5.25 and Figure 5.26.



	effch	techch	pech	sech	tfpch
2007	1,10	0,82	1,15	0,95	0,90
2008	1,09	1,15	1,00	1,09	1,25
2009	0,99	0,93	0,96	1,03	0,92
mean	1,06	0,96	1,03	1,02	1,01

Figure 5. 25 Changes of efficiencies and TFP for Model 1

	2007	2008	2009
effch	1,10	1,09	0,99
techch	0,82	1,15	0,93
pech	1,15	1,00	0,96
sech	0,95	1,09	1,03
tfpch	0,90	1,25	0,92

Figure 5. 26 Changes of efficiencies and TFP for Model 1

Malmquist Total Factor Productivity Index and its components are shown in Figure 5.25 and Figure 5.26 for the periods between 2006 to 2009. Furthermore, by analyzing every period individually, the reasons for increases or decreases in TFP are explained. The results can be summarized as follows:

- During the periods of analysis (2007, 2008, 2009), it is observed that there has been a noticeable decrease in the means of technical efficiencies of the establishments. The means of technical efficiencies of the establishments dropped to 1,09 in 2008 and 0,99 in 2009 from 1,10 in 2007. However, despite those drops, the means of the three periods has been realized as 1,06. This means that eight establishments as a group improved their technical efficiency by 6% between 2006-2009.
- In 2008, there was 25% increase in TFP index. The reasons for this positive development were 9% improvement in technical efficiency and 15% improvement in technological efficiency. The contribution to the increase in technical efficiency index came from the 9% increase in scale efficiency index which is sign of DMUs operating at appropriate scale.
- The means of total factor productivity change was lowest in 2007. There was 10% loss in average total factor productivity in 2007 compared to 2006. In this period, the positive development in the input-output compositions of DMUs, in other words increases in technical efficiency when technical efficiencies of DMUs were at highest level in 2007 could not prevent total factor productivity index from decrease.
- The fact that technological efficiency was showing negative signals in 2007 shows that the input-output composition in the production processes of DMUs were changing in negative way. With the negative effect of technological efficiency, efficient production frontier could not be shifted upward. The increase in technical efficiency, which has a positive contribution to TFP index, is important. While the increase in pure technical efficiency is contributing to TFP index in positive manner, the decrease in scale efficiency is affecting negatively.
- Although DMUs could not operate at appropriate scale in 2007, there were increases in scale efficiency changes of DMUs in 2008 and 2009. This positive development contributed positively (9% in 2008 and 3% in 2009) to technical efficiency.
- 2009 was the only year when the pure efficiency dropped. There was 4% loss in the pure efficiencies (a sign of managerial efficiency) of DMUs.

- TFP, technological efficiency and scale efficiency index reached maximum level in 2008.
- %1 increase in the total factor productivity of all DMUs is observed between 2006 to 2009. The losses in TFP index in 2007 and 2009 could not prevent %1 increase in TFP of all DMUs in the period between 2006 to 2009. Although there was an increase in TFP in this period, 4% decrease in technological efficiencies of DMUs was observed. During this period the positive developments in managerial efficiency and scale efficiency contributed to the technical efficiency positively, and this then provided increase in TFP
- In 2007 while there was 10% increase in means of technical efficiency, the biggest increase was in ÇAN (55% increase), and the biggest decrease was in ILGIN (67% decrease). There was no change in technical efficiency level of YENİKÖY. The technical efficiency index of SEYİTÖMER dropped to 1 in 2008 and 2009, from 1,42 in 2007. In other words, although there was no change in technical efficiency of SEYİTÖMER in 2008 and 2009, there was decrease comparing to 2007.
- The average technological efficiencies of establishments are also given above in tables and graphs. The positive developments (15% increase) in technological efficiency (or the positive developments regarding factors affecting production processes which affects the efficiency) was realized only in 2008. In 2007 and 2009 the establishments could not shift their production frontier upward, and therefore there were losses in technological efficiencies in those years.
- The biggest loss was 18% in 2007. In 2007, ÇAN was the only establishment which showed a 1% increase in change technological efficiency.
- In the analysis period, the maximum positive change in technological efficiency was observed in ÇAN with 33% increase in 2008. The lowest negative change during the analysis period in technological efficiency was in GARP, and YATAĞAN with 23% decrease in 2007.

The geometric means of the technical, technologic, pure and scale efficiencies and the geometric means of total factor productivity (index) of the DMUs for all the periods are calculated and given in Table 5.51, and shown in Figure 5.27 and Figure 5.28.

Table 5. 51 Efficiencies and TFP of DMUs for Model 1

	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**1,13**	0,88	1,00	**1,13**	0,99
ÇAN	**1,09**	**1,04**	**1,07**	**1,02**	**1,13**
YATAĞAN	**1,07**	0,90	1,03	**1,04**	0,96
YENİKÖY	1,00	0,97	1,00	1,00	0,97
GARP	**1,05**	0,93	0,99	**1,06**	0,97
ILGIN	0,95	0,99	1,00	0,95	0,93
SEYİTÖMER	**1,12**	1,00	**1,12**	1,00	**1,12**
BURSA	**1,06**	0,98	**1,06**	1,00	**1,04**
Mean	**1,06**	**0,96**	**1,03**	**1,02**	**1,01**

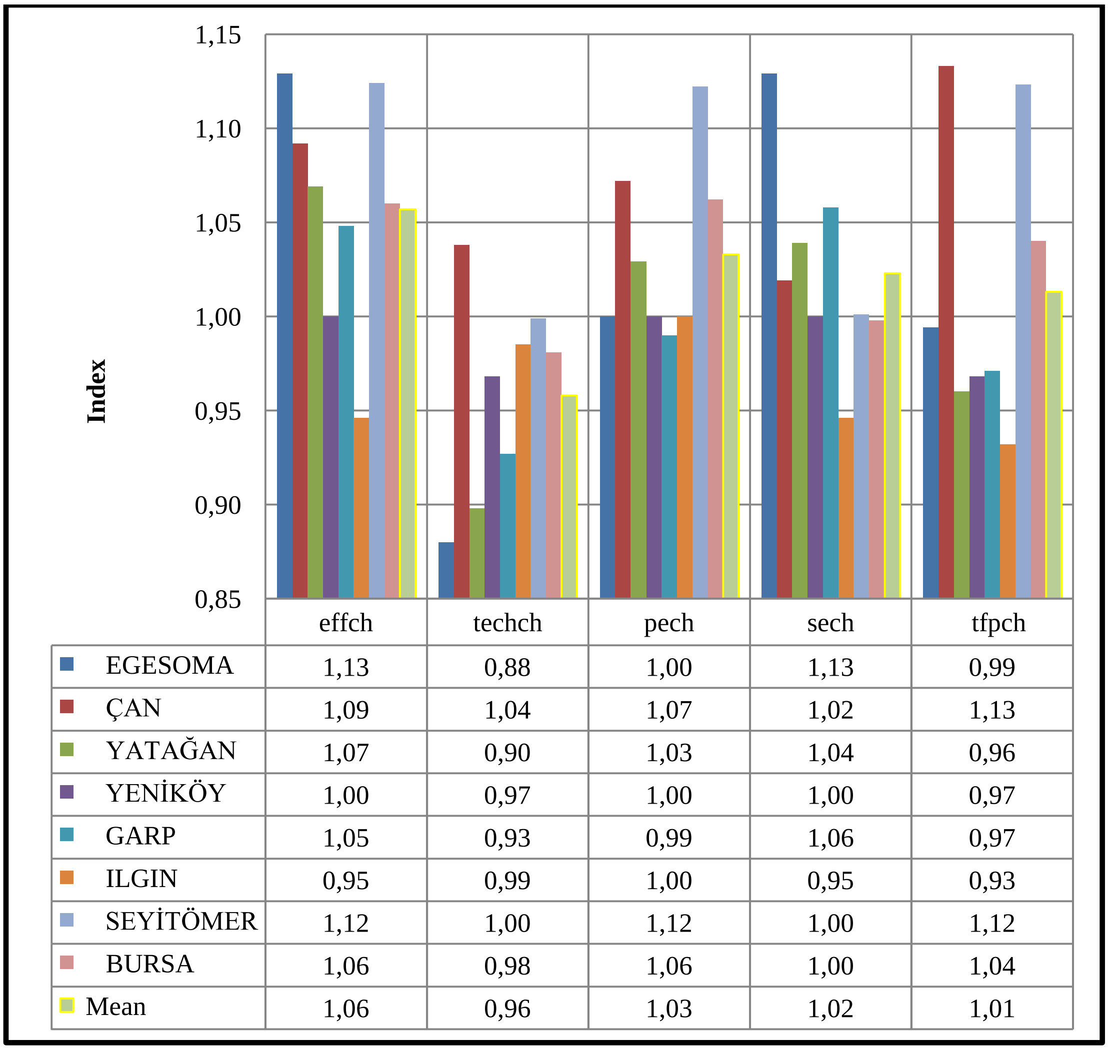
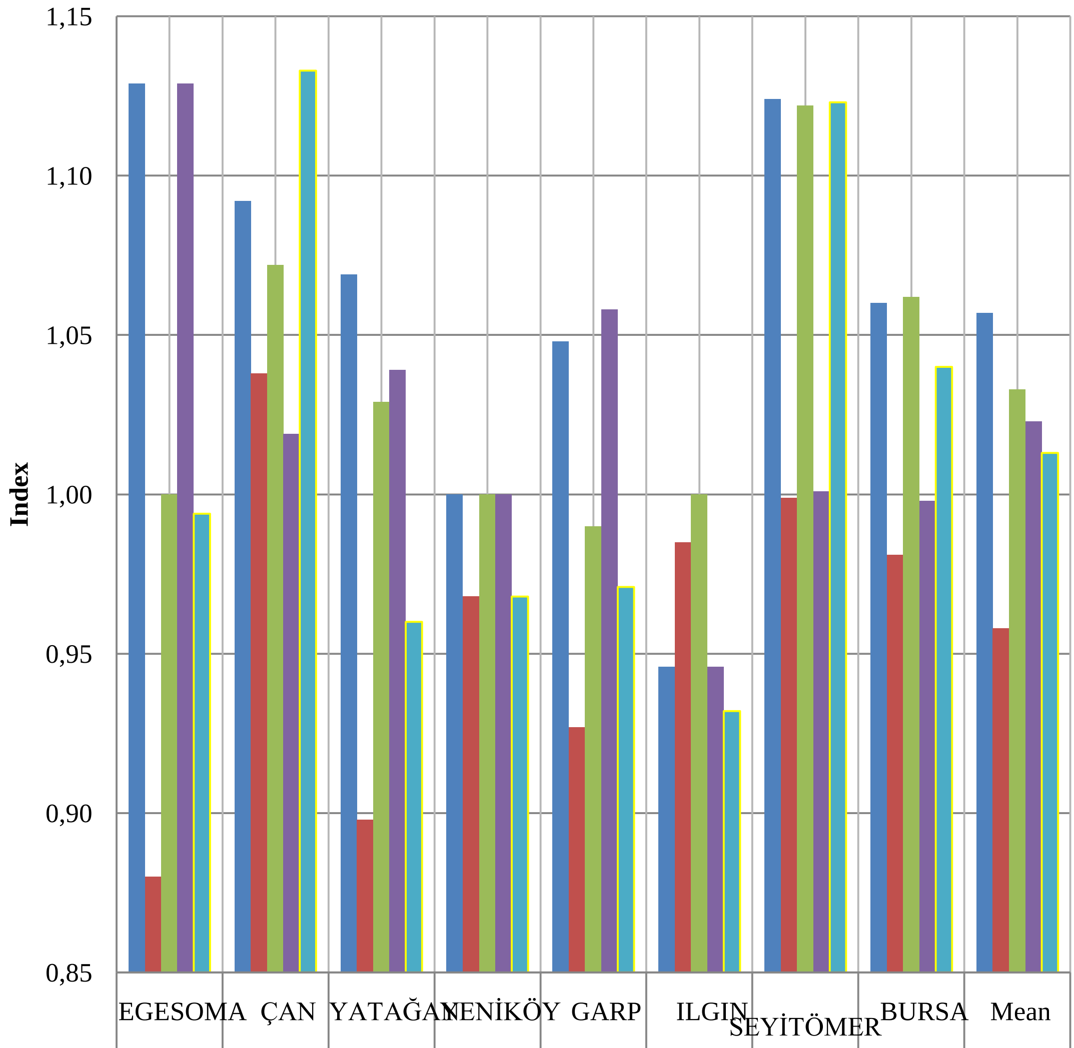


Figure 5. 27 Efficiencies and TFPs of DMUs for Model 1



	EGESOMA	ÇAN	YATAĞAN	YENİKÖY	GARP	ILGIN	SEYİTÖMER	BURSA	Mean
effch	1,13	1,09	1,07	1,00	1,05	0,95	1,12	1,06	1,06
techch	0,88	1,04	0,90	0,97	0,93	0,99	1,00	0,98	0,96
pech	1,00	1,07	1,03	1,00	0,99	1,00	1,12	1,06	1,03
sech	1,13	1,02	1,04	1,00	1,06	0,95	1,00	1,00	1,02
tfpch	0,99	1,13	0,96	0,97	0,97	0,93	1,12	1,04	1,01

Figure 5. 28 Efficiencies and TFPs of DMUs for Model 1

The means of Malmquist total factor productivity index and its components during three periods analyzed are shown in Figure 5.27 and Figure 5.28. Furthermore, the reasons for increase or decrease in TFP are explained so far. The conclusions drawn from the analysis and interpretation of Table 5.50, Figure 5.27 and Figure 5.28 are given below.

From Technical Efficiency Perspective

The mean of the technical efficiency indexes of eight establishment is 1,06. This means that eight establishments as a group improved their technical efficiency between 2006-2009. While the indexes of ILGIN, GARP and YENİKÖY are below the mean, that of EGESOMA, ÇAN, YATAĞAN and SEYİTÖMER are above it. BURSA has the same index value as the mean.

In terms of technical efficiency, EGESOMA was the most efficient (13% increase) followed by SEYİTÖMER (12% increase) and ÇAN (9% increase). ILGIN lost its efficiency (0,95), and YENİKÖY had no change in its technical efficiency level.

From Technological Efficiency Perspective

The mean of the technological efficiency indexes of eight establishment is 0,96. This means that eight establishments as a group lost their technological efficiencies by 4%. While the indexes of EGESOMA, YATAĞAN and GARP are below the mean, that of ÇAN, YENİKÖY, ILGIN and BURSA are above the mean. SEYİTÖMER has the technological efficiency index value of 1 which means, there was no change in its technological efficiency in this period.

In terms of technological efficiency, the most efficient establishment was ÇAN (4% increase). There was no change in technological efficiency level of SEYİTÖMER. The biggest decrease (12%) in technological efficiency level is realized at EGESOMA.

From Pure Technical Efficiency Perspective

The mean of the pure efficiency indexes of eight establishments is 1,03. While the indexes of EGESOMA, YENİKÖY, GARP, and ILGIN are below it, ÇAN, BURSA and SEYİTÖMER are above the mean. The index of YATAĞAN is same as the mean.

In terms of managerial efficiency, the most efficient establishment was SEYİTÖMER followed by ÇAN and BURSA. The managerial efficiency level of GARP decreased (%1 decrease). For EGESOMA, YENİKÖY and ILGIN there were no change in managerial efficiency levels.

From Scale Efficiency Perspective

The mean off the scale efficiency indexes of eight establishments was 1,02. While the indexes of YENİKÖY, ILGIN, SEYİTÖMER and BURSA are below, the index values of EGESOMA, YATAĞAN and GARP are above the mean. ÇAN has the same index value as the mean.

In terms of Scale efficiency, the most efficient establishment was EGESOMA followed by GARP and YATAĞAN. The scale efficiency level of ILGIN decreased by 5%. There were no changes in the scale efficiency levels of YENİKÖY, SEYİTÖMER and BURSA establishments.

From Total Factor Productivity (TFP) Perspective

The mean of the total factor productivity indexes of eight establishments is 1,01. While the indexes of EGESOMA, YATAĞAN, YENİKÖY, GARP and ILGIN are below the mean, those of ÇAN, SEYİTÖMER and BURSA are above the mean

In terms of total factor productivity, the most efficient establishment was ÇAN (13% increase) followed by SEYİTÖMER (12% increase) and BURSA (4% increase). ILGIN lost its total factor productivity (7% decrease).

5.4.2 Malmquist Index Model 2: Revenue Efficiency Analysis

For Model 2, Technical Efficiency (EFFCH), Technologic Efficiency (TECHCH), Pure Efficiency (PECH), Scale Efficiency (SECH) and Total Factor Productivity (TFPCH) changes of DMUs with respect to previous year and geometric means of the DMUs in each year is given in Table 5.52, Table 5.53 and Table 5.54.

Table 5. 52 Changes of efficiencies and TFP of DMUs for Model 2 in 2007

2007	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**1,29**	0,96	1,00	**1,29**	**1,24**
ÇAN	**1,17**	**1,21**	**1,17**	1,00	**1,41**
YATAĞAN	**1,29**	0,94	**1,20**	**1,07**	**1,20**
YENİKÖY	1,00	**1,05**	1,00	1,00	**1,05**
GARP	**1,10**	0,92	0,82	**1,34**	**1,01**
ILGIN	0,68	**1,02**	1,00	0,68	0,70
SEYİTÖMER	**1,20**	**1,05**	**1,20**	1,00	**1,26**
BURSA	**1,13**	0,99	**1,15**	0,98	**1,11**
Means	**1,09**	**1,01**	**1,06**	**1,03**	**1,10**

Table 5. 53 Changes of efficiencies and TFP of DMUs for Model 2 in 2008

2008	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**1,12**	**1,10**	1,00	**1,12**	**1,23**
ÇAN	0,80	**1,40**	0,78	**1,02**	**1,11**
YATAĞAN	**1,02**	**1,16**	**1,01**	**1,01**	**1,19**
YENİKÖY	1,00	**1,23**	1,00	1,00	**1,23**
GARP	0,97	**1,16**	0,98	0,99	**1,13**
ILGIN	**1,21**	**1,27**	1,00	**1,21**	**1,53**
SEYİTÖMER	1,00	**1,26**	1,00	1,00	**1,26**
BURSA	**1,05**	**1,29**	**1,06**	0,99	**1,35**
Means	**1,01**	**1,23**	**0,97**	**1,04**	**1,25**

Table 5. 54 Changes of efficiencies and TFP of DMUs for Model 2 in 2009

2009	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	0,99	0,97	1,00	0,99	0,97
ÇAN	**1,04**	0,96	**1,01**	**1,03**	1,00
YATAĞAN	0,91	**1,04**	0,91	1,00	0,95
YENİKÖY	1,00	**1,02**	1,00	1,00	**1,02**
GARP	**1,04**	**1,09**	**1,26**	0,83	**1,14**
ILGIN	**1,30**	**1,15**	1,00	**1,30**	**1,50**
SEYİTÖMER	1,00	**1,21**	1,00	1,00	**1,21**
BURSA	0,86	**1,14**	0,84	**1,03**	0,98
Means	**1,01**	**1,07**	**1,00**	**1,02**	**1,08**

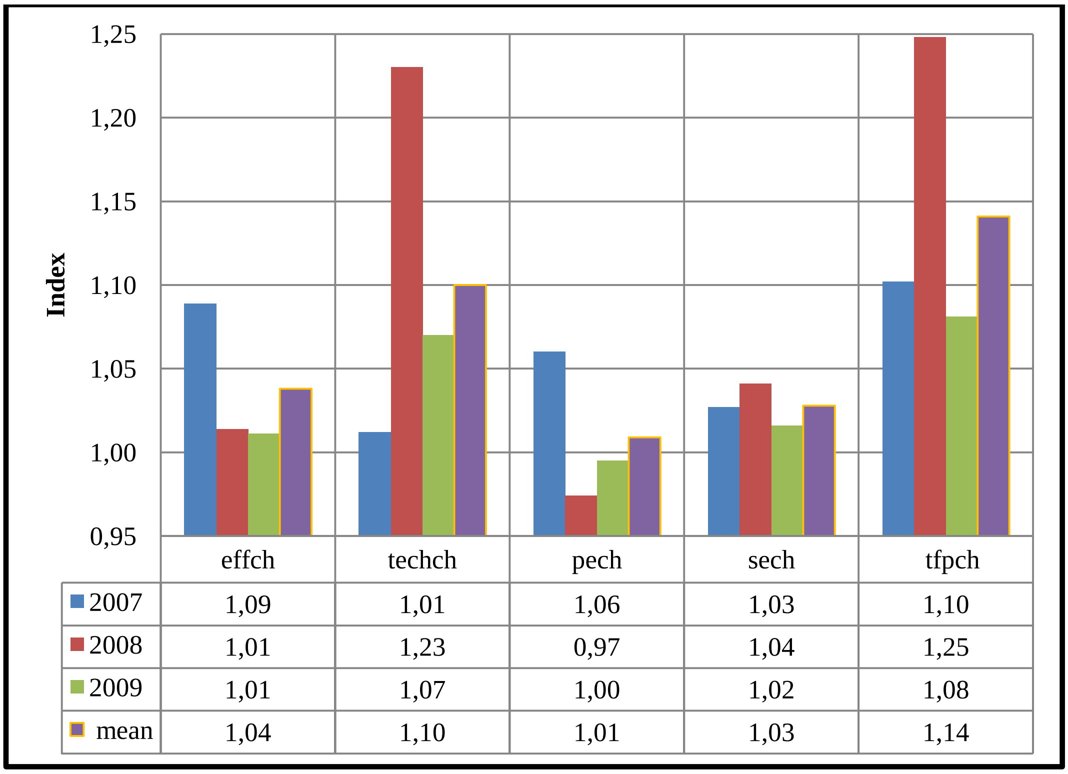
Values lower than 1 for Technical and technologic efficiencies which are the components of Total Factor Productivity indicate getting worst in technical and technologic efficiencies, while values higher than 1 for Technical and technologic efficiencies means getting better in technical and technologic efficiencies. In other words, technical efficiency value greater than 1 shows that the DMU caught the efficient production frontier, and the technologic efficiency value greater than 1 shows that the efficient production frontier shifts upward. When change in the Pure efficiency, and the scale efficiency which are the components of technical efficiency is greater than 1, this shows that the DMU is operating at efficient management and scale.

The means of the efficiency change values of the each DMU in each year (2007, 2008 and 2009) are given in Table 5.52, Table 5.53 and Table 5.54. The geometric means of the efficiency changes of all DMUs in 2007, 2008 and 2009 are given in Table 5.55.

Table 5. 55 Efficiency and TFP Changes of DMUs for Model 2

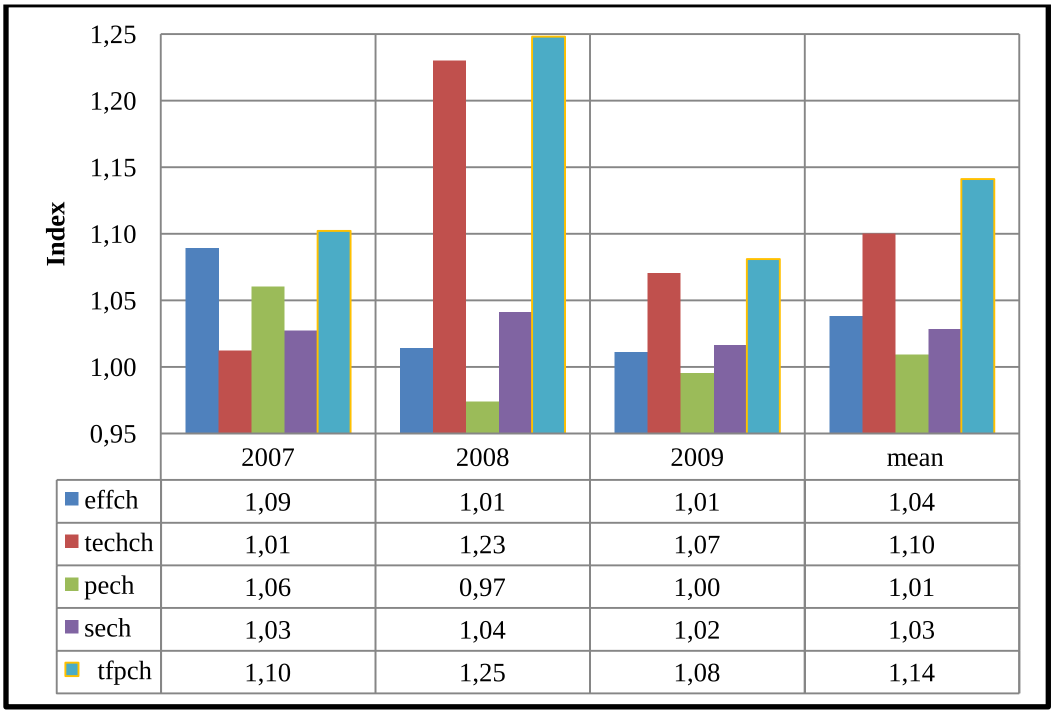
	EFFCH	TECHCH	PECH	SECH	TFPCH
2007	**1,09**	**1,01**	**1,06**	**1,03**	**1,10**
2008	**1,01**	**1,23**	0,97	**1,04**	**1,25**
2009	**1,01**	**1,07**	1,00	**1,02**	**1,08**
Means	**1,04**	**1,10**	**1,01**	**1,03**	**1,14**

The graphical presentation of the efficiency changes and total factor productivity change with time dimension is shown Figure 5.29 and Figure 5.30.



	effch	techch	pech	sech	tfpch
2007	1,09	1,01	1,06	1,03	1,10
2008	1,01	1,23	0,97	1,04	1,25
2009	1,01	1,07	1,00	1,02	1,08
mean	1,04	1,10	1,01	1,03	1,14

Figure 5. 29 Changes of efficiencies and TFP for Model 2



	2007	2008	2009	mean
effch	1,09	1,01	1,01	1,04
techch	1,01	1,23	1,07	1,10
pech	1,06	0,97	1,00	1,01
sech	1,03	1,04	1,02	1,03
tfpch	1,10	1,25	1,08	1,14

Figure 5. 30 Changes of efficiencies and TFP for Model 2

Malmquist Total Factor Productivity Index and its components are shown in Figures 5.29 and Figure 5.30 for the periods between 2006 to 2009. Furthermore, by analyzing every period individually, the reasons for increases or decreases in TFP are explained. The results can be summarized as follows:

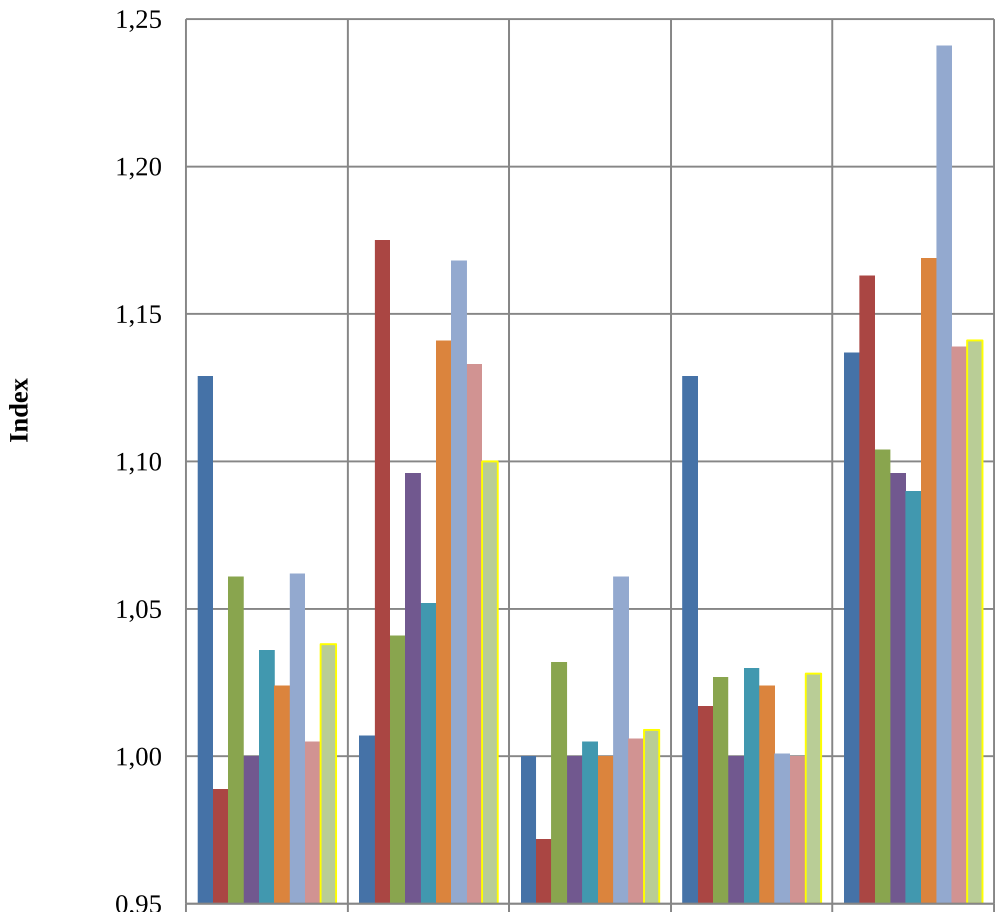
- From 2007 to 2009 there was a noticeable decrease in the means of technical efficiencies of the establishments. The means of technical efficiencies of the establishments dropped to 1,01 in 2008 from 1,09 in 2007 corresponding to 8% decrease. In 2009, it kept the same index level as 2008. However, despite this drops, the means of the three periods was realized as 1,04 (4% increase) which is slightly above 1.
- During the analysis periods (2007, 2008, 2009) there was 14% increase in the total factor productivity of eight establishments as a whole.
- In 2008, there was 25% increase in TFP of the establishments. The reasons for this positive development were a 1% increase in technical efficiency and 23% increase in technological efficiency. The contribution to the increase in technical efficiency came from the 4% increase in scale efficiency which is a sign of DMUs operating at appropriate scale.
- In 2007, there was a 9% increase in the mean of technical efficiency of eight establishments. The biggest increase occurred in YATAGAN and EGESOMA (29%), and the biggest decrease (32%) occurred in ILGIN. There was no change in the technical efficiency of YENİKÖY.
- The technical efficiency index of SEYİTÖMER was 1,20 in 2007, and dropped to 1 in 2008 and 2009. This means that there was no change in the technical efficiency index of SEYİTÖMER in 2008 and 2009.
- The technological efficiency index of the eight establishments increased by 1% in 2007, 23% in 2008 and 7% in 2009. This means that establishments as whole were able to shift the production frontier upward in those years.
- In 2007, 2008 and 2009, the biggest increase in technological efficiency index occurred in ÇAN with 40% increase in 2008. In those periods the biggest decrease in the technological efficiency index occurred in GARP with 8% decrease.

- There was a 25% increase in the TFP index in 2008. The reasons for this increase in TFP were the increases in technical (1%) and technological (23%) efficiency indexes. The positive contribution to the increase in technical efficiency index came from the 4% increase in scale efficiency index although there was 3% decrease in the pure efficiency index.
- The mean of the TFP indexes of the establishments had the second highest value in 2007. In 2007, there was a 10% increase in the mean of the TFP indexes of eight establishments. The reasons for this increase in the mean of TFP indexes were the 9% increase in technical efficiency index and 1% increase in the technological efficiency index. The 9% increase in the technical efficiency index means that there was a positive development in input-output compositions of the establishments in that year.
- 2008 was the only year when the pure efficiency index which is sign of managerial efficiency dropped. In the same year, there was a 4% increase in the scale efficiency index which shows the ability of the establishments to operate at appropriate scale.
- It is observed that TFP, technological efficiency index and scale efficiency index reached maximum level in 2008.

The geometric means of the technical, technologic, pure and scale efficiencies and the geometric means of total factor productivity (index) of the DMUs for all periods are calculated and given in Table 5.56, and shown in Figure 5.31 and Figure 5.32.

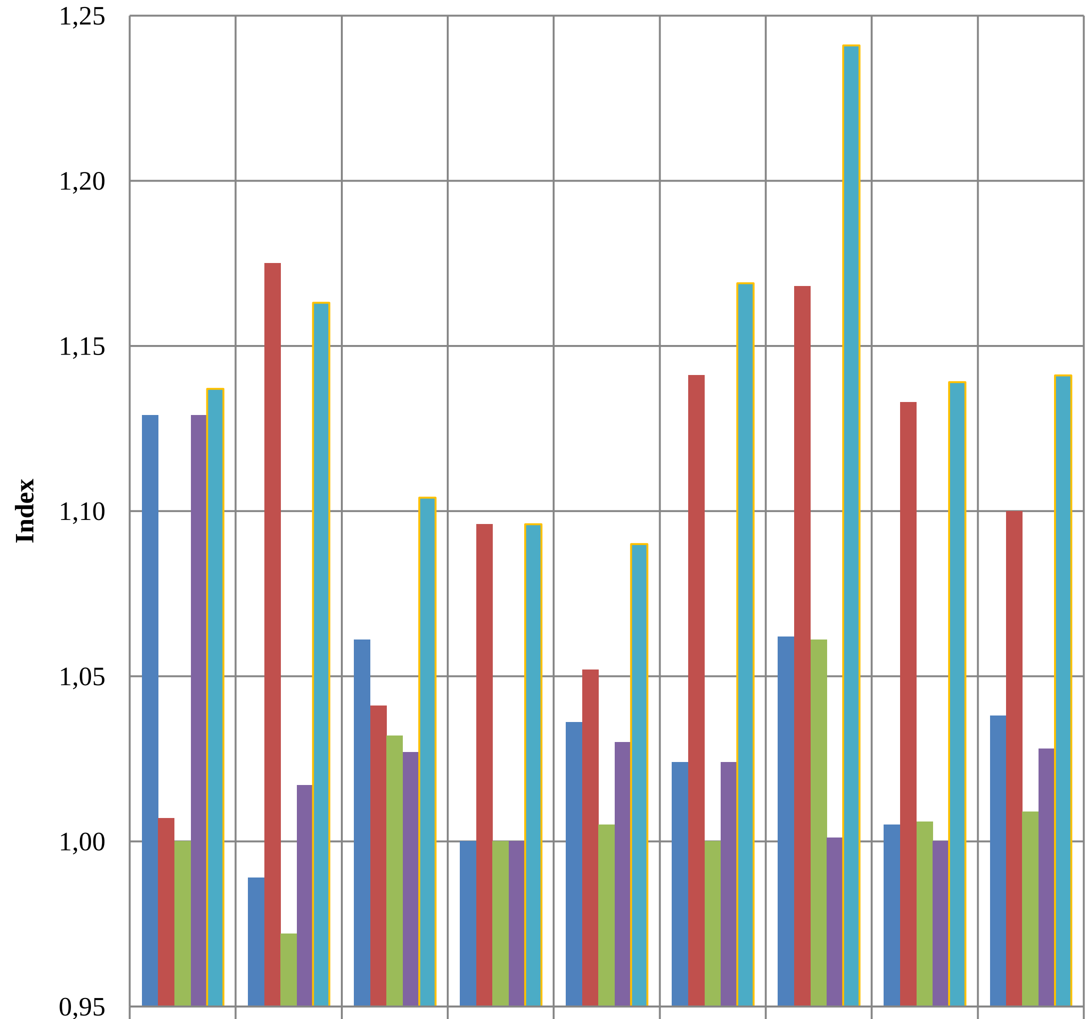
Table 5. 56 Efficiencies and TFP of DMUs for Model 2

	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**1,13**	**1,01**	1,00	**1,13**	**1,14**
ÇAN	0,99	**1,18**	0,97	**1,02**	**1,16**
YATAĞAN	**1,06**	**1,04**	**1,03**	**1,03**	**1,10**
YENİKÖY	1,00	**1,10**	1,00	1,00	**1,10**
GARP	**1,04**	**1,05**	**1,01**	**1,03**	**1,09**
ILGIN	**1,02**	**1,14**	1,00	**1,02**	**1,17**
SEYİTÖMER	**1,06**	**1,17**	**1,06**	1,00	**1,24**
BURSA	**1,01**	**1,13**	**1,01**	1,00	**1,14**
Means	**1,04**	**1,10**	**1,01**	**1,03**	**1,14**



	effch	techch	pech	sech	tfpch
EGESOMA	1,13	1,01	1,00	1,13	1,14
ÇAN	0,99	1,18	0,97	1,02	1,16
YATAĞAN	1,06	1,04	1,03	1,03	1,10
YENİKÖY	1,00	1,10	1,00	1,00	1,10
GARP	1,04	1,05	1,00	1,03	1,09
ILGIN	1,02	1,14	1,00	1,02	1,17
SEYİTÖMER	1,06	1,17	1,06	1,00	1,24
BURSA	1,00	1,13	1,01	1,00	1,14
mean	1,04	1,10	1,01	1,03	1,14

Figure 5. 31 Efficiencies and TFPs of DMUs for Model 2



	EGESOMA	ÇAN	YATAĞAN	YENİKÖY	GARP	ILGIN	SEYİTÖMER	BURSA	Mean
effch	1,13	0,99	1,06	1,00	1,04	1,02	1,06	1,00	1,04
techch	1,01	1,18	1,04	1,10	1,05	1,14	1,17	1,13	1,10
pech	1,00	0,97	1,03	1,00	1,00	1,00	1,06	1,01	1,01
sech	1,13	1,02	1,03	1,00	1,03	1,02	1,00	1,00	1,03
tfpch	1,14	1,16	1,10	1,10	1,09	1,17	1,24	1,14	1,14

Figure 5. 32 Efficiencies and TFPs of DMUs for Model 2

The means of Malmquist TFP index and its components during three periods analyzed in Figure 5.1 and Figure 5.32. Furthermore, the reasons for increases or decreases in TFP are explained so far. The conclusions drawn from the analysis and interpretation of Table 5.56, Figure 5.31 and Figure 5.32 are given below.

From Technical Efficiency Perspective

The mean of technical efficiency indexes of eight establishments is 1,04. While the indexes of ÇAN, YENİKÖY, ILGIN and BURSA are below the mean, that of EGESOMA, YATAĞAN and SEYİTÖMER are above the mean. GARP has the same index value as mean.

In terms of technical efficiency, EGESOMA was the most efficient (13% increase) followed by SEYİTÖMER (6% increase), YATAĞAN (6% increase) and GARP (4% increase). There was a 1% decrease in the technical efficiency index of ÇAN (0,99). There was no change in the technical efficiency index of YENİKÖY.

From Technological Efficiency Perspective

The mean of the technological efficiency indexes of the eight establishments is 1,1. This means that the eight establishments as a group increased their technological efficiencies by 10%. While the technological efficiency indexes of EGESOMA, YATAĞAN and GARP are lower than the mean, those of ÇAN, ILGIN, SEYİTÖMER and BURSA are above the mean. YENİKÖY has the same index value as the mean.

In terms of technological efficiency, the most efficient establishment was ÇAN (%18 increase) followed by SEYİTÖMER with 17% increase. EGESOMA showed the least increase in the technological efficiency index (1% increase).

From Pure Efficiency Perspective

The mean of the pure efficiency indexes of eight establishments is 1,01. While the pure efficiency indexes of EGESOMA, ÇAN, YENİKÖY and ILGIN are below the mean, those of YATAĞAN and SEYİTÖMER are above the mean. GARP and BURSA has the same index value as mean.

In terms of managerial efficiency, the most efficient establishment was SEYİTÖMER (6% increase) followed by YATAĞAN (3% increase). ÇAN lost managerial efficiency (3% decrease). There were no changes in the managerial efficiencies of EGESOMA, YENİKÖY and ILGIN.

From Scale Efficiency Perspective

The mean of scale efficiency indexes of eight establishments is 1,03. While scale efficiency indexes of ÇAN, YENİKÖY, ILGIN, SEYİTÖMER and BURSA are below the mean, EGESOMA (with a 13% increase) is above the mean. YATAĞAN and GARP have the same indexes as the mean.

In terms of scale efficiency, the most efficient establishment was EGESOMA. There was not any establishment whose scale efficiency index decreased. There was not any change in the scale efficiency indexes of YENİKÖY, SEYİTÖMER and BURSA.

From Total Factor Productivity (TFP) Perspective

The mean of the total factor productivity indexes of eight establishments is 1,14. This means that there is 14% increase in TFP indexes of the establishments as a group during 2006-2009. While the indexes of YATAĞAN, YENİKÖY and GARP are below the mean, those of ÇAN, ILGIN and SEYİTÖMER are above the mean. EGESOMA and BURSA has the same index values as the mean.

In terms of TFP, the most productive establishment was SEYİTÖMER (24% increase) followed by ILGIN (17% increase) and ÇAN (16% increase). There were no establishments whose TFP index decreased. GARP showed the lowest increase in TFP (9% increase).

5.4.3 Malmquist Index Model 3: Work Safety Efficiency Analysis

For Model 3, Technical Efficiency (EFFCH), Technologic Efficiency (TECHCH), Pure Efficiency (PECH), Scale Efficiency (SECH) and Total Factor Productivity (TFPCH) changes of DMUs with respect to previous year and geometric means in each year is given in Table 5.57, Table 5.58 and Table 5.59.

Table 5. 57 Changes of efficiencies and TFP of DMUs for Model 3 in 2007

2007	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**14,53**	0,49	**14,19**	**1,02**	**7,09**
ÇAN	1,00	**1,65**	1,00	1,00	**1,65**
YATAĞAN	**3,59**	**1,37**	**3,85**	0,93	**4,92**
YENİKÖY	1,00	0,27	1,00	1,00	0,27
GARP	0,16	0,33	0,10	**1,60**	0,05
ILGIN	1,00	**1,15**	1,00	1,00	**1,15**
SEYİTÖMER	0,86	0,96	0,87	0,99	0,82
BURSA	1,00	0,46	1,00	1,00	0,46
Means	**1,28**	**0,69**	**1,22**	**1,05**	**0,88**

Table 5. 58 Changes of efficiencies and TFP of DMUs for Model 3 in 2008

2008	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	0,02	**7,18**	0,06	0,39	0,17
ÇAN	1,00	0,42	1,00	1,00	0,42
YATAĞAN	**1,18**	**3,00**	1,00	**1,18**	**3,53**
YENİKÖY	0,76	**7,43**	1,00	0,76	**5,64**
GARP	0,62	**8,45**	0,58	**1,07**	**5,22**
ILGIN	1,00	**1,79**	1,00	1,00	**1,79**
SEYİTÖMER	0,69	**13,07**	0,83	0,84	**9,07**
BURSA	1,00	**4,27**	1,00	1,00	**4,27**
Means	**0,55**	**3,93**	**0,64**	**0,89**	**2,18**

Table 5. 59 Changes of efficiencies and TFP of DMUs for Model 3 in 2009

2009	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**43,00**	0,55	**16,92**	**2,54**	**23,48**
ÇAN	1,00	**5,00**	1,00	1,00	**5,00**
YATAĞAN	0,37	0,36	1,00	0,37	0,13
YENİKÖY	0,43	0,35	1,00	0,43	0,15
GARP	**4,39**	0,50	**3,88**	**1,13**	**2,19**
ILGIN	1,00	**3,38**	1,00	1,00	**3,38**
SEYİTÖMER	**1,68**	**2,79**	**1,40**	**1,20**	**4,70**
BURSA	1,00	0,23	1,00	1,00	0,23
Means	**1,63**	**0,89**	**1,76**	**0,93**	**1,45**

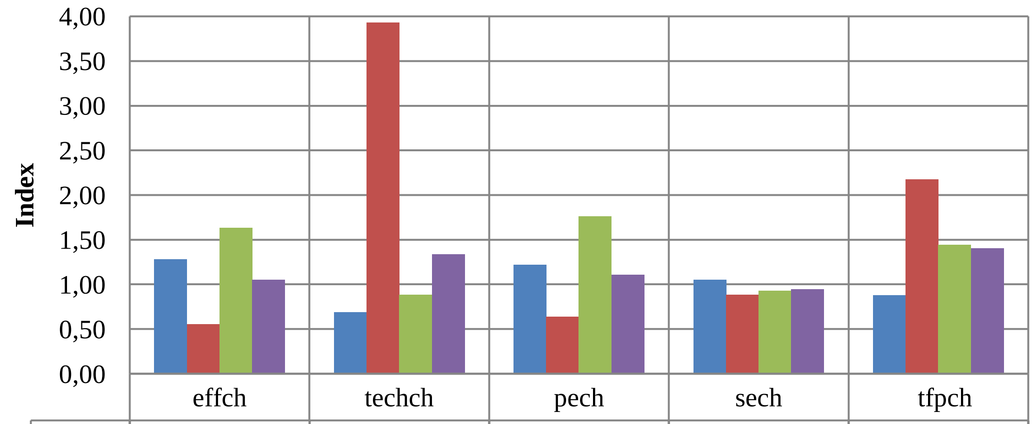
Values lower than 1 for Technical and technologic efficiencies which are the components of Total Factor Productivity means getting worst in technical and technologic efficiencies, while the value higher than 1 for Technical and technologic efficiencies means getting better in technical and technologic efficiencies. A Technical efficiency value greater than 1 show that the DMU catches the efficient production frontier, and a technologic efficiency value greater than 1 shows that the efficient production frontier shifts upward. When change in the pure efficiency the scale efficiency which are the components of technical efficiency is greater than 1, this shows that the DMU is operating at efficient management and scale.

The means of the efficiency change values of the each DMU in each year (2007, 2008 and 2009) are given in Table 5.57, Table 5.58 and Table 5.59. The geometric means of the efficiency changes of all DMUs in 2007, 2008 and 2009 are given in Table 5.60.

Table 5. 60 Efficiency and TFP changes of DMUs for Model 3

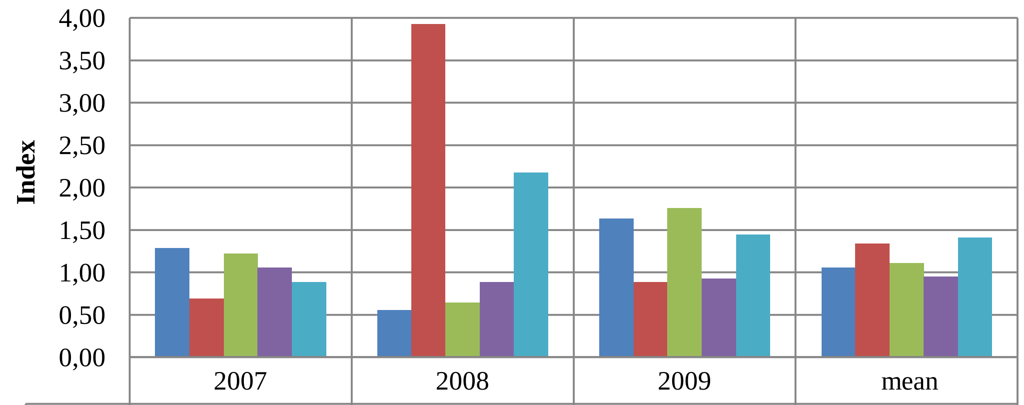
	EFFCH	TECHCH	PECH	SECH	TFPCH
2007	**1,28**	0,69	**1,22**	**1,05**	0,88
2008	0,55	**3,93**	0,64	0,89	**2,18**
2009	**1,63**	0,89	**1,76**	0,93	**1,45**
Means	**1,05**	**1,34**	**1,11**	**0,95**	**1,41**

The graphical presentation of the efficiency changes and total factor productivity change with time dimension is shown Figure 5.33 and Figure 5.34.



	effch	techch	pech	sech	tfpch
2007	1,28	0,69	1,22	1,05	0,88
2008	0,55	3,93	0,64	0,89	2,18
2009	1,63	0,89	1,76	0,93	1,45
mean	1,05	1,34	1,11	0,95	1,41

Figure 5. 33 Changes of efficiencies and TFP for Model 3



	2007	2008	2009	mean
effch	1,28	0,55	1,63	1,05
techch	0,69	3,93	0,89	1,34
pech	1,22	0,64	1,76	1,11
sech	1,05	0,89	0,93	0,95
tfpch	0,88	2,18	1,45	1,41

Figure 5. 34 Changes of efficiencies and TFP for Model 3

Malmquist Total Factor Productivity Index and its components are shown in Figure 5.33 and Figure 5.34 for the periods between 2006 to 2009. Furthermore, by analyzing every period individually, the reasons for increases or decreases in TFP are explained. The results can be summarized as follows:

- During the periods of analysis, the mean of the technical efficiencies of the establishments increased in 2007 and 2009 considerably (28% and 63% increases respectively). Although there was a 45% decrease in 2008, the mean of the three periods showed a 5% increase in the mean of technical efficiency indexes of the eight establishments. T

  This means that the efficiency of the establishments in utilizing the inputs to reduce the number of the accidents has improved during the period. However, if the drop in the technical efficiency index had not been realized in 2008, the mean of the technical efficiency index for the 2006-2009 period would be higher. Therefore, the drop realized in the technical efficiency level in 2008 has to be questioned, and precautions and measures has to be developed by TKİ authorities.

- When there was a 28% increase in the mean of technical efficiency indexes in 2007, the biggest increase occurred in EGESOMA, and the biggest decrease occurred in GARP, YENİKÖY, ILGIN and BURSA in 2007. This means that EGESOMA used its inputs efficiently to reduce the number of accidents in 2007, whereas GARP, YENİKÖY, ILGIN and BURSA did not.

- The technological efficiency index increased to 3,93 in 2008 from 0,69 in 2007, and dropped back to 0,89 in 2009. The mean of three periods showed 34% increase during the periods. This means that the production frontier shifted upward in three periods showing the successful utilization of the technology by establishments in combating with the accidents. Although the technological efficiency index improved in 2008, this could not compensate the technical efficiency drop.

- The mean of TFP indexes for the periods 2007, 2008 and 2009 increased 41%. This shows that the establishments all together improved their TFP in combating with the accidents. There was 118% increase in TFP in 2008 and 45% increase in 2009. The reasons for those increases were the increases in technological efficiency index in 2008, and the increases in technical efficiency index in 2009.

- In 2009, the contribution to the increase in technical efficiency came from the significant increases (76%) in pure efficiency (which is again is a sign of managerial efficiency in combating with the accidents) although there was a 7% decrease in scale efficiency which is a sign of not operating at appropriate scales of inputs in combating with the accidents. Therefore, by benefiting the inputs to a greater extend, better outcomes can be achieved in reducing the number of accidents.

- In 2008 and 2009 when the TFP indexes had the highest values, it can be said that the development of inputs-output (the number of accidents) compositions were in positive direction. In other words utilizing the inputs in combating with the accidents has improved.

- 2008 was the only year when there was a 36% decrease in the pure efficiency index, which is sign of managerial efficiency in combating with the accidents. When the 3 periods are considered as a whole, there is an increase of 11% in pure efficiency index of the establishments as whole.

The geometric means of the technical, technologic, pure and scale efficiencies and the geometric means of total factor productivity (index) of the DMUs for all the periods are calculated and given in Table 5.61, and shown in Figure 5.35 and Figure 5.36.

Table 5. 61 Efficiencies and TFPs of DMUs for Model 3

	EFFCH	TECHCH	PECH	SECH	TFPCH
EGESOMA	**2,44**	**1,24**	**2,42**	**1,01**	**3,03**
ÇAN	1,00	**1,51**	1,00	1,00	**1,51**
YATAĞAN	**1,16**	**1,14**	**1,57**	0,74	**1,32**
YENİKÖY	0,69	0,89	1,00	0,69	0,61
GARP	0,76	**1,12**	0,61	**1,25**	0,85
ILGIN	1,00	**1,91**	1,00	1,00	**1,91**
SEYİTÖMER	1,00	**3,27**	1,00	1,00	**3,27**
BURSA	1,00	0,77	1,00	1,00	0,77
Means	**1,05**	**1,34**	**1,11**	**0,95**	**1,41**

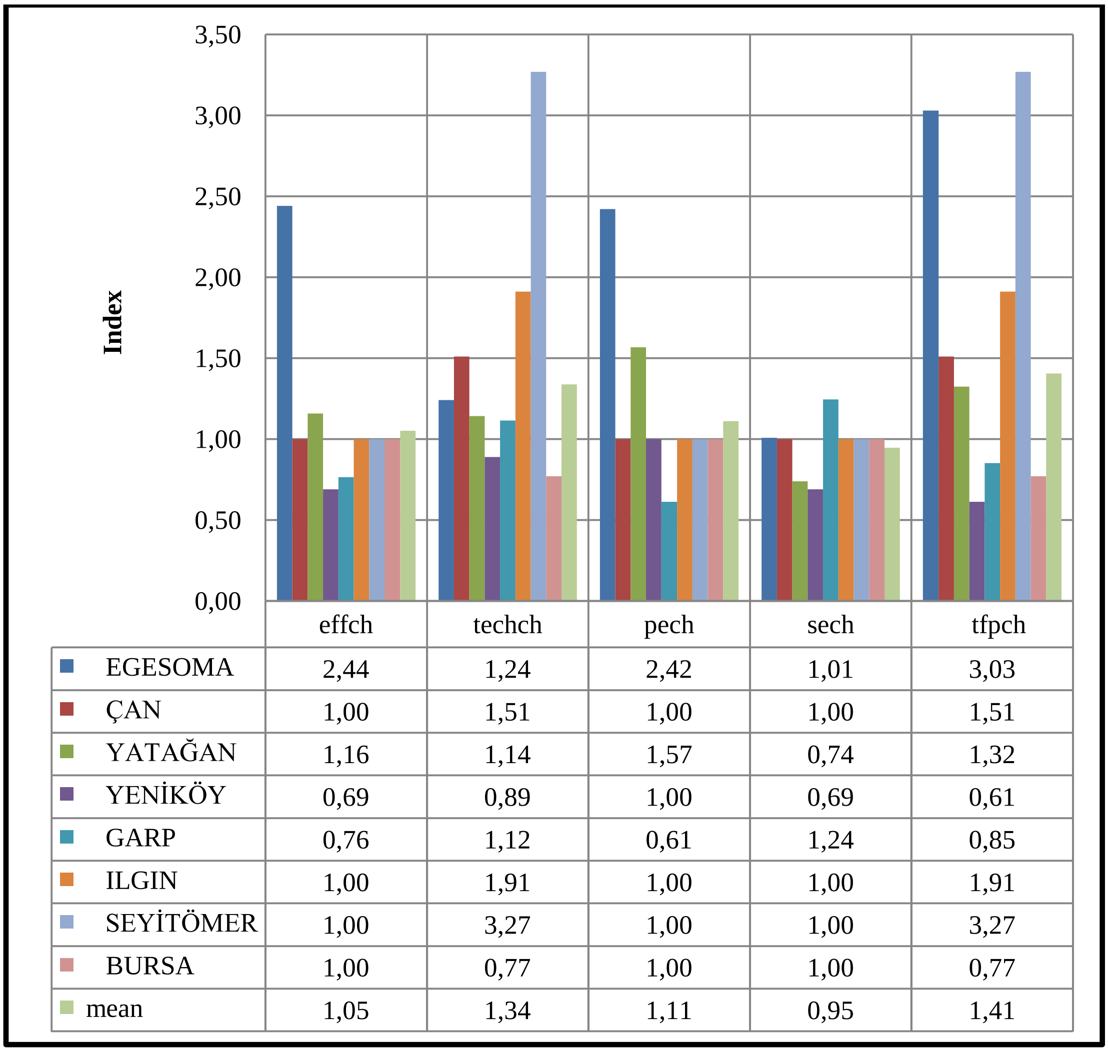
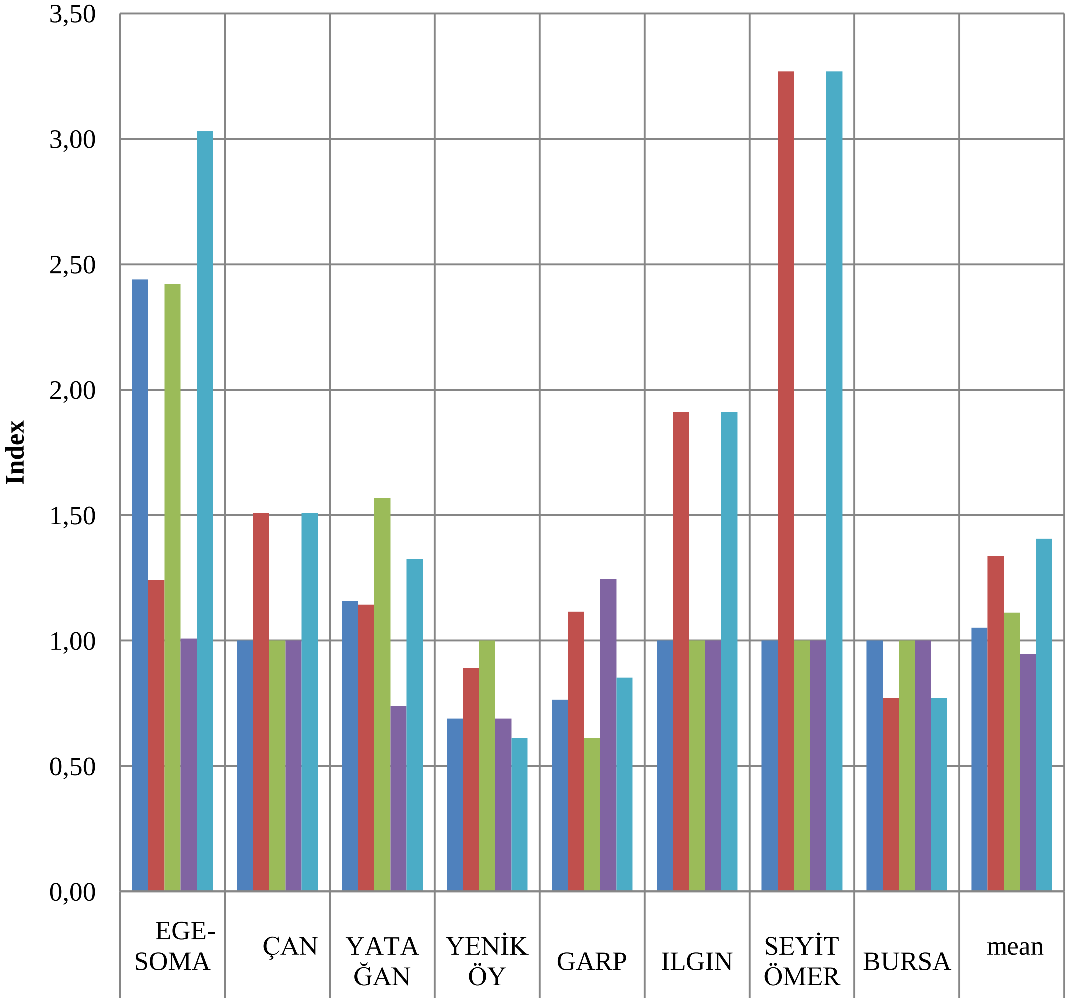


Figure 5. 35 Efficiencies and TFPs of DMUs for Model 3

Figure 5. 36 Efficiencies and TFPs of DMUs for Model 3



	EGE-SOMA	ÇAN	YATAĞAN	YENİKÖY	GARP	ILGIN	SEYİTÖMER	BURSA	mean
effch	2,44	1,00	1,16	0,69	0,76	1,00	1,00	1,00	1,05
techch	1,24	1,51	1,14	0,89	1,12	1,91	3,27	0,77	1,34
pech	2,42	1,00	1,57	1,00	0,61	1,00	1,00	1,00	1,11
sech	1,01	1,00	0,74	0,69	1,24	1,00	1,00	1,00	0,95
tfpch	3,03	1,51	1,32	0,61	0,85	1,91	3,27	0,77	1,41

The means of Malmquist TFP index and its components during three periods are shown in Figure 5.35 and Figure 5.36. Furthermore, the reasons for increases or decreases in TFP are explained so far. The conclusions drawn from the analysis and interpretation of Table 5.61, Figure 5.35 and Figure 5.36 are given below.

From Technical Efficiency Perspective

Technical efficiency shows how efficient DMUs were in transforming their inputs to output, which was the minimization of the number of accidents in the Work Safety Efficiency model.

The mean of the technical efficiency indexes of the eight establishments in 2006-2009 period was 1,05.This means the use of the inputs by the establishments as a group has improved in combating with the accidents. While the indexes of YENİKÖY, ÇAN, ILGIN, SEYİTÖMER, GARP and BURSA are below the mean, those of EGESOMA and YATAĞAN are above the mean.

In terms of technical efficiency, the most efficient establishment was EGESOMA (144% increase) followed by YATAĞAN (16% increase). YENİKÖY and GARP were the most inefficient with 31% and 24% decreases respectively.

This shows that EGESOMA and YATAĞAN made improvements in utilizing their inputs to combat with the accidents, but YENİKÖY and GARP did not. There were no changes in the efficiency of ÇAN, ILGIN, SEYİTÖMER and BURSA in utilizing their inputs to reduce the number of accidents during the period.

From Technological Efficiency Perspective

Technological efficiency shows upward (positive) or downward (negative) shift of the efficient frontier which is interpreted as technological change.

The mean of the technological efficiency indexes of eight establishments is 1,34. This means that the eight establishments as a group realized 34% increases during these 4 years (or the three periods, and the efficient frontier shifted upward). While the indexes of EGESOMA, YATAĞAN, YENİKÖY, GARP and BURSA are below the mean, those of ÇAN, ILGIN and SEYİTÖMER were above the mean.

In terms of technological efficiency the most efficient establishment was SEYİTÖMER (3,27) followed by ILGIN (1,91). There was a decrease of the index of BURSA (0,77). Similarly, YENİKÖY had also 11% decrease (0,89) in the technological efficiency index.

From Pure Efficiency Perspective

Pure efficiency is a sign of managerial efficiency in combating with the accidents.

The mean of the pure efficiency indexes of the eight establishments is 1,11. This means that the managerial efficiency of the establishments in combating with the accidents improved during the period.

While the indexes of ÇAN, YENİKÖY, GARP, ILGIN, SEYİTÖMER and BURSA are below the mean, those of EGESOMA and YATAĞAN were above the mean. EGESOMA and YATAĞAN showed the most biggest improvement, and GARP realized a drop in its managerial efficiency in reducing the number of accidents during the period.

In terms of managerial efficiency the most efficient establishments was EGESOMA (142% increase) followed by YATAĞAN (57% increase). GARP showed a 39% decrease in the pure efficiency index value. There were no changes in the managerial efficiency indexes of ÇAN, YENİKÖY, ILGIN, SEYİTÖMER and BURSA in combating with the accidents during 2006 to 2009.

From Scale Efficiency Perspective

Scale efficiency showed whether the establishments were utilizing their inputs at appropriate scales or not in combating with the accidents.

The mean of the scale efficiency indexes of eight establishments is 0,95. This means that there was a 5% decrease in the mean of scale efficiency indexes of the eight establishments as a group, which is sign of not operating at appropriate scale. While the indexes of YATAĞAN and YENİKÖY are below the mean, those of EGESOMA, ÇAN, GARP, ILGIN, SEYİTÖMER and BURSA are above the mean.

In terms of scale efficiency, the most efficient establishment was GARP. YATAĞAN and YENİKÖY showed decreases in terms of scale efficiency. For ÇAN, ILGIN, SEYİTÖMER and BURSA, the index values were same as the mean (there were no changes in their scale efficiencies between 2006 to 2009).

From Total Factor Productivity (TFP) Perspective

The mean of the TFP indexes of the eight establishments is 1,41. This means that the establishments improved their total factor productivity in combating with the accidents during 2006 to 2009 period. While the indexes of YATAĞAN, YENİKÖY, GARP and BURSA are below the mean, those of EGESOMA, ÇAN, ILGIN and SEYİTÖMER are above the mean.

In terms of TFP index, the most productive establishment was SEYİTÖMER (3,27) followed by EGESOMA (3,03). The least productive establishments, on the other hand, were YENİKÖY (39% decrease), GARP (15% decrease) and BURSA (23% decrease).

CHAPTER 6

CONCLUSIONS

Natural resources are very important for the welfare of countries and nations. They are the main sources to meet the vital needs of humankind. Natural resources are transformed to the benefits through a series of operations which are carried out by organizations. The efficiency in those operations, and of course the efficiency of those organizations are very important for many reasons. Among those scarcity and competition can be listed as the most important ones. Natural resources are scarce, and therefore they have to be utilized efficiently. However, even the scarcity of the natural resources were not the case, the competitiveness of a resource is important in order to find a proper place in the market. Both scarcity and competition requires effective and efficient operations in every stages of the life cycle through which a natural resources passes, from early mining activities to the final production phase. Therefore, the measure of efficiency in operations, and the efficiency of organizations which carry out those operations become important.

In recent years, the risks created by the import of energy on the security of energy supply has encouraged countries to utilize local resources in addition to other policy orientations such as the use of renewable energy, energy efficiency, and new energy technologies. For many countries including Turkey, coal is at the top of local resources because coal is present in wide geographic areas throughout the world and has longer lasting reserves when compared against both oil and natural gas.

Data Envelopment Analysis (DEA) is a non-parametric, linear programming-based methodology used to determine to what extent enterprises are using their resources to produce outputs, and to what extent they are operating efficiently. Enterprises operating in knowledge of their efficiency level, and the analyses that have been made in this regard are very important for the management of enterprises who bear the responsibility to become more efficient. Moreover, analyzing the dynamic development of the enterprises' efficiency level in time is also very important for the management of the enterprises, and to provide such richness of evaluation, inclusion of the time dimension to the analyses is valuable in this regard.

In Turkey's coal sector, public enterprises are the market's dominant players. 87% of the known reserves belong to the public enterprises; Turkish Coal Directorate (TKI), Electricity Generation General Directorate (EUAŞ), and Mine Survey and Analysis General Directorate (MTA). In 2010, 48% of brown coal production was from the eight enterprises of the General Directorate of Turkish Coal (TKİ), while 38% was realized by EUAŞ Afşin-Elbistan establishment that supplies coal to the Afşin-Elbistan Thermal Power Plant. The remaining 14% was realized by a number of small-to medium scale private companies.

In this study, the efficiencies of the eight establishments of the Turkish Coal Enterprises (TKI) between 2006 and 2009 were analyzed by using Data Envelopment Analysis (DEA), Super Efficiency (SE) and Malmquist Total Factor Productivity Index (MI) methodologies.

If we put aside EÜAŞ, whose main area of activity is generating electricity, TKİ is in a dominant position in the Turkish lignite sector. Therefore, that the eight enterprises of TKİ having been included within the scope of this study is important.

For the analyses, three output oriented models were constructed and used: Model 1: Production Efficiency, Model 2: Revenue Efficiency and Model 3:Work Safety Efficiency. In determining the input and output data used in the analyses, it was benefited from similar studies searched in the literature, knowledge of business and economics and a series of brainstorming of the expert panel consisting of ten high level representatives of the public and private lignite mining companies as well as that of the Turkish Ministry of Energy and Natural Resources.

As a part of the analyses, first the production and revenue efficiencies of the establishments were analyzed by using CRS and VRS methods of DEA. Within this context, efficient and inefficient establishments for the years between 2006 and 2009, and benchmarks for inefficient establishments to move to becoming efficient were determined. Furthermore, the target values and improvement potentials for the inefficient establishments to becoming more efficient were calculated by using 2009 realized values of inputs and outputs.

Second, the efficiency rankings of the efficient establishments among themselves between 2006 and 2009 were determined by using SE methodology.

Third, to provide the dynamic analysis of the development of the establishments' efficiency levels in time, the changes of production, revenue and work safety efficiencies of the establishments between 2006 and 2009 were analyzed using the Malmquist Index (MI) methodology. MI analyses included the analysis of the efficiencies in four efficiency components (Technical, Technological, Pure and Scale efficiencies) as well as the calculation of the Total Factor Productivity Indexes of the establishments.

The detailed evaluations of the DEA, SE and MI analyses results of Model 1 (Production Efficiency), Model 2 (Revenue Efficiency) and Model 3 (Work Safety Efficiency), and recommendations for each establishment based on the results, including target values and potential improvements, were provided in Sections 5.3 and 5.4.

Because VRS analysis excludes the scale efficiency in determining the efficient establishments compared to CRS analysis which requires scale and pure technical efficiencies together, the conclusions and recommendations here were preferred to base on CRS analyses results. This was because of the importance of the scale efficiencies and inefficiencies for the operations of the establishments of TKİ. For other studies where scale efficiency were not critical, VRS analyses results could be preferred. However inclusion of CRS and VRS analyses together into the study was beneficial in seeing how the list of efficient establishments were changing when the scale efficiency condition is ignored.

6.1 Conclusions on the DEA and SE Analyses Results

Production Efficiency

According to the CRS analyses of Production Efficiency model, YENİKÖY was the most efficient establishment among the eight establishments of TKİ. YENİKÖY was efficient for all the years between 2006 and 2009. Except for 2006, SEYİTÖMER was efficient for the remaining years between 2006 and 2009.

In the CRS-SE analyses for the years 2007 to 2009 when the number of efficient establishments was two, YENİKÖY came first, and SEYİTÖMER came second in the efficiency ranking of efficient establishments. This means that YENİKÖY was more successful in transforming its inputs to the lignite production compared to other establishments. SEYİTÖMER was the second most efficient establishment after YENİKÖY in utilizing its inputs in the lignite production process.

GARP and ILGIN were the most inefficient establishments sharing last two places in the ranking between 2006 and 2009.

Revenue Efficiency

According to the CRS analyses of Revenue Efficiency model, YENİKÖY was the most efficient establishment among the eight establishments of TKİ. YENİKÖY was efficient for all the years between 2006 and 2009. SEYİTÖMER was the second most efficient establishment after YENİKÖY. Except for 2006, SEYİTÖMER was efficient for the remaining years between 2006 and 2009. EGESOMA was the third efficient establishment. EGESOMA was efficient in 2008, and very close to the efficiency frontier in 2009 (with 100,64 efficiency score). It can be said that EGESOMA improved its efficiency level in time between 2006 and 2009.

In the CRS-SE analyses for 2008 when the number of efficient establishments was three, and for the years 2007 to 2009 when the number of efficient establishments was two, YENİKÖY came first, SEYİTÖMER came second and EGESOMA came third in the efficiency ranking of efficient establishments. This means that YENİKÖY was more successful in transforming its inputs to the sales revenue compared to other establishments. SEYİTÖMER was the second, and EGESOMA was the third most efficient establishment after YENİKÖY in utilizing its inputs in generating sales revenue.

BURSA and ILGIN were the most inefficient establishments sharing last two places in the ranking between 2006 and 2009.

Target values and improvement potentials

By using the 2009 CRS analyses results, benchmarks, target values and improvement potentials for inefficient establishments to move becoming more efficient for Production Efficiency and Revenue Efficiency models were provided in Section 5.3.4 based on the 2009 realized values of inputs and outputs.

6.2 Conclusions on the MI Analyses Results

Production Efficiency

According to the MI analyses, when the 8 establishments of TKİ are considered as a whole in terms of **production efficiency,** while there was 6% improvement in their technical efficiencies which is a sign of efficiency in transforming their inputs to outputs, there was a 4% decrease in technological efficiencies. An improvement of 2% in scale efficiency and 3% of pure efficiency contributed to the increase in technical efficiency of establishments. This means that TKİ establishments as a whole made slight improvements in their scale and managerial efficiencies between 2006 and 2009. Although there was a 4% decrease in technological efficiencies of the establishments, due to the 6% improvement in technical efficiency, total factor productivity (TFP) index of the establishments improved 1% during 2006-2009 period.

There was a 15,1% improvement in technological efficiency of the 8 establishments together in 2008. In order to increase TFP index as a whole, measures should be taken by TKI authorities to keep the technological efficiency of the establishments at higher levels as was the case in 2008.

In pure efficiency of the establishments, which is a sign of managerial efficiency, there was a 3% improvement in the period between 2006 and 2009. However, the 15% improvement realized in 2007 was not be maintained in 2008 and 2009. There was a 1% improvement in 2008 and a 4% decrease in 2009 in pure efficiencies of the establishments. This shows that TKI establishments are able to improve managerial efficiency at higher rates as was the case in 2007. In this respect, TKI authorities should develop new managerial strategies and review the organizational structure of the establishments so that they can eliminate inefficiencies in the management of the establishments.

Although there was a 9% improvement in the scale efficiency of the establishments as a whole in 2008, the improvement of scale efficiency between the 2006 to 2009 period was less than this, at 2%. In order to lead the establishments operate at appropriate scales, TKİ authorities should take necessary measures such as restructuring the activities of the establishments by considering realized values, target values and improvement potentials in the inputs and outputs of the establishments as given in Section 5.3.4.

In terms of TFP index, while there was a 25% improvement in 2008, there was an 8% drop in 2009. The reason for this drop might be the decrease in power demand in Turkey in 2009 due to the global economic crises, because the main market for the lignite produced by TKİ establishments is the power sector. This means that the lignite production of TKİ establishments is very sensitive to the developments in the power market. Therefore, TKİ authorities should follow the power market developments closely, develop alternative market strategies, and develop scenarios to prepare the establishments to the worst or best cases.

Revenue Efficiency

According to the MI analyses, when the 8 establishments of TKİ are considered as a whole in terms of **revenue efficiency,** there was a 4% improvement in the technical efficiencies and a 10% improvement in the technological efficiencies of establishments. An improvement of 3% in scale efficiency and 1% in pure efficiency contributed to the increase in technical efficiency of establishments. This means that TKİ establishments as a whole made slight improvements in their scale and managerial efficiencies between 2006 and 2009. In addition to the improvement in technical efficiency, a 10% decrease in technological efficiency caused a 14% improvement in TFP index of the establishments during 2006-2009 period.

While there was an 9% improvement in technical efficiency of the establishments in 2007, this high rate of improvement could not be maintained in 2008 and 2009. Similarly, the improvement in technological efficiency which was 23% in 2008 dropped to 7% in 2009. Keeping the improvement in technological efficiency high is important in order to increase the TFP index. Therefore, TKI authorities should take measures to increase the technological efficiency of the establishments as was done in 2008.

In pure efficiency of the establishments which is a sign of managerial efficiency, there was a 1% improvement in the period between 2006 and 2009. However, the 6% improvement realized in 2007 could not be maintained in 2008 and 2009. There was a 3% drop in 2008 and a 1% drop in 2009 in pure efficiencies of the establishments. This shows that TKI establishments are able to improve managerial efficiency at higher rates as was the case in 2007. In this respect, TKI authorities should develop new managerial strategies and review the organizational structure of the establishments so that they can eliminate inefficiencies in the management of the establishments.

Although there was a 4% improvement in the scale efficiency of the establishments as a whole in 2008, the 3% improvement of scale efficiency between 2006-2009 period was less than this. In order to provide the establishments with operating at appropriate scales, TKİ authorities should take necessary measures such as restructuring the activities of the establishments by considering realized values, target values and improvement potentials in the inputs and outputs of the establishments as given in Section 5.3.4.

In terms of TFP index, while there was a 25% improvement in 2008, there was an 8% drop in 2009. TFP index of the establishments as a whole increased 14% during 2006-2009 period. The reason for the drop in TFP index in 2009 might be the decrease in power demand in Turkey in 2009 due to the global economic crises, because the main market for the lignite produced by TKİ establishments is the power sector. This means that the lignite production of TKİ establishments is very sensitive to the developments in the power market. Therefore, TKİ authorities should follow the power market developments closely, develop alternative market strategies, and develop scenarios to prepare the establishments to the worst or best cases.

Work Safety Efficiency

According to the MI analyses, when the 8 establishments of TKİ are considered as a whole in terms of **work safety efficiency,** there were improvements in the all efficiency indexes except for scale efficiency. This shows that the efficiencies of the establishments improved during 2006 to 2009 period in combating with the accidents.

Because of the 5% increase in technical efficiency and 34% increase in technological efficiency, TFP index improved 41% during 2006-2009 period. In this period an 11% increase in pure efficiency contributed to the improvement in the technical efficiency positively while a 5% drop in scale efficiency affected negatively. The biggest improvement in TFP index occurred in 2008, triggered by huge improvement in technological efficiency. This means that the 8 establishments as a whole were successful in utilizing their inputs to decrease the number of accidents during 2006 to 2009. More important than this, the efficiency frontier of the establishments shifted upward as a result of the high improvement in technological efficiency which means again that TKİ establishments as a whole improved their technologies in work safety.

The improvement in pure efficiency shows that managerial efficiency in work safety during 2006 to 2009 was also improved; however, the drop in scale efficiency should signal the TKİ authorities to take measures for the establishments to operate at appropriate scales in reducing the accidents.

Another important observation in terms of the work safety efficiency is related to the drops in the efficiency indexes of YENİKÖY and GARP establishments. During the 2006 to 2009 period, there was a 31% drop in technical efficiency, an 11% drop in technological efficiency, a 31% drop in scale efficiency, and as a result a 39% drop in TFP index of YENİKÖY. Similarly, there was a 24% drop in technical efficiency mostly triggered by 39% drop in pure efficiency, and a 15% drop in TFP index of GARP. This means that those establishments did not use their inputs in reducing the number of accidents efficiently. With the inputs provided, they could perform better compared to other establishments in reducing the accidents. Therefore, TKİ authorities should understand the reasons behind these decreases in work safety performances of YENİKÖY and GARP establishments, and should develop measures by taking the best practices of efficient establishments.

6.3 Contribution to the Research and Recommendations for Future Studies

In the literature survey it was observed that the applications of DEA, SE and MI methodologies in the efficiency assessments of profit and non-profit organizations have been rising.

However, the applications of the methodologies in the mining sector were limited compared to other sectors. Especially in Turkey, there have been a limited number of studies using those models in the mining sector.

Furthermore, although the individual applications of DEA, SE and MI methodologies were found in the literature, the applications of the three models together have not been met with, at least in the mining sector.

Therefore, this study using the DEA, SE and MI methodologies together is definitely a contribution to the literature, and a guide for the researchers in the subject.

This study is also an important contribution in practice for TKİ authorities to observe the efficiency analyses of the TKİ establishments, and other organizations in being familiar with new tools and approaches in assessing their efficiencies.

The selection of the inputs and outputs are the most critical stage in DEA, SE and MI analyses. Especially the relevance of inputs in relation to the outputs is critical, and a special care must be shown in selecting the inputs from a set of inputs if exist.

In this study the inputs and outputs were comprehensive enough, and the relevance of inputs in relation to outputs was obvious through basic knowledge in business and economics. Although this was the case, it was also benefited from the opinions of the expert panel through a subjective brain storming methodology.

However, in studies where a number of alternatives for inputs and outputs selection exist, some other statistical methodologies such as correlation and factor analysis techniques may suit best in determining the level of relevance between inputs and outputs, and ultimately resulting in the selection of best inputs and outputs combinations.

Inclusion of CRS and VRS analyses together into this study was beneficial in seeing how the list of efficient establishments were changing when the scale efficiency condition is ignored, because VRS analysis excludes the scale efficiency in determining the efficient establishments compared to CRS analysis which requires scale and pure technical efficiencies together. For TKİ establishments, the operating scales were important in assessing their efficiencies, and therefore in developing recommendations and conclusions

CRS analyses results were taken as reference. However, in other studies where scale efficiency is not critical, VRS analyses results could also be preferred.

The aim of this study was to perform efficiency analysis of the establishments of TKİ by using the DEA, SE and MI methodologies. Extensions of this study is possible by applying those methodologies to other mining business units such as Turkish Hard Coal Enterprises (TTK), ETİMADEN, and private companies.

Furthermore, the efficiency analysis of TKİ with respect to other selected coal producing companies in other countries in the world would be an important future study in the subject.

REFERENCES

Abbott, M., “The productivity and efficiency of the Australian electricity supply industry”, Energy Economics, Vol. 28, pp. 444-454, 2006.

Ahn, T.S., “Efficiency Related Issues in Higher Education: A Data Envelopment Analysis Approach”, Ph.D. Thesis, The University Of Texas at Austin, Texas, pp. 14-47, 1987.

Andersen, P., Petersen, N.C., “A Procedure for Ranking Efficient Units in Data Envelopment Analysis”, Management Science, Vol. 39, No. 10, pp.1261-1264, 1993.

Aslankaraoğlu, N., “Veri Zarflama Analizi ve Temel Bileşenler Analizi ile AB Ülkelerinin Sıralanması”, M.S. Thesis, Gazi University Fen Bilimleri Enstitüsü, 2006.

Atan, M., “Türkiye Bankacılık Sektöründe Veri Zarflama Analizi ile Bilançoya Dayalı Mali Etkinlik ve Verimlilik Analizi”, Ekonomik Yaklaşım Dergisi”, Cilt No: 48, Sayı: 14, pp. 211

Athanassopoulos, A., “Assessing the comparative spatial disadvantage (CSD) of regions in the European Union using non-radial data envelopment analysis methods”, European Journal of Operational Research, Vol.94 (3), pp.439-452, 1996.

Banker, R.D., Charnes, A., Cooper, W. W., "Some models for estimating technical and scale inefficiencies in data envelopment analysis”, Management Science, Vol. 30(9), pp. 1078-1092, 1984.

Banker, R.D., Conrad, R.F, Strauss, R.P., “A comparative application of data envelopment analysis and translog methods: An illustrative study of hospital production” Management Science, Vol. 32, pp. 30-44 1986.

Banker, R.D., Charnes A., Cooper, W. W., "Some models for estimating technical and scale inefficiencies in data envelopment analysis”, Management Science, Vol. 30(9), pp.1078-1092, 1984.

Banker, R., Thrall, R., “Estimation of returns to scale using Data Envelopment Analysis”, European Journal Of Operational Research, Vol., 62(1), pp. 74-84, 1992.

Banker, R., “Estimating Most Productive Scale Size Using Data Envelopment Analysis”, European Journal Of Operational Research, Vol. 17(1), pp. 35-44, 1984.

Banker, R., Charnes. A., Cooper, W., Schinnar, A., “A Bi-Extremal Principle for Frontier Estimation and Efficiency Evaluations”, Management Science, Vol. 27(12), pp. 1370-1382, 1981.

Banker, R.D., Conrad, R.F., Strauss, R.P., “A comparative application of data envelopment analysis and translog methods: An illustrative study of hospital production”, Management Science, Vol.32, pp. 30-44, 1986.

Barros, C. P., “Efficiency Analysis of hydroelectric generating plants”, Energy Economics, Vol. 30, pp. 59-75, 2008.

Boussofiane A., Dyson, R.G., Thanassoulis, E. “Applied Data Envelopment Analysis”, European Journal of Operational Research, Vol. 52, pp. 1-15, 1991.

Bowlin W.F., “An Analysis of the Financial Performance of Defense Business Segments Using Data Envelopment Analysis”, Journal of Accounting and Public Policy, Vol. 18(4/5), pp. 287-310, 1999.

Bowlin, W.F., “Evaluating the Efficiency of US Air Force Real-Property Maintenance Activities”, Journal of The Operational Research Society, Vol. 38 (2), pp. 127-35, 1987.

BP, “Statistical Review of World Energy June 2011”, London, 2011

Caves, D.W., Christensen, L.R., Diewert, W.E., “The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity”, Econometrica, Vol. 50, No. 6, 1982.

Charnes A., Cooper, W., Rhodes, E., “Measuring the efficiency of decision making units”, European Journal of Operational Research, Vol.2., pp. 429-444, 1978.

Charnes, A., Cooper, W.W., Rhodes, E., “Short Communication: Measuring the Efficiency of Decision Making Units”, European Journal of Operational Research, Vol. 3(4), p. 339, 1979.

Charnes, A., Cooper, W., “Programming with linear fractional functionals”, Naval Research Logistics Quarterly, Vol. 9, pp. 181-185, 1962.

Charnes. A., Cooper. W., “An Explicit General Solution in Linear Fractional Programming”, Naval Research Logistics Quarterly, Vol. 20, pp. 449-467, 1973.

Chen, T., “A measurement of the resource utilization efficiency of university libraries”, International Journal of Production Economics, Vol.53, pp. 71-80, 1997.

Chen, Y., Liang, L., Yang, F., Zhu, J., ”Evaluation Of Information Technology Investment: A Data Envelopment Analysis Approach”, Computers & Operations Research, Vol. 33, pp.1368–1379, 2006.

Cingi, S., Tarım, A., “Türk Banka Sisteminde Performans Ölçümü: DEA- Malmquist TFP Endeksi Uygulaması”, TBB Araştırma Tebliğleri Serisi, Vol. 01, pp. 9-11, 2000.

Coelli, T., “A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program, CEPA Working Paper 96/08”, Center for Productivity Analysis, Department of Econometrics, University of England, Australia, 1996.

Drake, L., Simper, R. ,”The measurement of English and Welsh police force efficiency: A comparison of distance function models”, European Journal of Operational Research, Vol. 147, pp. 165-186, 2002.

Düzakın, E., Düzakın, H., "Measuring the performance of manufacturing firms with super slacks based model of data envelopment analysis: An application of 500 major industrial enterprises in Turkey", European Journal of Operational Research, Vol. 182, pp. 1412-1432, 2007

Easton, L., Murphy D. J., Pearson J.N., "Purchasing Performance Evaluation: With Data Envelopment Analysis", European Journal of Purchasing & Supply Management, Vol. 8, pp. 123–134, 2002.

EPDK, "Elektrik Piyasası, Lisans", www.epdk.gov.tr, last visited on August 08, 2011.

Estache, A., Rossi, M. A., "Do regulation and ownership drive the efficiency of electric distribution? Evidence from Latin America", Economics Letter, Vol. 86, pp. 253-257, 2005.

Ethelene, W. "Academic Library Performance Measures And Undergraduates' Library Use And Educational Outcomes", Library & Information Science Research, Vol.24, pp. 107–128, 2002.

ETKB, "İstatistik", www.enerji.gov.tr, last visited on August 08, 2011a.

ETKB, "Enerji, Elektrik", www.enerji.gov.tr, last visited on August 08, 2011b.

Fare, R., Grosskoph, S., Lovell, C., "Production Frontiers", Cambridge University Press, 1994.

Fare. R., Grosskoph, S., Norrys, M., Zhang, Z., "Productivity Growth. Technical Progress and Efficiency Changes in Industrialized Countries", American Economic Review Vol. 84, pp. 66–83, 1994.

Fare. R., Grosskopf, S., Lovell, C., "The Structure of Technical Efficiency", Scandinavian Journal Of Economics, Vol. 85(2), pp. 181-90, 1983.

Gattoufi, S., Oral M., Reisman A., "A Taxonomy For Data Envelopment Analysis", Socio-Economic Planning Sciences, Vol. 38, pp. 141–158, 2004.

Gattoufi, S., Oral, M., Reisman, A., "Data Envelopment Analysis Literature: A Bibliography Update (1951-2001) ", Socio-Economic Planning Sciences, in Press, 2003.

Hammond, C. J.," Efficiency In The Provision Of Public Services: A Data Envelopment Analysis Of UK Public Library Systems", Applied Economics, Vol. 34, pp. 649-657 2002.

Hawdon, D., "Efficiency, performance and regulation of the international gas industry", Energy Policy, Vol. 31, pp. 1167-1178, 2003.

Hong, F., Wu, J., Zeng, C., "Comparative study on efficiency performance of listed coal mining companies in China and the US", Energy Policy, Vol. 37, pp. 5140-5148, 2009.

IEA, "World Energy Outlook 2010", International Energy Agency, Paris, 2010a.

IEA, "Energy Policies of Countries Turkey 2009 Review", International Energy Agency, Paris, 2010b.

IEA Statistics, “Coal Information 2010”, International Energy Agency, Paris, 2010c.

IEA, “Key World Energy Statistics 2010”, International Energy Agency, Paris, 2010d.

IEA, “Statistics and Balance”, www.iea.org, last visited on August 08, 2011a.

IEA Statistics, “Coal Information 2010”, International Energy Agency, Paris, 2011b.

Jamasb, T., Pollitt, M., Triebs, T., “Productivity and efficiency of US gas transmission companies: A European regulatory perspective”, Energy Policy, Vol. 36, pp. 3398-3412, 2008.

Johnes, J. ”Data Envelopment Analysis And Its Application to The Measurement of Efficiency in Higher Education”, Economics of Education Review, in Press, 2005.

Kao, C., Hung, H., ”Efficiency Analysis of University Departments: An Empirical Study”, The International Journal of Management Science, in Press, 2006.

Kahraman, C., Ulukan, Z., Tolga, E., “Selection among advanced manufacturing technologies using fuzzy data envelopment analysis”, Tatra Mountains Mathematical Publications, Vol. 16, pp. 1-13, 1999.

Kasap, Y., “Türkiye Kömür Madenciliğinde Etkinlik ve Verimlilik Gelişimi: Veri Zarflama Analizi”, Doktora Tezi, Eskişehir Osmangazi Üniversitesi Maden Mühendisliği Bölümü, Nisan 2008.

Kulshreshtha, M., Parikh, J. K., “Study of efficiency and productivity growth in opencast and underground coal mining in India: a DEA analysis”, Energy Economics, Vol. 24, pp. 439-453, 2002.

Lei, T., Ri-jia, D., “Efficiency assessment of coal mine safety input by data envelopment analysis”, Journal of China University of Mining and Technology, Vol. 18, pp. 0088-0092, 2008.

Lewin, A.Y., Morey, R.C., “Measuring the Relative Efficiency and Output Potential of Public Sector Organizations: An Application of Data Development Analysis”, International Journal of Policy Analysis and Information Systems, Vol. 5(4), pp. 267-285, 1981.

Mao, W., Koo, W., “Productivity Growth, Technological Progress, and Efficiency Change In Chinese Agriculture After Rural Economic Reforms: A DEA Approach”, China Economic Review, Vol. 8(2), pp. 157-174, 1997.

Martic, M., Savic, G., “An application of DEA for comparative analysis and ranking of regions in Serbia with regards to social-economic development”, European Journal of Operational Research, Vol. 132, pp. 343-356, 2001.

MTA Genel Müdürlüğü, “Türkiye Linyit Envanteri”, Envanter Serisi-202, Ankara, 2010.

Mukherjee, K., “Energy use efficiency in the Indian manufacturing sector: An interstate analysis”, Energy Policy, Vol. 36, pp. 662-672, 2008.

Mukherjee, K., “Energy use efficiency in U.S. manufacturing: A nonparametric analysis”, Energy Economics, Vol. 30, pp. 76-96, 2008.

Nicholson, W., “Microeconomic Theory, Basic Principles and Extensions, Fourth Edition”, The Dreyden Press, a division of Holt, Rinehart and Winston, Inc., pp. 671-697, USA, 1989.

Norman, M., Stoker, B., “Data Envelopment Analysis : The Assessment of Performance”. Waley, New York. (7):29-35 (1991).

Özyigit, T., “Gelismekte Olan Ülkelerin Göreli Sosyo-Ekonomik Performanslarının Degerlendirilmesi”, M.S. Thesis, “Galatasaray Üniversitesi Fen Bilimleri Enstitüsü, Istanbul, xi 2000.

Ramos-Real, F. J., Tovar, B., Iootty, M., Almeida, E. F., Pinto, H. Q., “The evolution and main determinants of productivity in Brazilian electricity distribution 1998-2005: An empirical analysis, Energy Economics, Vol. 31, pp. 298-305, 2009.

Ran, J., Hui, L., “Performance efficiency of listed coal firms”, Finance and Economy, pp. 181-182, 2006.

Retzlaff, R.D.L., “A Data Envelopment Analysis approach to Discriminant Analysis”, Annals of Operations Research, Vol.73, pp.299-321, 1997.

Reyes, R. P., Tovar, B., “Explaining the inefficiency of electrical distribution companies: Peruvian firms”, Energy Economics, in pres, 2010.

Roll, Y., Golany, B. Seroussy, D. “Measuring The Efficiency Of Maintenance Units in The Israeli Air Force”, European Journal of Operational Research,Vol.43(2), pp. 136-42 1989.

Ruggiero, J.,” Measurement Error, Education Production And Data Envelopment Analysis”, Economics of Education Review**,** in Press (2005)

Scheel, H., “EMS: Efficiency Measurement System User’s Manual”, Version 1.3, 2000.

Schiller, B. R., “The Economy Today, Fifth Edition”, McGraw-Hill, Inc., pp. 6, USA, 1991.

Sengupta, J.K., “A fuzzy systems approach in data envelopment analysis”, Computers. And Mathematical Applications, Vol. 24, pp. 259-266, 1992.

Sharma, K. R., Leung, P. S. and Zane, L., “Performance Measurement Of Hawaii State Public Libraries: An Application Of Data Envelopment Analysis”, Agricultural and Resource Economics Review, Vol. 28, pp. 190-198, 1999.

Sherman, H.D. “Data Envelopment Analysis as a New Managerial Audit Methodology-Test And Evaluation”, A Journal Of Practice and Theory, Vol. 4(1), pp. 35-52, 1984.

Shim, W., “Applying DEA Technique to Library Evaluation in Academic Research Libraries”, Library Trends, Vol. 51(3), pp. 312-332, 2003.

Shim, W., “Assessing technical efficiency of research libraries”, Advances in Library Administration and Organization, Vol. 17, pp. 243-339, 2000.

Sözen, A., Alp, İ.. “Comparison of Turkey's Performance of Greenhouse Gas Emissions and Local/Regional Pollutants with EU Countries”, Energy Policy, Vol.37(12), pp. 5007-5018, 2009.

Sözen, A., Alp, İ., Özdemir, A., "Assessment of Operational and Environmental Performance of the Thermal Power Plants in Turkey by Using Data Envelopment Analysis", Energy Policy, Vol. 38, pp. 6194-6203, 2010.

Sözen, A., "Course notes and handouts", Gazi UniversityTechnology Facultyi, 2010.

TEİAŞ Genel Müdürlüğü, "Türkiye Elektrik İstatistikleri", www.teias.gov.tr, last visited on August 08, 2011a.

TKİ Genel Müdürlüğü, "2006 Yılı Faaliyet Raporu", www.tki.gov.tr, last visited on August 08, 2011a.

TKİ Genel Müdürlüğü, "2007 Yılı Faaliyet Raporu", www.tki.gov.tr, last visited on August 08, 2011b.

TKİ Genel Müdürlüğü, "2008 Yılı Faaliyet Raporu", www.tki.gov.tr, last visited on August 08, 2011c.

TKİ Genel Müdürlüğü, "2009 Yılı Faaliyet Raporu", www.tki.gov.tr, last visited on August 08, 2011d.

TKİ Genel Müdürlüğü, "2010 Yılı Faaliyet Raporu", www.tki.gov.tr, last visited on August 08, 2011e.

TKİ Genel Müdürlüğü, "Konu: Bilgi Talebi", TKİ Genel Müdürlüğünün 1428 sayılı teyit yazısı, 08.07.2011f.

TTK Genel Müdürlüğü, "Taşkömürü Sektör Raporu", www.taskomuru.gov.tr, last visited on August 08, 2011a.

TTK Genel Müdürlüğü, "İstatistik Yıllığı 2010", www.taskomuru.gov.tr, last visited on August 08, 2011b.

Ünalan, G. "Kömür Jeolojisi", Maden Tetkik ve Arama Genel Müdürlüğü, Eğitim Serisi-41, Ankara, 2010.

Wang, J. H., Ngan, H. W., Engriwan, W., Lo, K. L., "Performance based regulation of the electricity supply industry in Hong Kong: An empirical efficiency analysis approach", Energy Policy, Vol. 35, pp. 609-615, 2007.

Wang, S. N., Yi, R. H., Wang, W., "Evaluating the performances of decision-making units based on interval efficiencies", Journal of Computational and Applied Mathematics, Vol. 216, pp. 328-343, 2008.

Wei, Y., Liao, H., Fan, Y., "An empirical analysis of energy efficiency in China's iron and steel sector", Energy, Vol. 32, pp. 2262-2270, 2007.

Wei, X., Wang, I., "Efficiency evaluation of listed coal companies in China by DEA model", Statistics and Decision-making, December, pp.61-63, 2005.

Wolf, C, "Does ownership matter? The performance and efficiency of State Oil vs. Private oil (1987-2006)", Energy Policy, Vol. 37, pp. 2642-2652, 2009.

Vaninsky, A., “Efficiency of electric power generation in the United States: Analysis and forecast based on data envelopment analysis”, Energy Economics, Vol. 28, pp. 326-338, 2006.

Vassiloglou, M., Giokas, D., “A Study of the Relative Efficiency of Bank Branches: an Application of Data Envelopment Analysis”, Journal of the Operational Research Society, Vol. 41(7), pp. 591-7, 1990.

Vitaliano, D. F., “Assessing Public Library Efficiency Using Data Envelopment Analysis”, Annals of Public and Cooperative Economics, Vol.69 (1), pp. 107-122, 1998.

Yu, M., “Measuring Physical Efficiency of Domestic Airports in Taiwan with Undesirable Outputs And Environmental Factor”, Journal of Air Transport Management, Vol. 10, pp. 295–303, 2004.

Yun, Y.B., Nakayama, H., Tanino, T., “A Generalized Model For Data Envelopment Analysis”, European Journal of Operational Research, Vol. 157, pp. 87–105, 2004.

Zhang, X., Huang, G. H., Lin, Q., Yu, H., “Petroleum-contaminated groundwater remediation system design: A data envelopment analysis based approach”, Expert Systems with Applications, Vol. 36, pp. 5666-5672, 2009.

Zhu, J., “Data envelopment analysis vs. principal component analysis: An illustrative study of economic performance of Chinese cities”, European Journal of Operational Research, Vol. 111, pp. 50-61, 1998.

APPENDICES

Appendix 1. Malmquist Index Analyses DEAP Computer Outputs

MODEL 1

Results from DEAP Version 2.1
Output orientated Malmquist DEA

MALMQUIST INDEX SUMMARY

year = 2007

firm	effch	techch	pech	sech	tfpch
1	1.416	0.802	1.000	1.416	1.135
2	1.545	1.009	1.553	0.995	1.559
3	1.226	0.769	1.074	1.142	0.943
4	1.000	0.876	1.000	1.000	0.876
5	1.219	0.765	0.935	1.303	0.932
6	0.327	0.798	1.000	0.327	0.261
7	1.419	0.810	1.414	1.004	1.150
8	1.387	0.787	1.419	0.978	1.092

year = 2008

firm	effch	techch	pech	sech	tfpch
1	1.074	1.017	1.000	1.074	1.092
2	0.841	1.328	0.816	1.030	1.117
3	1.035	1.107	1.124	0.920	1.145
4	1.000	1.160	1.000	1.000	1.160
5	0.901	1.110	0.994	0.906	1.000
6	2.168	1.168	1.000	2.168	2.532
7	1.000	1.163	1.000	1.000	1.163
8	1.057	1.180	1.064	0.994	1.248

year = 2009

firm	effch	techch	pech	sech	tfpch
1	0.946	0.837	1.000	0.946	0.792
2	1.002	0.834	0.971	1.032	0.836
3	0.964	0.850	0.903	1.068	0.819
4	1.000	0.891	1.000	1.000	0.891
5	1.048	0.938	1.043	1.004	0.983
6	1.194	1.026	1.000	1.194	1.225
7	1.000	1.058	1.000	1.000	1.058
8	0.811	1.018	0.794	1.021	0.825

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2007	1.097	0.824	1.153	0.952	0.904
2008	1.086	1.151	0.996	1.090	1.250
2009	0.991	0.928	0.961	1.031	0.919
Mean	**1.057**	**0.958**	**1.033**	**1.023**	**1.013**

MALMQUIST INDEX SUMMARY OF FIRM MEANS

firm	effch	techch	pech	sech	tfpch
1	1.129	0.880	1.000	1.129	0.994
2	1.092	1.038	1.072	1.019	1.133
3	1.069	0.898	1.029	1.039	0.960
4	1.000	0.968	1.000	1.000	0.968
5	1.048	0.927	0.990	1.058	0.971
6	0.946	0.985	1.000	0.946	0.932
7	1.124	0.999	1.122	1.001	1.123
8	1.060	0.981	1.062	0.998	1.040
Mean	**1.057**	**0.958**	**1.033**	**1.023**	**1.013**

[Note that all Malmquist index averages are geometric means]

MODEL 2

Results from DEAP Version 2.1

Output orientated Malmquist DEA

MALMQUIST INDEX SUMMARY

year = 2007

firm	effch	techch	pech	sech	tfpch
1	1.290	0.957	1.000	1.290	1.235
2	1.172	1.205	1.174	0.999	1.412
3	1.285	0.936	1.202	1.069	1.202
4	1.000	1.049	1.000	1.000	1.049
5	1.102	0.918	0.824	1.336	1.011
6	0.684	1.018	1.000	0.684	0.697
7	1.199	1.051	1.196	1.003	1.261
8	1.129	0.986	1.149	0.982	1.113
Mean	**1.089**	**1.012**	**1.060**	**1.027**	**1.102**

year = 2008

firm	effch	techch	pech	sech	tfpch
1	1.123	1.098	1.000	1.123	1.233
2	0.795	1.401	0.777	1.023	1.114
3	1.021	1.161	1.007	1.013	1.185
4	1.000	1.230	1.000	1.000	1.230
5	0.969	1.163	0.982	0.987	1.127
6	1.212	1.265	1.000	1.212	1.534
7	1.000	1.256	1.000	1.000	1.256
8	1.047	1.292	1.056	0.991	1.353
Mean	**1.014**	**1.230**	**0.974**	**1.041**	**1.248**

year = 2009

firm	effch	techch	pech	sech	tfpch
1	0.994	0.971	1.000	0.994	0.965
2	1.039	0.961	1.008	1.031	0.999
3	0.910	1.039	0.909	1.002	0.945
4	1.000	1.019	1.000	1.000	1.019
5	1.042	1.092	1.255	0.830	1.137
6	1.296	1.154	1.000	1.296	1.495
7	1.000	1.208	1.000	1.000	1.208
8	0.859	1.141	0.837	1.026	0.981
Mean	**1.011**	**1.070**	**0.995**	**1.016**	**1.081**

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2007	1.089	1.012	1.060	1.027	1.102
2008	1.014	1.230	0.974	1.041	1.248
2009	1.011	1.070	0.995	1.016	1.081
Mean	**1.038**	**1.100**	**1.009**	**1.028**	**1.141**

MALMQUIST INDEX SUMMARY OF FIRM MEANS

firm	effch	techch	pech	sech	tfpch
1	1.129	1.007	1.000	1.129	1.137
2	0.989	1.175	0.972	1.017	1.163
3	1.061	1.041	1.032	1.027	1.104
4	1.000	1.096	1.000	1.000	1.096
5	1.036	1.052	1.005	1.030	1.090
6	1.024	1.141	1.000	1.024	1.169
7	1.062	1.168	1.061	1.001	1.241
8	1.005	1.133	1.006	1.000	1.139
Mean	**1.038**	**1.100**	**1.009**	**1.028**	**1.141**

[Note that all Malmquist index averages are geometric means]

MODEL 3

Results from DEAP Version 2.1
Output orientated Malmquist DEA

MALMQUIST INDEX SUMMARY

year = 2007

firm	effch	techch	pech	sech	tfpch
1	14.533	0.488	14.194	1.024	7.091
2	1.000	1.647	1.000	1.000	1.647
3	3.591	1.369	3.853	0.932	4.916
4	1.000	0.273	1.000	1.000	0.273
5	0.164	0.328	0.103	1.595	0.054
6	1.000	1.151	1.000	1.000	1.151
7	0.855	0.958	0.865	0.989	0.820
8	1.000	0.458	1.000	1.000	0.458
Mean	**1.283**	**0.687**	**1.219**	**1.052**	**0.882**

year = 2008

firm	effch	techch	pech	sech	tfpch
1	0.023	7.184	0.059	0.394	0.167
2	1.000	0.418	1.000	1.000	0.418
3	1.176	2.999	1.000	1.176	3.528
4	0.758	7.433	1.000	0.758	5.635
5	0.618	8.449	0.577	1.072	5.223
6	1.000	1.794	1.000	1.000	1.794
7	0.694	13.070	0.826	0.840	9.073
8	1.000	4.272	1.000	1.000	4.272
Mean	**0.554**	**3.928**	**0.640**	**0.866**	**2.177**

year = 2009

firm	effch	techch	pech	sech	tfpch
1	43.000	0.546	16.921	2.541	23.482
2	1.000	5.002	1.000	1.000	5.002
3	0.368	0.364	1.000	0.368	0.134
4	0.432	0.347	1.000	0.432	0.150
5	4.385	0.500	3.884	1.129	2.194
6	1.000	3.376	1.000	1.000	3.376
7	1.684	2.788	1.400	1.203	4.696
8	1.000	0.234	1.000	1.000	0.234
Mean	**1.633**	**0.886**	**1.760**	**0.928**	**1.446**

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2007	1.283	0.687	1.219	1.052	0.882
2008	0.554	3.928	0.640	0.866	2.177
2009	1.633	0.886	1.760	0.928	1.446
Mean	**1.051**	**1.337**	**1.111**	**0.946**	**1.406**

MALMQUIST INDEX SUMMARY OF FIRM MEANS

firm	effch	techch	pech	sech	tfpch
1	2.440	1.242	2.421	1.008	3.030
2	1.000	1.510	1.000	1.000	1.510
3	1.159	1.143	1.568	0.739	1.324
4	0.689	0.890	1.000	0.689	0.613
5	0.764	1.115	0.613	1.245	0.852
6	1.000	1.911	1.000	1.000	1.911
7	1.000	3.269	1.000	1.000	3.269
8	1.000	0.771	1.000	1.000	0.771
Mean	**1.051**	**1.337**	**1.111**	**0.946**	**1.406**

[Note that all Malmquist index averages are geometric means]

Appendix 2. DEA-EMS Program Sample Computer Outputs of Model 2

(M2 2006 VZA CRS)

C:\Program Files\EMS\2006 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	144,86%	0,00	1,00	0,00	1,00	4 (4,70)	95,05	0,03	18,85	0,01
2	ÇAN	154,52%	1,00	0,00	0,00	1,00	4 (0,84)	0,00	82,58	68,11	0,00
3	YATAĞAN	159,78%	0,00	0,00	1,00	1,00	4 (1,16)	57,77	94,33	0,04	0,02
4	YENİKÖY	100,00%	0,56	0,00	0,44	1,00	7				
5	GARP	176,83%	0,00	1,00	0,00	1,00	4 (3,31)	44,84	0,01	01,43	0,01
6	ILGIN	229,65%	0,00	0,00	1,00	1,00	4 (0,14)	93,80	76,64	0,00	0,00
7	SEYİTÖMER	119,89%	0,00	0,00	1,00	1,00	4 (0,97)	72,43	40,15	1,11	0,61
8	BURSA	222,42%	0,00	0,00	1,00	1,00	4 (0,75)	14,71	81,58	0,00	0,01

(M2 2006 VZA CRS SE)

C:\Program Files\EMS\2006 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	144,86%	0,00	1,45	0,00	1,00	4 (4,70)	95,05	0,03	18,85	0,01
2	ÇAN	154,52%	1,55	0,00	0,00	1,00	4 (0,84)	0,00	82,58	68,11	0,00
3	YATAĞAN	159,78%	0,00	0,00	1,60	1,00	4 (1,16)	57,77	94,33	0,04	0,02
4	YENİKÖY	58,40%	0,32	0,00	0,26	1,00	7				
5	GARP	176,83%	0,00	1,77	0,00	1,00	4 (3,31)	44,84	0,01	01,43	0,01
6	ILGIN	229,65%	0,00	0,00	2,30	1,00	4 (0,14)	93,80	76,64	0,00	0,00
7	SEYİTÖMER	119,89%	0,00	0,00	1,20	1,00	4 (0,97)	72,43	40,15	1,11	0,61
8	BURSA	222,42%	0,00	0,00	2,22	1,00	4 (0,75)	14,71	81,58	0,00	0,01

(M2 2006 VZA VRS)

C:\Program Files\EMS\2006 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	100,00%	0,96	0,01	0,03	1,00	2				
2	ÇAN	145,33%	1,00	0,00	0,00	1,00	4 (0,78) 6 (0,22)	0,00	16,52	83,48	0,00
3	YATAĞAN	147,26%	0,00	0,00	1,00	1,00	1 (0,03) 4 (0,97)	81,30	32,23	0,22	0,02
4	YENİKÖY	100,00%	0,12	0,88	0,00	1,00	5				
5	GARP	107,11%	0,00	0,00	1,00	1,00	1 (0,45) 4 (0,55)	69,59	06,26	2,75	0,20
6	ILGIN	100,00%	0,00	0,52	0,47	1,00	3				
7	SEYİTÖMER	119,58%	0,00	0,00	1,00	1,00	4 (0,97) 6 (0,03)	69,41	19,90	0,01	0,00
8	BURSA	215,56%	0,00	0,00	1,00	1,00	4 (0,71) 6 (0,29)	87,29	52,98	0,00	0,00

(M2 2006 VZA VRS SE)

C:\Program Files\EMS\2006 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	57,73%	0,00	0,00	0,00	1,00	2				
2	ÇAN	145,33%	2,04	0,00	0,00	1,00	4 (0,78) 6 (0,22)	0,00	16,52	83,48	0,00
3	YATAĞAN	147,26%	0,00	0,00	0,68	1,00	1 (0,03) 4 (0,97)	81,30	32,23	0,22	0,02
4	YENİKÖY	43,54%	0,09	0,66	0,00	1,00	5				
5	GARP	107,11%	0,00	0,00	0,77	1,00	1 (0,45) 4 (0,55)	69,59	06,26	2,75	0,20
6	ILGIN	big	77,35	86,61	89,47	1,00	3				
7	SEYİTÖMER	119,58%	0,00	0,00	1,31	1,00	4 (0,97) 6 (0,03)	69,41	19,90	0,01	0,00
8	BURSA	215,56%	0,00	0,00	2,43	1,00	4 (0,71) 6 (0,29)	87,29	52,98	0,00	0,00

(M2 2007 VZA CRS)

C:\Program Files\EMS\2007 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SP {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SP {O}
1	EGE-SOMA	112,31%	0,00	1,00	0,00	1,00	4 (3,87)	06,24	0,00	65,89	0,01
2	ÇAN	131,81%	1,00	0,00	0,00	1,00	4 (0,82)	0,00	70,51	96,99	0,41
3	YATAĞAN	124,37%	0,00	0,20	0,80	1,00	4 (0,81) 7 (0,25)	92,92	0,02	0,02	0,02
4	YENİKÖY	100,00%	0,86	0,00	0,14	1,00	6				
5	GARP	160,54%	0,00	0,18	0,82	1,00	4 (2,61) 7 (0,26)	12,56	0,02	0,03	0,02
6	ILGIN	335,51%	0,19	0,00	0,81	1,00	4 (0,08) 7 (0,10)	0,00	82,03	0,01	0,01
7	SEYİTÖMER	100,00%	0,00	0,00	1,00	1,00	4				
8	BURSA	197,07%	0,18	0,00	0,82	1,00	4 (0,40) 7 (0,36)	0,00	90,78	0,30	0,18

(M2 2007 VZA CRS SE)

C:\Program Files\EMS\2007 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SP {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SP {O}
1	EGE-SOMA	112,31%	0,00	1,12	0,00	1,00	4 (3,87)	06,24	0,00	65,89	0,01
2	ÇAN	131,81%	1,32	0,00	0,00	1,00	4 (0,82)	0,00	70,51	96,99	0,41
3	YATAĞAN	124,37%	0,00	0,25	1,00	1,00	4 (0,81) 7 (0,25)	92,92	0,02	0,02	0,02
4	YENİKÖY	71,43%	0,61	0,00	0,10	1,00	6				
5	GARP	160,54%	0,00	0,29	1,31	1,00	4 (2,61) 7 (0,26)	12,56	0,02	0,03	0,02
6	ILGIN	335,51%	0,63	0,00	2,73	1,00	4 (0,08) 7 (0,10)	0,00	82,03	0,01	0,01
7	SEYİTÖMER	85,32%	0,00	0,00	0,85	1,00	4				
8	BURSA	197,07%	0,35	0,00	1,62	1,00	4 (0,40) 7 (0,36)	0,00	90,78	0,30	0,18

(M2 2007 VZA VRS)

C:\Program Files\EMS\2007 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SP {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SP {O}
1	EGE-SOMA	100,00%	1,00	0,00	0,00	1,00	2				
2	ÇAN	123,80%	1,00	0,00	0,00	1,00	4 (0,76) 6 (0,24)	0,00	65,31	04,19	0,00
3	YATAĞAN	122,49%	0,00	0,09	0,91	1,00	1 (0,02) 4 (0,72) 7 (0,26)	80,29	3,36	2,25	1,56
4	YENİKÖY	100,00%	0,28	0,72	0,00	1,00	3				
5	GARP	129,91%	0,00	0,00	1,00	1,00	1 (0,56) 7 (0,44)	59,14	05,37	0,16	0,15
6	ILGIN	100,00%	0,00	0,72	0,28	1,00	2				
7	SEYİTÖMER	100,00%	0,00	0,00	1,00	1,00	3				
8	BURSA	187,55%	0,21	0,00	0,79	1,00	4 (0,38) 6 (0,29) 7 (0,33)	0,00	91,22	0,02	0,02

(M2 2007 VZA VRS SE)

C:\Program Files\EMS\2007 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SP {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SP {O}
1	EGE-SOMA	51,03%	0,00	0,00	0,00	1,00	2				
2	ÇAN	123,80%	1,69	0,00	0,00	1,00	4 (0,76) 6 (0,24)	0,00	65,31	04,19	0,00
3	YATAĞAN	122,49%	0,00	0,08	0,80	1,00	1 (0,02) 4 (0,72) 7 (0,26)	80,29	3,36	2,25	1,56
4	YENİKÖY	52,31%	0,26	0,67	0,00	1,00	3				
5	GARP	129,91%	0,00	0,00	1,11	1,00	1 (0,56) 7 (0,44)	59,14	05,37	0,16	0,15
6	ILGIN	big	67,40	28,34	48,69	1,00	2				
7	SEYİTÖMER	80,92%	0,00	0,00	0,96	1,00	3				
8	BURSA	187,55%	0,47	0,00	1,81	1,00	4 (0,38) 6 (0,29) 7 (0,33)	0,00	91,22	0,02	0,02

(M2 2008 VZA CRS)

C:\Program Files\EMS\2008 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V}	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	100,00%	0,00	1,00	0,00	1,00	1				
2	ÇAN	165,77%	1,00	0,00	0,00	1,00	4 (0,90)	0,00	99,86	36,15	0,57
3	YATAĞAN	121,87%	0,00	0,93	0,07	1,00	1 (0,06) 4 (0,87)	27,82	0,00	0,21	0,01
4	YENİKÖY	100,00%	0,50	0,00	0,50	1,00	4				
5	GARP	165,69%	0,00	0,30	0,70	1,00	4 (3,07) 7 (0,19)	29,29	0,02	0,04	0,00
6	ILGIN	276,75%	0,00	0,00	1,00	1,00	7 (0,14)	31,60	68,13	0,02	0,03
7	SEYİTÖMER	100,00%	0,00	0,00	1,00	1,00	3				
8	BURSA	188,28%	0,27	0,00	0,73	1,00	4 (0,05) 7 (0,63)	0,00	14,90	0,15	0,04

(M2 2008 VZA CRS SE)

C:\Program Files\EMS\2008 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V}	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	97,60%	0,00	0,98	0,00	1,00	1				
2	ÇAN	165,77%	1,66	0,00	0,00	1,00	4 (0,90)	0,00	99,86	36,15	0,57
3	YATAĞAN	121,87%	0,00	1,13	0,09	1,00	1 (0,06) 4 (0,87)	27,82	0,00	0,21	0,01
4	YENİKÖY	77,22%	0,39	0,00	0,38	1,00	4				
5	GARP	165,69%	0,00	0,49	1,16	1,00	4 (3,07) 7 (0,19)	29,29	0,02	0,04	0,00
6	ILGIN	276,75%	0,00	0,00	2,77	1,00	7 (0,14)	31,60	68,13	0,02	0,03
7	SEYİTÖMER	85,98%	0,00	0,00	0,86	1,00	3				
8	BURSA	188,28%	0,51	0,00	1,37	1,00	4 (0,05) 7 (0,63)	0,00	14,90	0,15	0,04

(M2 2008 VZA VRS)

C:\Program Files\EMS\2008 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V}	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	100,00%	1,00	0,00	0,00	1,00	2				
2	ÇAN	159,26%	1,00	0,00	0,00	1,00	4 (0,86) 6 (0,14)	0,00	32,07	61,78	0,00
3	YATAĞAN	121,64%	0,00	1,00	0,00	1,00	1 (0,04) 4 (0,96)	40,35	0,02	14,70	0,03
4	YENİKÖY	100,00%	0,22	0,78	0,00	1,00	3				
5	GARP	132,29%	0,00	0,00	1,00	1,00	1 (0,55) 7 (0,45)	74,80	60,77	0,05	0,05
6	ILGIN	100,00%	0,00	0,83	0,17	1,00	2				
7	SEYİTÖMER	100,00%	0,00	0,00	1,00	1,00	2				
8	BURSA	177,56%	0,28	0,00	0,72	1,00	4 (0,08) 6 (0,38) 7 (0,54)	0,00	54,42	0,04	0,02

(M2 2008 VZA VRS SE)

C:\Program Files\EMS\2008 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V}	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	49,64%	0,00	0,00	0,00	1,00	2				
2	ÇAN	159,26%	2,25	0,00	0,00	1,00	4 (0,86) 6 (0,14)	0,00	32,07	61,78	0,00
3	YATAĞAN	121,64%	0,00	1,25	0,00	1,00	1 (0,04) 4 (0,96)	40,35	0,02	14,70	0,03
4	YENİKÖY	62,34%	0,23	0,84	0,00	1,00	3				
5	GARP	132,29%	0,00	0,00	1,12	1,00	1 (0,55) 7 (0,45)	74,80	60,77	0,05	0,05
6	ILGIN	big	0,29	42,28	61,35	1,00	2				
7	SEYİTÖMER	84,62%	0,00	0,00	0,93	1,00	2				
8	BURSA	177,56%	0,58	0,00	1,53	1,00	4 (0,08) 6 (0,38) 7 (0,54)	0,00	54,42	0,04	0,02

(M2 2009 VZA CRS)

C:\Program Files\EMS\2009 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	100,64%	0,17	0,83	0,00	1,00	4 (3,64) 7 (0,64)	0,00	0,01	08,52	0,08
2	ÇAN	159,56%	1,00	0,00	0,00	1,00	4 (0,97)	0,00	58,98	71,94	0,00
3	YATAĞAN	133,90%	0,22	0,78	0,00	1,00	4 (0,10) 7 (0,94)	0,00	0,01	75,25	0,05
4	YENİKÖY	100,00%	0,67	0,00	0,33	1,00	6				
5	GARP	159,06%	0,38	0,00	0,62	1,00	4 (1,12) 7 (1,95)	0,00	98,87	0,07	1,17
6	ILGIN	213,61%	0,36	0,00	0,64	1,00	4 (0,12) 7 (0,10)	0,00	94,84	0,29	0,13
7	SEYİTÖMER	100,00%	0,00	0,00	1,00	1,00	5				
8	BURSA	219,08%	0,37	0,00	0,63	1,00	4 (0,37) 7 (0,45)	0,00	31,51	0,21	1,34

(M2 2009 VZA CRS SE)

C:\Program Files\EMS\2009 VZA M2 Örnekexample.xls_CRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	100,64%	0,17	0,84	0,00	1,00	4 (3,64) 7 (0,64)	0,00	0,01	08,52	0,08
2	ÇAN	159,56%	1,60	0,00	0,00	1,00	4 (0,97)	0,00	58,98	71,94	0,00
3	YATAĞAN	133,90%	0,29	1,05	0,00	1,00	4 (0,10) 7 (0,94)	0,00	0,01	75,25	0,05
4	YENİKÖY	79,78%	0,53	0,00	0,27	1,00	6				
5	GARP	159,06%	0,61	0,00	0,98	1,00	4 (1,12) 7 (1,95)	0,00	98,87	0,07	1,17
6	ILGIN	213,61%	0,76	0,00	1,37	1,00	4 (0,12) 7 (0,10)	0,00	94,84	0,29	0,13
7	SEYİTÖMER	80,76%	0,00	0,00	0,81	1,00	5				
8	BURSA	219,08%	0,81	0,00	1,38	1,00	4 (0,37) 7 (0,45)	0,00	31,51	0,21	1,34

(M2 2009 VZA VRS)

C:\Program Files\EMS\2009 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	100,00%	0,76	0,23	0,01	1,00	2				
2	ÇAN	158,01%	1,00	0,00	0,00	1,00	4 (0,95) 6 (0,05)	0,00	79,01	92,57	0,00
3	YATAĞAN	133,86%	0,22	0,78	0,00	1,00	1 (0,01) 4 (0,06) 7 (0,93)	0,00	0,01	10,11	0,08
4	YENİKÖY	100,00%	0,74	0,00	0,26	1,00	3				
5	GARP	105,41%	0,00	0,00	1,00	1,00	1 (0,35) 7 (0,65)	70,93	58,89	0,09	0,09
6	ILGIN	100,00%	0,01	0,49	0,51	1,00	2				
7	SEYİTÖMER	100,00%	0,00	0,00	1,00	1,00	3				
8	BURSA	212,04%	0,32	0,00	0,68	1,00	4 (0,34) 6 (0,23) 7 (0,43)	0,00	09,16	0,51	0,37

(M2 2009 VZA VRS SE)

C:\Program Files\EMS\2009 VZA M2 Örnekexample.xls_VRS_RAD_OUT

	DMU	Score	NE {I}{V}	IE {I}{V}	OE {I}{V}	SR {O}{V	Benchmarks	{S} NE {I}	{S} IE {I}	{S} OE {I}	{S} SR {O}
1	EGE-SOMA	50,51%	0,00	0,00	0,00	1,00	2				
2	ÇAN	158,01%	2,04	0,00	0,00	1,00	4 (0,95) 6 (0,05)	0,00	79,01	92,57	0,00
3	YATAĞAN	133,86%	0,30	1,03	0,00	1,00	1 (0,01) 4 (0,06) 7 (0,93)	0,00	0,01	10,11	0,08
4	YENİKÖY	71,87%	0,63	0,00	0,22	1,00	3				
5	GARP	105,41%	0,00	0,00	0,74	1,00	1 (0,35) 7 (0,65)	70,93	58,89	0,09	0,09
6	ILGIN	big	99,66	70,47	63,67	1,00	2				
7	SEYİTÖMER	80,75%	0,00	0,00	0,48	1,00	3				
8	BURSA	212,04%	0,81	0,00	1,71	1,00	4 (0,34) 6 (0,23) 7 (0,43)	0,00	09,16	0,51	0,37

CURRICULUM VITAE

PERSONAL INFORMATION

-Surname, Name : Çimen, Selahattin

-Nationality : Turkish

-Date and Place of Birth : 03.10.1964, Sivas

-Marital Status : Married

-Phone : 90-532-251 82 38

-E-mail : s.cimen@ttmail.com

EDUCATION

Degree	Institution	Year of Graduation
-MS	Portland State Univ. Eng. Management, USA	1992
-MBA (*)	Istanbul Univ., Business Adm. Faculty	1986
(*):Partially completed, transcript is available.		
-BS (with honor)	Istanbul Technical Univ. Mining Eng.	1985

TRAININGS

Degree	Institution	Year of Graduation
-Diploma	ILO, Turin-Italy	1998
-Certificate	GTZ&SPO	1998
-Diploma	IP3, Washington	1997
-Certificate	GTZ&SPO	1997
-Certificate	GTZ&SPO	1997
-Certificate	GTZ&SPO	1997
-Certificate	UNIDO, GTZ&SPO	1997
-Certificate	GTZ&SPO	1997

FELLOWSHIPS AND AWARDS

Title	Institution	Year
-Fellowship	Eisenhower Fellowships (EF)	2001
-Fellowship Award	Special Mr. Phill Reed Fellowship Aw. (EF)	2001
-Distinguished Alumni Award	Portland State University, USA	2001
-Member of "The Academy of Distinguished Alumni"	Portland State University, USA	2001-present

He has received 8 scholarships, awards and/or honor status during his academic career.

WORK EXPERIENCE

Year	Place	Enrollment
-June 2009-Present	MENR (Ministry of Energy and Nat. Res.)	Deputy Undersecretary
-Oct. 2007-Present	BOTAŞ	Board Member
-Sept. 2007-June 2009	MENR	Undersecretary
-Sept. 2007-June 2009	International Energy Agency, Paris	Board Member
-Sept. 2007-June 2009	National Oil Stock Commission of Turkey	Chairman
-May. 2003-June 2009	Administrative Council, MENR	Chairman
-2004-2009	Advisory Council TUBİTAK-MAM	Member
-Sept. 2007-June 2009	BİRECİK Company	Chairman of the Board
-May.2003-Sept. 2007	MENR	Deputy Undersecretary
-May.2003-Oct. 2007	Turkish Electricity Trade Co. (TETAŞ)	Board Member
-Apr. 2003-May 2003	TETAŞ	General Director
-March 2003-June 2003	Turkish Public Enterprises Ass.	Chairman of the Board
-Feb. 2001-May. 2003	General Directorate of Energy Affairs (MENR)	General Director
-March 2001- Oct. 2001	Turkish Electricity Generation Co.	Board Member
-Apr. 1986 -Feb. 2001	State Planning Organization	Planning Expert
-1996-2001	Electricity Fund, MENR	Board Member
-1996-1998	World Mining Congress, Turkish National Committee	Board Member
-1996-Present	World Mining Congress Turkish National Committee	Member
-1998-Present	World Energy Council Turkish National Committee	Member

FOREIGN LANGUAGES

Advanced English, Fair French