EFFICIENCY ANALYSIS OF TURKISH NATURAL GAS DISTRIBUTION COMPANIES BY USING DEA METHOD

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ABSTRACT

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The history of natural gas in Turkey started in 1970s by the usage of domestic gas in cement factories. However, natural gas began penetrating the energy market in 1980s with the usage of natural gas in Ankara. In the following years, the number of cities using natural gas reached six. Then, a new era started with the enactment of Natural Gas Market Law in 2001 and 53 distribution tenders have been realized by Energy Market Regulatory Authority until 2009. This thesis analyzes the performance of 38 Turkish natural gas distribution companies by using a non-parametric method, Data Envelopment Analysis. The results are used to determine the most proper model specification, to detect the important criteria affecting the efficiency levels and to find the common characteristics of the most inefficient firms. The results show that public firms compared to private firms, non-tender firms compared to tender firms, large firms compared to small firms and firms operating in more developed areas compared to firms operating in underdeveloped areas utilize resources and manage costs more efficiently. However, we can not get a certain conclusion about the comparison of old firms and new firms. Lastly, we try to detect the common characteristics of the most inefficient firms and find that the major problem is low delivery amount.

Keywords: Data Envelopment Analysis, Efficiency, Natural Gas Distribution

ÖZ

TÜRKİYEDEKİ DOĞAL GAZ DAĞITIM ŞİRKETLERİNİN ETKİNLİKLERİNİN VZA YÖNTEMİ KULLANILARAK İNCELENMESİ

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Türkiye'de doğal gaz piyasasının tarihi 1970'lerde ülke içinde üretilen doğal gazın çimento fabrikalarında kullanılmasıyla başlamıştır. Fakat doğal gazın enerji piyasasında yaygınlaşması 1980'lerde Ankara'da kullanılmasıyla gerçekleşmiştir. Sonraki yıllarda şehir sayısı altıya yükselmiştir. Daha sonra, 2001'de Doğal Gaz Piyasası Kanununun yasalaşmasıyla yeni bir dönem başlamış ve 2009 yılına kadar 53 adet dağıtım ihalesi gerçekleştirilmiştir. Bu tez 38 doğal gaz şirketinin performansını Veri Zarflama Analizi yöntemini kullanarak analiz etmektedir. Ulaşılan sonuçlar en uygun modelin seçiminde, etkinlik düzeyini belirleyen faktörlerin tespitinde ve en etkinsiz firmaların ortak özelliklerinin tespitinde kullanılmıştır. Yapılan analiz sonucunda kamu şirketlerinin özel şirketlere oranla, ihalesiz şirketlerin ihalelilere oranla, büyük şirketlerin küçüklere oranla ve sosyo-ekonomik açıdan gelişmiş bölgelerde bulunanların diğerlerine oranla hem kaynakların kullanılması hem de maliyetlerin yönetilmesi açısından daha etkin olduğu görülmektedir. Fakat eski şirketler ile yenilerin karşılaştırılmasında kesin bir kanaate ulaşılamamıştır. Son olarak etkinlik düzeyi en düşük şirketlerin ortak özellikleri belirlenmeye çalışılmış ve en temel problemin dağıtım miktarının düşüklüğü olduğu ortaya çıkmıştır.

Anahtar Kelimeler: Veri Zarflama Analizi, Etkinlik, Doğal Gaz Dağıtım

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CHAPTER 1

INTRODUCTION

Natural gas market has developed rapidly in recent years with the start of liberalization and privatization process. Parallel to the developments in the world, Turkey decided to deregulate wholesale, import, export and storage activities and to regulate transmission and distribution sectors of the natural gas market with the enactment of the Natural Gas Market Law (NGML) in 2001. The law proposes a new market structure in which Energy Market Regulatory Authority of Turkey (EMRA) is responsible for the regulation in the market.

Since the enactment of the law, the most important development has become natural gas distribution license tenders. Up to 2003, natural gas distribution networks were constructed only in 6 cities, but within six years after 2003 natural gas distribution companies started to operate in more than 60 cities. These new distribution networks have been built by private companies winning the license tenders (EMRA, 2002, 2009h, 2009j).

Distribution companies are monopolies, so the prices of these companies are regulated according to their costs. As a result, these companies tend to operate inefficiently. To solve this problem and to induce the regulated companies to be more efficient, parametric and non-parametric methods have been used in tariff regulations in some European countries like the Netherlands, the United Kingdom and Norway to some extent, especially for operational expenditures[1]. The results of these studies have been used in tariff setting process so that the inefficient firms are compelled to operate more efficiently. However, these methods have not been used in tariff regulation in Turkey. To compel regulated firms to become more efficient,

[1] For details, see Plagnet (2006).

these methods have to be used also in Turkey and we hope that this study will be the first step in this area.

In this study, 38 Turkish natural gas distribution companies most of which were set up within the last six years are analyzed in terms of their economic efficiency. Parametric and non-parametric methods can be used in economic efficiency analysis. Parametric methods are ordinary least square (OLS), corrected ordinary least square (COLS), modified ordinary least square (MOLS) and stochastic frontier analysis (SFA) which are based on econometrics. On the other hand, non-parametric methods are data envelopment analysis (DEA) and total factor productivity (TFP) which are based on linear programming (LP) and efficiency scores are estimated by solving LP problems. In this thesis, DEA method is used and the relative efficiency level of each firm compared to others is estimated. By using DEA, technical efficiency (TE) scores, allocative efficiency (AE) scores and cost efficiency (CE) scores are calculated under the assumptions of both constant returns to scale (CRS) and variable returns to scale (VRS). Also, the nature of technology of each firm is determined by applying non-increasing returns to scale (NIRS) model.

The distribution companies can not determine their output level because the relevant legislation makes them accountable for providing distribution service to all customers in their defined area. Therefore, to increase the efficiency, the distribution companies have to decrease the amount of inputs. Taking into account this fact input oriented DEA models are more proper to analyze the performance of the firms. Furthermore, these firms can not set their prices which are fixed by the regulatory authority according to the firms’ capital and operational costs, so CE analysis should be used to measure whether the firms manage their costs effectively.

Seven models are set up to analyze economic efficiency level of the firms and four DEA models (CRS DEA, VRS DEA, NIRS DEA and CE DEA) are solved to estimate efficiency scores of these seven models. The results are used to determine the most proper model specification and to analyze the performance of the firms by comparing public versus private, new versus old, tender versus non-tender, small versus large and firms operating in developed area versus less developed areas. The results show that the public firms are more efficient in terms of TE and they manage their costs more successfully. Secondly, we can not get a certain conclusion about the comparison of the new firms versus the old firms. Thirdly, the non-tender firms efficiently utilize the resources and successfully manage the costs compared to the tender firms. Fourthly, when we compare the small firms with the large firms, we reach a conclusion that the large ones have higher scores for all efficiency criteria. Lastly, we find that the firms operating in more developed areas have higher scores.

In chapter 2, a general framework of Turkish natural gas market is explained. It starts with the comparison of the market structure before NGML and after NGML and the role of EMRA over the market. Then, some brief information is given about the market activities including production, import, export, wholesale, compressed natural gas (CNG) sale and distribution, storage and transmission. Lastly, the legislation, facts and figures about the Turkish natural gas distribution sector are explained in detail.

Chapter 3 focuses on the analytical framework of DEA method. In this context, input and output oriented models, CRS DEA model, VRS DEA model, NIRS DEA model, cost minimization model and inclusion of environmental factors into the model are described. Then, the empirical studies which used DEA method to analyze the performance of decision making units (DMU) operating in distribution sector and the results of these studies are briefly explained.

Chapter 4 introduces the data set and some partial productivity indicators. Then, the specification of the models set up to measure the efficiency levels for the companies is explained. It also provides estimation results showing the efficiency scores and effects of selected factors on efficiency. Moreover, the effect of the different model specifications on efficiency in terms of the input-output selection, the number of variables and the environmental factors are investigated. Lastly, the results are analyzed to determine the fairness of the claim that private companies are more efficient than the public ones within the context of Turkish natural gas distribution sector, to see the effect of maturity level of the firms on efficiency, to compare the performance of the companies getting license with tender and the companies getting license without tender and to show the effect of the size of firms on the efficiency. Last chapter is reserved for concluding comments, as usual.

CHAPTER 2

TURKISH NATURAL GAS MARKET

The history of natural gas in Turkey started with the exploration of natural gas in Hamitabat and Kumrular region by TPAO in 1970. This gas was consumed by cement factories in Pınarhisar in 1976 (Yardım, 1998). However, natural gas began penetrating the energy market in the late 1980s to meet the increasing demand for electricity and to mitigate the air pollution in big cities like İstanbul, Ankara and İzmit.

The first studies on natural gas were observed in 1983 with discussions on “Demand and Supply of Natural Gas” by the General Directorate of BOTAŞ (Öztürk et al, 2003). Then, an agreement was signed between Turkey and the former USSR to transport natural gas to Turkey in 1984 (EMRA, 2002). In spite of this, the real development of natural gas use in the country started in 1986 with the signing of the “First Sales and Purchase Agreement” by the former USSR (BOTAŞ, 2007). During the former years of this agreement, the demand for natural gas was relatively low for a variety of reasons, such as the lack of the necessary infrastructure in cities and the industrial sector for the use of natural gas, insufficient knowledge about natural gas use, and uncertainties related to the transformation of existing systems to natural gas-fired systems (Yardım, 1998). This contract provided the delivery of 6 bcm/y (billion cubic meters/year) for 25 years and the flow started in 1987 with 0.552 bcm/y (EMRA, 2002).

The build-up of the Turkish gas market started by introducing gas in power generation in 1987 and in fertilizer production in 1988. In Turkey, Hamitabat and Ambarlı natural gas combined circle power plants were built in a short period and have been operated since 1986 and 1988, respectively (Yardım, 1998). In October 1988, natural gas began to be used for residential and commercial purposes in Ankara, Turkey. Following Ankara, residential and commercial use of natural gas started in İstanbul in January 1992, in Bursa in December 1992, in İzmit in September 1996, and in Eskişehir in October 1996 (BOTAŞ, 2008).

The fast increase in demand has risen the amount of supply and a new agreement has been signed with Algeria in 1988 to buy natural gas in liquefied (LNG) form. Imports of LNG from Algeria started in 1994 after the completion of the Marmara LNG Terminal (WECTNC, 1999). As a result, natural gas consumption that started at 0.5 bcm/y in 1987 reached around 37 bcm/y in 2008 (BOTAŞ, 2009d and TPAO, 2009).

In this chapter, we will first explain the market structure before the Law no. 4646 and the market structure after this law by investigating market activities and players. Then, the characteristics and some brief information about each market activity classified according to license type will be examined. Finally, more detailed information about Turkish natural gas distribution sector will be given.

2.1 Market Structure

Like many other sectors, natural gas sector was also constructed and developed by a public company, BOTAŞ. BOTAŞ was set up in 1974 as an affiliated company of TPAO to transport Iraqi crude oil through Turkey (BOTAŞ, 2008). Later, the duties and responsibilities of BOTAŞ were expanded to include natural gas transportation and import activities according to Law no. 350 in 1988. After two years, this law was repealed by a new Law no. 397 by which the right of import (including LNG form), sales and transmission of natural gas was given to BOTAŞ as a monopoly in the sector. Nonetheless, the distribution right in a city would be given to a company by the Council of Ministers (Law no. 397, 1990). This structure has changed considerably by the enactment of NGML. The monopoly right of BOTAŞ was repealed by the liberalization of the market. In this section, the market structure stemming from these two laws will be explained.

2.1.1 Market Structure before the Law No 4646

In the period when the Law no. 397 was in effect, BOTAŞ was the most important player in the market and got the monopoly right on import, sales and transmission activities. Furthermore, the distribution activity in two cities (Eskişehir and Bursa) was also accomplished by BOTAŞ. In addition to BOTAŞ, there were four distribution companies, operating in Ankara, İstanbul, İzmit and Adapazarı, all of which were public companies controlled by the relevant municipalities. The customers who consumed more than 1 million cubic meters were also supplied by BOTAŞ (Law no. 397, 1990). The market structure of this period is given in Figure 2-1.

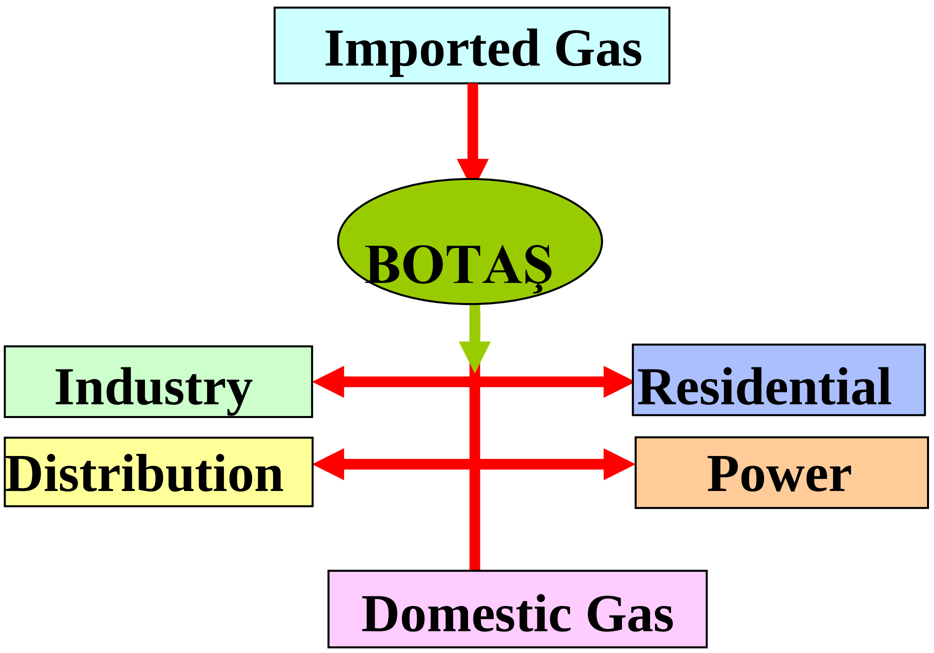

Figure 2-1: Previous Market Structure

Source: EMRA

In this framework, BOTAŞ was responsible for construction and operation of gas pipelines. Investment decisions were taken by BOTAŞ and presented to Ministry of

Energy and Natural Resources (MENR) and State Planning Organization (SPO) for approval. The criteria used for evaluation of such extensions were based on general energy policy guidelines and economic considerations (Öztürk et al., 2004).

The principal governmental authority in the energy sector was MENR being responsible for energy planning and conservation issues. Nevertheless, it was not MENR who was setting the gas prices, but BOTAŞ was the responsible party for the price setting. Moreover, the domestic producers were determining their own prices for the gas sold to industry. These prices were not subject to approval by MENR. In contrast, MENR was responsible for the approval of gas prices charged by the distribution companies. The general approach to pricing was of a cost-plus type tempered by considerations ensuring gas competitivity and penetration in the market. The prices were supposed to cover the import cost of gas, transmission and distribution costs (Öztürk et al., 2004).

2.1.2 Market Structure after the Law No 4646

As a part of energy market restructuring, the legal structure of the natural gas market was reformed in 2001 by a new law which can be considered as a first step toward gradual liberalization and vertical separation in the market. NGML was enacted for a variety of reasons including the intent to end government control on the natural gas sector to eliminate inefficiencies, the harmonization of its energy policy and legislation with that of the EU and to attract foreign investment in the energy infrastructure (Hacısalihoğlu, 2008).

Objective of this law is enounced in Article-1 of NGML as:

> This Law concerns with liberalization of the natural gas market and thus formation of a financially sound, stable and transparent markets along with institution of an independent supervision and control mechanism over the same, so as to ensure supply of good-quality natural gas at competitive prices to consumers in a regular and environmentally sound manner under competitive conditions (EMRA, 2009a).

Additionally, it aims to ensure the existence of an independent regulatory and supervisory system by designating EMRA as the sole authority and describes the procedures for regulations in the market. NGML is the main regulatory statute of the natural gas market. The new legal environment is projected to encourage privatization, establish a more competitive environment and prepare the ground for the integration to the EU natural gas market by harmonizing regulations (Çetin et al., 2007).

The most important aim of NGML is to enhance the competition in natural gas market. As some of these rules are regarding trading activities, some others regulate the infrastructure of the companies' activities. The law requires vertical disintegration of BOTAŞ after 2009. At that time, BOTAŞ will sell 10% of its share of gas import contracts to private companies in order to reinforce competition. The law limits the amount an importer company can buy from abroad to 20% of the national consumption. Similarly, wholesalers can not have market shares more than 20% to ensure that competition will be institutionalized. Distribution companies can not buy more than half of their gas from a single wholesaler or importer (EMRA, 2009a). The law gives discretion to EMRA to change these ratios. In addition, transmission and storage companies are subject to rules regarding third party access. In other words, they can not discriminate among their customers, except the unavailability of capacity and the existence of financial risks related to the current contracts (Çetin et al, 2007).

The law covers the import, transmission, distribution, storage, marketing, trade and export activities and the rights and obligations of all real and legal persons relating to these activities (EMRA, 2009a) within a structure depicted in Figure 2-2. According to the new structure, there are three segments in the market. First segment consists of the supply activities which are import and domestic production. The second segment is related to marketing activity that is wholesale of natural gas in all forms including gas, LNG and CNG. The third segment is consumption segment in which there are eligible and non-eligible customers. As the former can buy natural gas only from the relevant distribution company, the latter can buy from an import company, wholesale company or distribution company. Furthermore, export is included in the consumption segment.

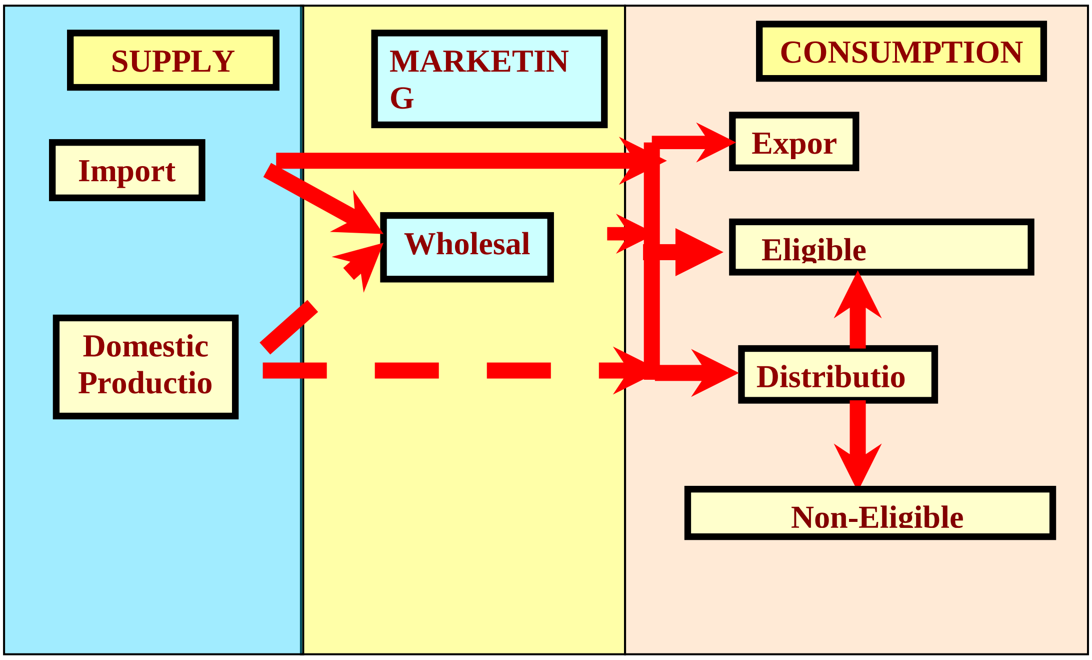

Figure 2-2: Market Structure Envisaged in NGML

Source: EMRA

In addition to the classification in Figure 2-2, we can divide natural gas market activities into two groups which are infrastructure and trading. Transmission, storage and distribution activities form the infrastructure segment, whereas import, wholesale and export are members of the trading segment. The trading companies use the infrastructure by paying the regulated tariffs to sell natural gas to distribution firms, eligible customers and CNG firms within the country.

Before focusing on market activities in the following section, it will be helpful to explain the role of EMRA over the market and the regulations about BOTAŞ in order to understand the market structure.

EMRA was initially established in 2001 by the Electricity Market Law no. 4628 (EML) on March 3, 2001 as the Electricity Market Regulatory Authority. The authority's name became Energy Market Regulatory Authority by NGML and EMRA became responsible for both markets, namely electricity and natural gas. Then by the Petroleum Market Law and the LPG Market Law, the authority of

EMRA encompassed all energy markets. It is administratively independent and financially autonomous. While it is administratively related to MENR, it is independent in its authority over the market (EML, 2001). The major source of its income is the fees collected from the industry (EML, 2001). The duties of EMRA related to natural gas market are listed in Article 5/A of EML. The most important duties are;

- Regarding the issues for which an authority has been granted to EMRA by NGML, to approve any and all kinds of regulations regarding the natural gas market activities and to ensure the execution thereof,
- To take and implement any and all kinds of decisions regarding issue of licenses and certificates as provided in NGML as well as the compliance with and termination of such licenses and certificates,
- To regulate procedures and principles regarding the formation of tariff and price in the areas where competition is non-existent or insufficient,
- To approve the tariffs set up for the activities stated in NGML and to take decisions regarding the revisions of tariffs,
- To take decisions to file applications with any legal or administrative authority, for purposes including litigation and enforcement of any penalty or sanction, as part of EMRA's authority to supervise, carry out preliminary investigations and inquiries concerning the natural gas market operations (EMRA, 2009o).

The main responsibility of EMRA concerning the market is to set up and implement regulations to ensure the establishment of a competitive natural gas market where all market segments will be open to new entrants. The main tools of EMRA to regulate the market are licenses and tariffs. According to Article 4 of NGML, companies are required to obtain licenses from EMRA for transmission, export, import, wholesale, distribution, storage and CNG sales and distribution activities. Article 6 of NGML issues general principles of licenses and certificates. Separate licenses are required for each market activity and for each facility respectively, if the aforementioned activities are to be conducted in more than one facility. Licenses are granted for a minimum of 10 and a maximum of 30 years (EMRA, 2009a). As of 2009, EMRA issued 17 transmission (1 pipeline license, 16 LNG transmission licenses), 60 distribution, 17 import (3 spot LNG licenses), 1 export, 4 storage, 54 CNG and 28 wholesale licenses (EMRA, 2009b).

In addition to granting licenses, the other important duty of EMRA is to regulate tariffs of the firms in case of the insufficiency or non-existence of competition (EML, 2001). In this context, EMRA regulates and approves connection, transmission, storage, wholesale and retail sales tariffs (EMRA, 2009a). According to Article 11 of NGML, transmission, connection and retail sale tariffs are "regulated" ones which will always be set by EMRA in any case. On the other hand, storage and wholesale prices are deregulated by NGML and EMRA is responsible to set these prices only if there is not sufficient competition.

EMRA also issued several secondary regulations consisting of the rules and conditions about licenses, tariffs, internal installations, market certificates, transmission network operations, distribution and consumer services and facilities. In addition to issue regulations, EMRA is responsible for organizing tenders for natural gas distribution licenses (EMRA, 2009a). Furthermore, Article 8 of NGML assigns another duty that EMRA is responsible for solving disputes of access to the transmission and distribution systems.

BOTAŞ was Turkey's sole natural gas importer before NGML. However, NGML abolished the monopoly rights of BOTAŞ on importation, distribution, storage and the sale of natural gas. Moreover, the law stipulates BOTAŞ to be legally unbundled after 2009 to form separate companies for transmission, storage and trade.

By Temporary Article 2 of NGML, the monopoly rights of BOTAŞ in imports, and consequently in practice the wholesale pricing of natural gas, are to be reduced gradually. Because BOTAŞ has a dominating position in the gas market and there are few possibilities for new entrants to import, NGML requires BOTAŞ to transfer part of its import contracts every year through a tendering process. Reducing BOTAŞ' share in imports will be absolutely necessary for the market liberalization to be successful and competition to develop. However, the process has been delayed by the complexity of releasing these contracts and the veto of seller country and is not expected to be completed until the end of 2009. So far only 4 bcm/y of Russian gas are released (IEA, 2005). Thus, market share of BOTAŞ has decreased by less than 90% and four new importers have stepped into the market

As it has been mentioned, there were three main strategies about BOTAŞ in NGML including gas release, unbundling and privatization of two distribution areas operating in Bursa and Eskişehir. However, only one of these three strategies was successfully realized and two distribution affiliate firms of BOTAŞ, namely Esgaz and Bursagaz were privatized.

2.2 Market Activities

In this section, we will give some brief information about each activity defined in NGML, namely production, import, export, wholesale, CNG sale and distribution, storage and transmission. The classification of the activities fundamentally is based on the license types listed in the law.

2.2.1 Production

The Petroleum Law no. 6326 draws the outline of natural gas exploration and production activities. According to this law, the General Directorate of Petroleum Affairs (GDPA) grants exploration and operating licenses (GDPA, 2009). Production activity is not included in the jurisdiction of the regulator. Namely, EMRA does not have authority over exploration activities. However, the marketing activities of production companies are regulated in Article 4 of NGML and subject to the control of EMRA. According to NGML, producers can sell produced gas to importers, wholesalers, distributors or eligible consumers by getting a wholesaler license. Producers can sell 20% of their annual production to eligible consumers directly. They have to sell the rest to importers, distributors or wholesalers. They can also export the gas with an exporter license (EMRA, 2009a).

The natural gas reserves of Turkey is very low (Table 2-1). Total reserves explored so far is only 23 bcm which is less than the annual consumption of Turkey. Furthermore, the remaining producible reserves is less than 7 bcm.

Table 2-1: Natural Gas Reserves in Turkey (million m^3)

Company	**Total Reserve**	**Producible Gas**	**Cumulative Production**	**Producible Reserves**
TPAO	11,443	8,601	7,409	1,192
N.V.TURKSE PERENCO	4,654	3,258	238	3,020
AMITY OIL INT. and TPAO	1,899	1,482	1,065	417
THRACE BASIN	1,942	1,789	1,082	707
THRACE BASIN and PINNACLE TURKEY	1,287	1,170	524	646
TOREADOR and TPAO and STRATIC	1,740	1,090	256	834
AMITY OIL INT.	11	11	0	11
TOTAL	**22,976**	**17,400**	**10,574**	**6,827**

Source: TPAO (2009)

Natural gas production started in 1970s and reached 1 bcm/y in 2008 (TPAO, 2009). Current Turkish gas production meets around 3% of domestic gas consumption requirements. Prospects for finding more gas reserves are considered as good, but domestic production is not expected to increase significantly. The country’s gas fields are located in Thrace Basin, West Black Sea and Southeast Anatolia and total reserves are slightly lower than 7 bcm/y (TPAO, 2009). Major gas producers in Turkey are TPAO, Thrace Basin, Amity Oil, Stratic Energy, Toreador Turkey, and Perenco. During the last three years, TPAO produced around 50% of total amount and followed by Thrace Basin having a share of 35% (Table 2-2).

Table 2-2: Natural Gas Production between 2006 and 2008

Company	2006 (m^3)	2007 (m^3)	2008 (m^3)
Amity Oil Int.Pty Ltd.	137,763,842	92,365,351	66,675,059
TPAO	412,615,946	421,464,200	488,235,188
Thrace Basin Nat.Gas Corp.	351,004,760	303,456,051	338,741,728
Stratic Energy Inc.	0	10,077,532	20,564,066
Toreador Turkey Ltd.	0	30,232,597	61,228,069
Total Production	901,384,548	857,595,731	975,444,111

Source: EMRA (2009j)

2.2.2 Import

Turkey is a rapidly growing importer and consumer of natural gas, due to the fact that it is surrounded by major gas-exporting countries in the Middle East and Central

Asia. Turkey produces only a small amount of natural gas, and thus gas imports have increased rapidly. Natural gas transportation is a crucial issue in the Caspian Sea/Central Asia regions. Turkey would like to diversify its import sources and has signed gas import deals with a number of countries, including Algeria, Nigeria, Egypt, Iran, Iraq, Russia and Turkmenistan (BOTAŞ, 2008). Turkey's natural gas supply contracts are tabulated in Table 2-3. Most of the natural gas import agreements are held by BOTAŞ which has already signed eight long term sales and purchase contracts with five different supply sources, totaling a contracted amount of 63.8 bcm/y. BOTAŞ will not sign a new purchase contract until its share in the imports falls below 20% of the national consumption (EMRA, 2009a). Other four contracts were signed by private companies which got this right in gas release tender of BOTAŞ (BOTAŞ, 2008).

Around 36% of natural gas came from Russia through Bulgaria, 26% from Russia through the Black Sea, around 23% from Azerbaijan and Iran through pipeline and 14% from Algeria and Nigeria as LNG in 2008 (Figure 2-3). Turkey's reliance on Russia for gas imports reached over 60%, which seems to undercut Turkey's goal of diversifying suppliers. However, gas from Russia has come through two routes since

2003 (BOTAŞ, 2008). This diversification of routes provided a considerable advantage to Turkey during Ukraine crises in 2008 and 2009.

Table 2-3: Natural Gas Purchase Contracts

Contract Holder	Source Country	Contracted Volume (bcm/y)	Date Signed	Duration (years)	Project Status	Gas Flow Date
BOTAŞ	Russia	6	14-Feb-86	25	In Operation	1987
BOTAŞ	Algeria	4	14-Apr-88	20	In Operation	1994
BOTAŞ	Nigeria	1.2	09-Nov-95	22	In Operation	1999
BOTAŞ	Iran	10	08-Aug-96	25	In Operation	2001
BOTAŞ	Russia	16	15-Dec-97	25	In Operation	2003
BOTAŞ	Russia	4	18-Feb-98	23	In Operation	1998
Shell	Russia	0.25	18-Feb-98	23	In Operation	1998
Avrasya	Russia	0.5	18-Feb-98	23	In Operation	1998
Bosphorus	Russia	0.75	18-Feb-98	23	In Operation	1998
Enerco	Russia	2.5	18-Feb-98	23	In Operation	1998
BOTAŞ	Turkmenistan	16	21-May-99	30	-	-
BOTAŞ	Azerbaijan	6.6	12-Mar-01	15	In Operation	2007

Source: Author generated from BOTAŞ (2008), BOTAŞ (2009a) and EMRA (2009j)

At present, import sources by other parties are limited to countries that BOTAŞ does not import from (EMRA, 2009a). According to IEA, this provision can hamper new entry once gas demand increases and there will be room in the market for new gas supply contracts. Therefore, the government should amend NGML and refrain from setting market rules which prohibit the market players from looking for the cheapest sources of supply and favor one company (IEA, 2005).

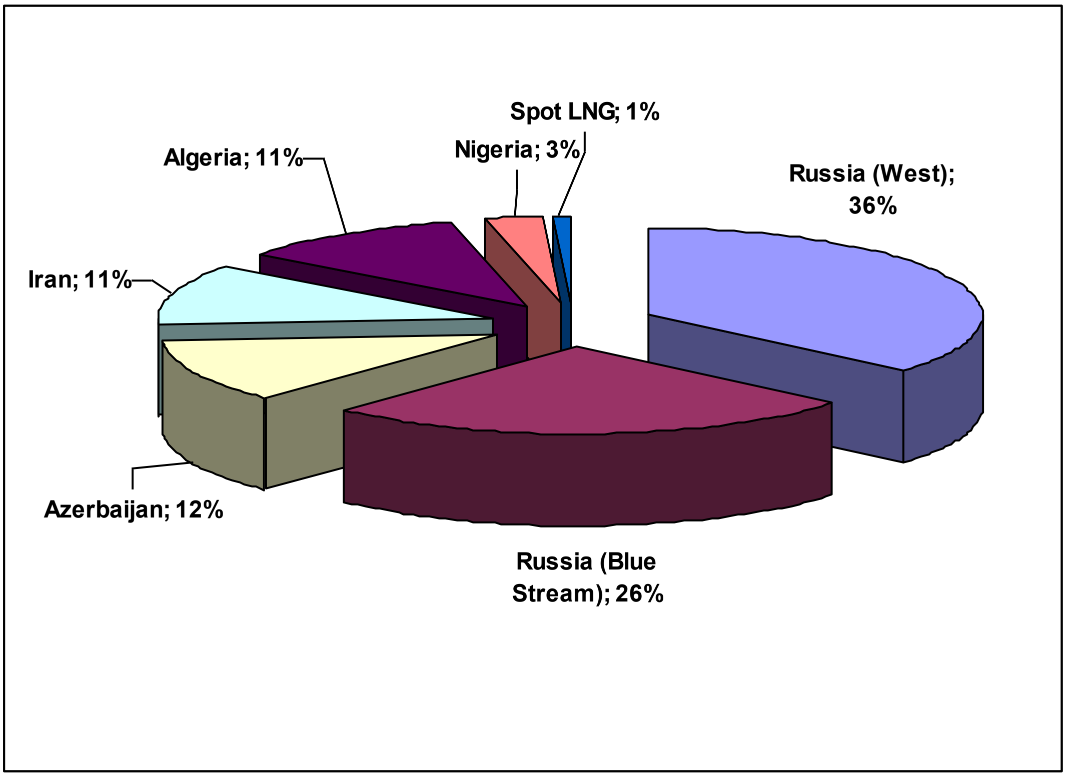

Figure 2-3: Turkish Import Shares in 2008.

Source: EMRA (2009j)

2.2.3 Export

Turkey only exports natural gas to Greece through Greece-Turkey Natural Gas Pipeline. This project started with a meeting of the “Trilateral Working Group” of the EU, Turkey and Greece which was held in Brussels on July 7, 2000 under the EU Commission INOGATE Program. According to the “Concluding Statement” issued at the end of the Meeting; a Technical Working Group would be established to conduct studies on the bilateral pipeline between the two countries and the realization of the Southern Europe Gas Ring for the purpose of transportation of the natural gas produced in Caspian Basin, Russia, Middle East, Southern Mediterranean countries and other sources through Turkey and Greece to European markets. A Memorandum of Cooperation regarding to the Project was signed by BOTAŞ and

The Public Gas Corporation of Greece (DEPA) on January 18, 2001 (Öztürk et al., 2004).

For the realization of the Southern Europe Gas Ring; the first step was planned to be the connection of transmission networks of Turkey and Greece by a pipeline to be constructed. For this aim, the inter-governmental agreement between the ministries of Turkey and Greece and the purchase agreement between BOTAŞ and DEPA were signed in 2003. According to the purchase agreement the gas shipment would start in 2006 with 250 million cubic meters and will increase to 750 million cubic meters in the following years (BOTAŞ, 2009b).

The first phase of the project was successfully completed and gas flowed in 2007 with one year delay. The Turkey-Greece interconnection consists of 300 km of pipeline of which 200 km pass through Turkish territory and about 17 km cross the Marmara Sea. The pipeline has an initial capacity of 3.6 bcm/y, and could eventually carry more than 12 bcm/y (BOTAŞ, 2009b). Turkey exported 0.436 bcm/y natural gas to Greece through this pipeline in 2008 (BOTAŞ, 2009c).

2.2.4 Wholesale

Wholesalers can buy natural gas from importers, producers and other wholesalers and sell gas to distributors, importers, exporters, other wholesalers, CNG firms and eligible consumers at market prices (EMRA, 2009a). Importers have all legal rights of wholesalers without the necessity of getting a wholesale license. Wholesalers must satisfy regulations on storage capacity, transportation conditions and origins of buying. The law requires wholesalers and importers to store 10% of the imported or sold gas for 5 years after the license date (EMRA, 2009a).

NGML limits the market share of any importer or wholesaler to 20% of the national annual demand forecast. This applies also to BOTAŞ who can not enter new purchase contracts until its share of imports falls to the required level according to Temporary Article 2 of NGML (EMRA, 2009a).

There are 28 firms, who have wholesale license, but some of them buy and sell natural gas in gas form, others have got license to sell LNG. Regarding 2008 natural gas sale figures, BOTAŞ sold 36 bcm (BOTAŞ, 2009d), producers sold 1 bcm (TPAO, 2009) and Shell sold some amount around 0.25 bcm, because its contracted capacity is only 0.25 bcm (BOTAŞ, 2008). However, this structure in wholesale market will change in 2009, because other three importers who took BOTAŞ' contract over and new spot LNG importers also got licenses and will start to import and sell gas in the market (EMRA, 2009j). As a result, if we take into consideration the demand projection of EMRA for 2009 that is 35 bcm (EMRA, 2009n) and the contracted amount of new importers (4 bcm/y in total) and domestic production (around 1 bcm/y), most probably the market share of BOTAŞ will decrease below 90%; even it can be lower than 80%.

In addition to gas form, natural gas is also sold in LNG form which is bought by the industrial consumers who are not connected to pipeline network. The first firm who got wholesale license to sell LNG is Habaş (EMRA, 2009b) who sold first LNG in 2004 (BOTAŞ, 2008). The sale amount started with 64 million cubic meters in 2004 and has abruptly grown in the following years. The volume exceeded 500 million cubic meters in 2007 (BOTAŞ, 2008) with 10 LNG wholesale firms (BOTAŞ, 2009e). LNG sale prices were regulated by EMRA from 2004 to the end of 2007 because of insufficient competition (EMRA, 2009c). Then, parallel to the improvement of competition LNG tariff was deregulated (EMRA, 2009c). This process was successfully managed by EMRA and has increased its reliability as it only intervenes if the competition has failed.

2.2.5 Compressed Natural Gas Sale and Distribution

CNG firms can buy natural gas from importers, wholesalers, producers and distributers and sell to vehicles and consumers who are not connected to network (EMRA, 2009a). NGML considers CNG distribution and sale activities as important activities and there are some detailed rules about them. Nonetheless, CNG market has not developed as expected. Although the number of CNG sale and distribution companies is high, the amount of sales is very low.

2.2.6 Storage

According to NGML, there are two types of storage: storage via LNG terminals and underground storage (EMRA, 2009a). Storage facilities are required to provide third party access under an approved terminal code which is prepared by the relevant firm and approved by EMRA (EMRA, 2009e). NGML deregulates storage facilities and envisages them to be set in the market. However, tariffs have been determined by EMRA since 2003 (EMRA, 2009c) because of the lack of enough storage capacity (EMRA, 2009d).

Underground natural gas storage facilities are planned to regulate fluctuations in consumption and to help in the case of gas supply deficits. However, owing to the oversupply risk arising from the take-or-pay supply contracts, gas storage is also needed to avoid penalties. Storage capacities will also be important for the development of transit capacities.

The Northern Marmara-Değirmenköy underground storage facility is operating since 2007 (TPAO, 2008) and there are two more underground storage projects which are under development, namely Tuz Gölü (Salt Lake) and Tarsus. The Northern Marmara-Değirmenköy uses the depleted natural gas fields in these two locations for storage (BOTAŞ, 2008). Its working gas capacity is 1.6 bcm/y, withdrawal capacity during winter season is 18 million cubic meters per day and injection capacity is 14 million cubic meters per day (BOTAŞ, 2009f). TPAO who is the owner of this storage facility sold the whole capacity to BOTAŞ with an agreement that was signed in 1999 before the enactment of NGML (BOTAŞ, 2007). However, if the capacity can be increased, the extra capacity will be supplied under the third party access conditions according to NGML. In Tuz Gölü project, natural gas will be injected into large caverns that will be produced by leaching of salt domes. The engineering and consultancy studies for the project and the environmental impact assessment have been completed. Its working capacity is 1 bcm/y (BOTAŞ, 2008). The second project is Tarsus underground storage facility, which would use sodium carbonate beds as storage facilities.

In addition to underground storage facilities, there are two LNG terminals in Turkey. First terminal (Marmara Ereğlisi LNG Terminal) has been operated since 1994 by BOTAŞ .The terminal is used to store LNG imported from Algeria and Nigeria and to gasify and inject gas into the main transmission line (BOTAŞ, 2008). Its total send-out capacity is 918,750 cubic meters per hour and the annual operation capacity is 8.05 bcm/y of natural gas (BOTAŞ, 2009f). The other terminal (EGEGAZ) has been operated by Ege Gaz A.Ş. since 2006 (EGEGAZ, 2009). This terminal had also been used by only BOTAŞ until the end of 2008. However, after the amendment of permitting spot LNG import in NGML in the summer of 2008, Egegaz A.Ş. got spot LNG license (EMRA, 2009b) and started to import LNG by the beginning of 2009 and used the terminal to store and gasify this LNG. Total send-out capacity of this terminal is 685,000 cubic meters per hour and the annual operation capacity is 6 bcm/y (EGEGAZ, 2009).

2.2.7 Transmission

Transmission through pipeline is carried out by BOTAŞ with a network length exceeding 11,000 km (BOTAŞ, 2009g). NGML does not restrict the number of transmission companies apart from EML which permits only Turkish Electricity Transmission Company (TEİAŞ) to have transmission lines. Nevertheless, no one has applied to get transmission license to construct and operate pipeline except BOTAŞ (EMRA, 2009b).

Third-party access to the transmission grid is a crucial element of institutionalizing competition in the natural gas market. To guarantee the non-discriminative third party access, the rights and obligations of suppliers and operators of a transmission network have to be regulated (EMRA, 2009f). For this aim, BOTAŞ prepared Network Code and submitted to EMRA for approval. This code was approved in 2004 (EPDK, 2009g). According to the code, suppliers have to sign the Standard Transmission Agreement and reserve capacity for entry and exit points to use the network. Suppliers have to balance their entry and exit volumes and submit nomination for each reserved point before the relevant day (EPDK, 2009g).

According to NGML, the transmission company is obliged to connect demanding legal users to the ‘most appropriate’ grid in a year. The connection application can only be rejected under the conditions of technical and/or economical insufficiency. Even so, if the applicant accepts to pay all costs of the needed network expansion, the transmission company can not reject the application. In any case, EMRA has the dispute resolution authority with respect to transmission issues (EMRA, 2009a).

The transmission company makes transportation contracts with importers, wholesalers, producers and exporters. It also enters into delivery contracts with producers, eligible consumers, storage companies and other transmission companies (EPDK, 2009g).

The gas transmission network is composed of more than 11 thousand km of high-pressure transmission lines. Figure 2-4 shows the existing pipelines as well as those under construction or planned.

In addition to domestic transmission, the cross-border transmission activity is also important for Turkey. Turkey has a unique geographic position by being at the crossroads between Europe and Asia. Turkey’s strategic location makes it a natural ‘‘Energy Bridge’’ between the major natural gas production areas in the Middle East and Caspian Sea regions on the one hand and consumer markets in Europe on the other. Thanks to this geographic advantage, Turkey will certainly play a significant role in the world’s energy market in the 21st century (Ediger et al., 2007).

The three main cross-border gas pipeline projects that Turkey supports are the Turkey-Greece-Italy Natural Gas Pipeline Project, Nabucco Project and the South Caucasus Pipeline (SCP) project (BOTAŞ, 2008). The first project is conducted by DEPA, BOTAŞ and Edison of Italy as a part of “South European Gas Ring Project”. The objective is to transport natural gas produced in the Caspian basin, Middle East, South Mediterranean countries and other international sources to the European markets. The capacity of this project will be 12 bcm/y; 3 bcm/y of which will be consumed in Greece and the rest will be transported to Italy (BOTAŞ, 2009b). More detailed information about this project has already been given in Section 2.2.3.

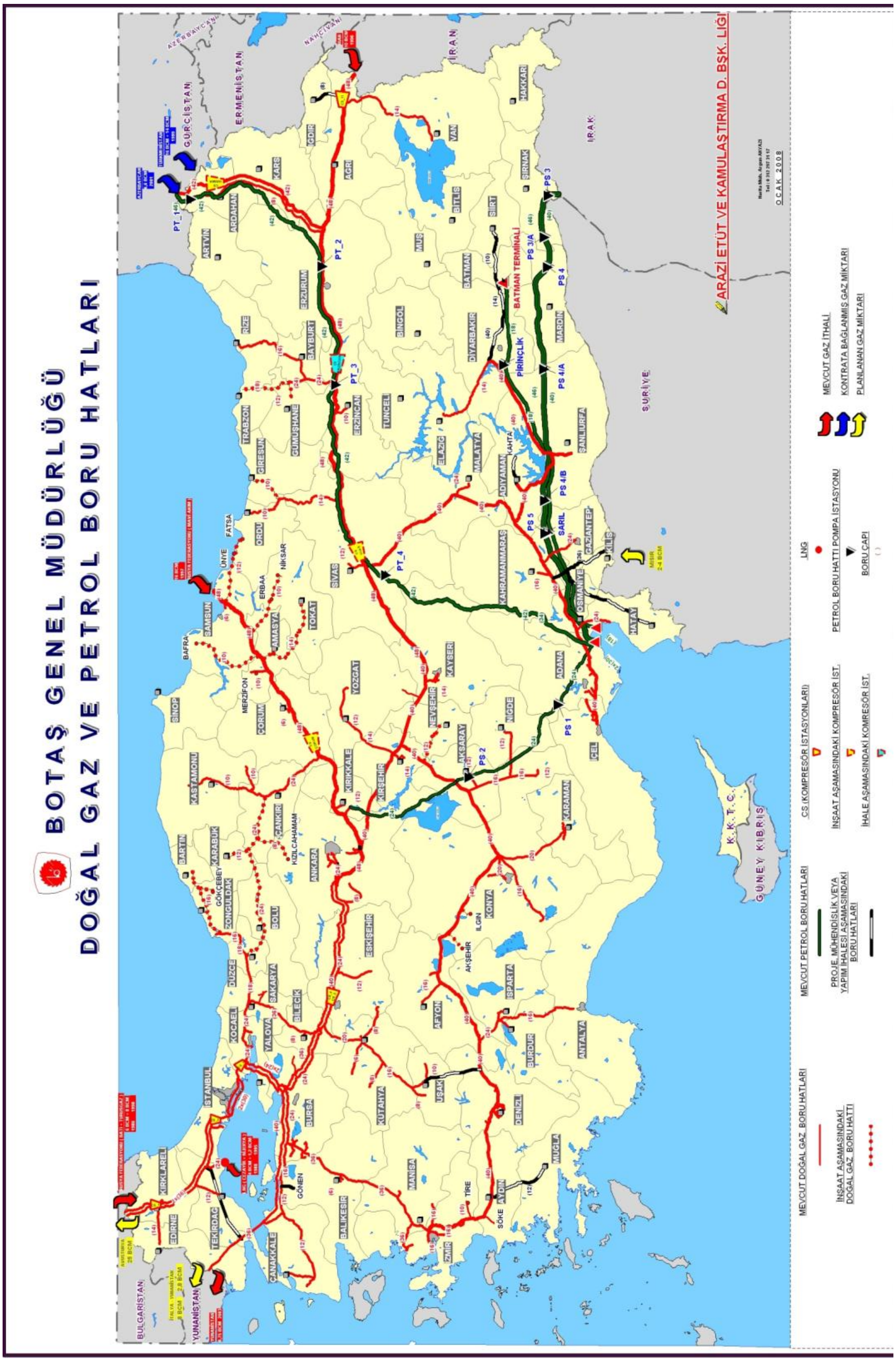

Figure 2-4: Transmission Pipeline Map as of 2008

Source: BOTAŞ (2009h)

Nabucco is the most popular transit project among the transit projects. The pipeline will be constructed by the transit countries independent from the supplier countries. It will transport natural gas from Azerbaijan, Turkmenistan, Iran and Iraq to European market through Turkey, Bulgaria, Romania, Hungary and Austria (BOTAŞ, 2009i). The Co-operation Agreement was signed among the associated companies of the respective countries on October 11, 2002. Nabucco Pipeline Study Company was established on June 24, 2004 to conduct studies on the business development issues regarding the project; the commissioning of the pipeline is expected by the end of 2009. Nabucco Gas Pipeline International (NIC) was set up by abolishing Nabucco Pipeline Study Company in 2005 with the development of the project. The total length of the pipeline is estimated to be 3,300 km of which 1998 km will pass through Turkish territories. The maximum capacity of the pipeline is 31 bcm/y. It will start at the Georgian/Turkish and Iranian/Turkish borders leading to Baumgarten and further, and will end in Austria where it connects to other European markets (BOTAŞ, 2008 and BOTAŞ, 2009i). Lastly, an inter-governmental agreement was signed on July 14, 2009.

The third project, South Caucasus Pipeline Project, was also completed and first natural gas flow started in 2007. The length of this pipeline is 670 km that is capable of transporting 8.1 bcm/y of gas from the Shah Sea field in Azerbaijan to Turkey through Tbilisi. The capacity can be expanded to 22 bcm/y by adding new compression stations (BOTAŞ, 2008).

2.3 Distribution Sector

Distribution activities constitute the final stage of the natural gas supply system that channels this energy source to many different uses: industrial, automotive, commercial, residential, and thermo-power generation, as well as non-energy uses such as raw material for petrochemical plants. According to NGML, distribution companies can sell natural gas to eligible and non-eligible consumers by purchasing it from importers and wholesalers.

The transport network is the most costly portion of the natural gas chain. Furthermore, there is a significant economies of scale and it has lower unit costs when larger volumes are shipped. These characteristics make the distribution of natural gas a capital-intensive activity. As a result, the gas transport and distribution network facilities have some specific features that characterize the industry as a natural monopoly. These features are the indivisibility of the equipment; extended construction times and long periods for investment return; high and non-recoverable fixed costs; and sub additive cost functions (Silveira et al., 2007).

Until the enactment of NGML, the distribution companies were set up only in six big cities (BOTAŞ, 2008). Then, EMRA who is responsible for organizing tenders for natural gas distribution licenses according to NGML have carried out tenders. Prequalification for tendering is based on the financial strength and experience of the potential licensees. Evaluation of the tenders is based on the unit service and depreciation charge for supplying one kWh of natural gas to consumers (EMRA, 2009h). Licenses are granted for a minimum of 10 and a maximum of 30 years. The tender process has been carried out in 57 distribution areas since 2003 and 53 of them have been successfully completed. Other four tenders were cancelled by the Board to be executed in the future (EMRA, 2009i). The construction of distribution networks has started and in 46 distribution areas the first gas delivery has been achieved (EMRA, 2009j).

According to NGML, a company can only serve at most two cities. However, this number may be increased by the Board taking into consideration the development level of the city, the consumption capacity and the number of users. The Board may divide a city into more than one distribution area the borders of which are to be determined according to the density of population and award the contract separately for each region. The Board used this right and increased the number of cities several times and according to the last decision (the Decision no 1436/5 in 2007) the number of cities is increased to 20 (EMRA, 2009k).

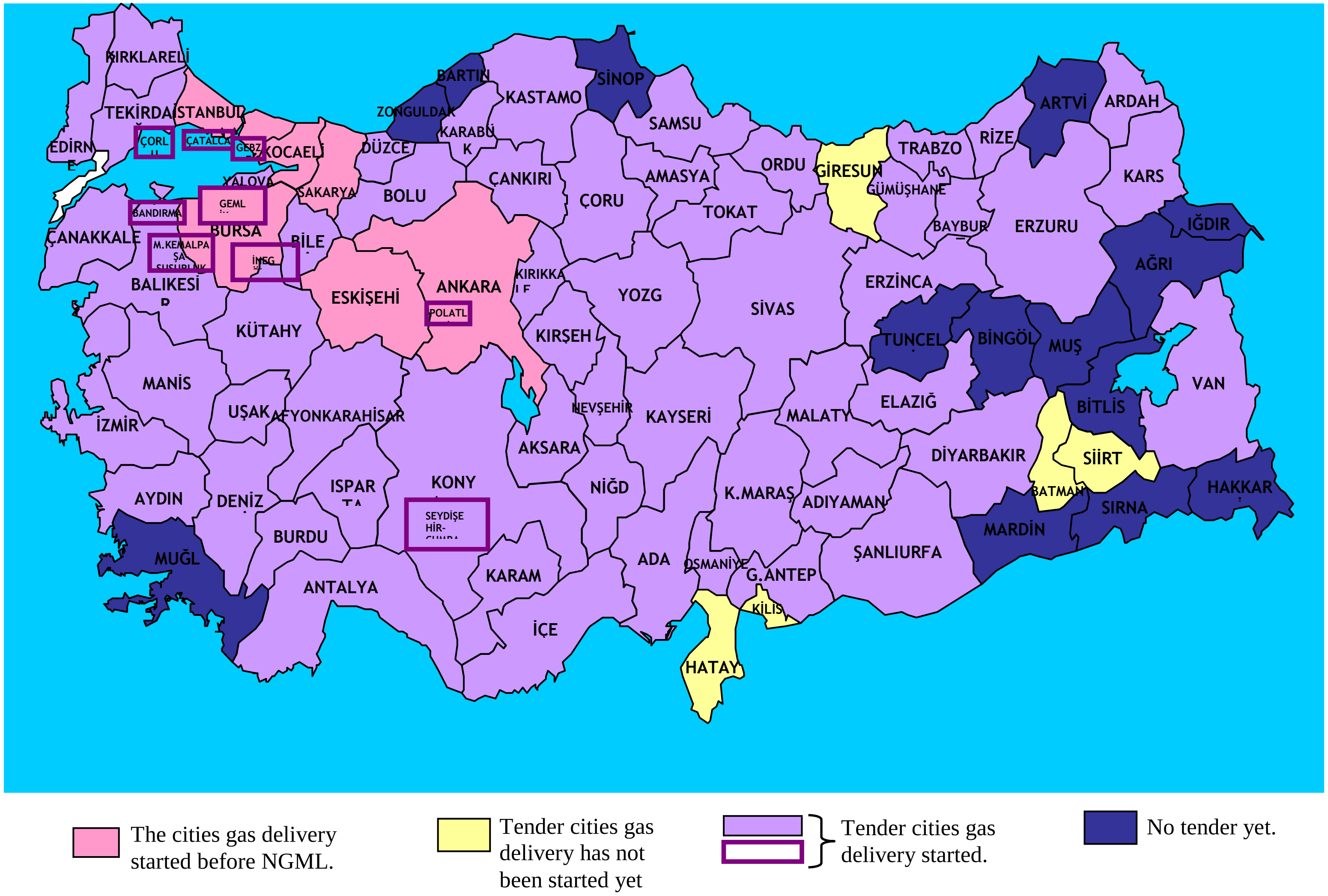

Figure 2-5: Distribution Sector Map

Source: Author generated from BOTAŞ (2009j) and EMRA (2009h)

Before the enactment of NGML, in all six cities the distribution service was conducted by public companies. In Istanbul, Ankara, İzmit and Adapazarı municipality companies were distributing gas as BOTAŞ was operating distribution networks in Bursa and Eskişehir (BOTAŞ, 2008). NGML ordered privatization of all these companies. Then, distribution companies were set up in Eskişehir and Bursa as affiliated companies of BOTAŞ and these two companies were privatized in 2003-2004 by the Privatization Authority (BOTAŞ, 2007). In addition, Adapazarı Distribution Company was privatized by the relevant municipality in September, 2003 (AGDAŞ, 2009). Later, İzmit Distribution Company was privatized by İzmit Municipality and Gas de France took over the company at the end of 2008 (İZGAZ, 2009). Başkentgaz who has the distribution right in Ankara also was tendered, but tender was cancelled because the winning bidders did not pay the money. As a result, there are two public companies in Turkish distribution sector in 2009: Istanbul and Ankara.

As of 2009, there are 60 natural gas distribution companies in Turkey operating in 67 cities as shown in Figure 2-5. Natural gas delivery has been occurred in 62 of these 67 cities at the end of 2008.

Table 2-4 presents basic information about natural gas distribution companies in Turkey (EMRA, 2009h). It is quite clear from Table 2-4 that this is a recent market, with only a few companies operating at considerable scale. In the table, tender dates, first gas delivery date, the distribution margin which is designated as unit service and deprecation charges in NGML and connection charges are given. The former charge is collected in exchange for the delivery of unit natural gas which has 1 kWh energy. The latter charge are received when a subscriber connecting to a distribution network.

Table 2-4: Some Characteristics of Turkish Natural Gas Distribution Companies

Company	**Tender Date**	**Gas Delivery Date**	**Distribution Margin (¢/kWh)**	**Connection Charge (USD)**
Ankara – BAŞKENTGAZ*	1985	10.20.88	0.52	180
İstanbul – İGDAŞ*	12.25.86	01.01.92	0.53	180
Bursa – BURSAGAZ*	1989	12.01.92	0.23	180
Bahçeşehir (İstanbul)- BAHÇEŞEHİR*	1991	1995	0.60	180
İzmit – İZGAZ*	10.15.92	09.01.96	0.47	180
Adapazarı – AGDAŞ*	12.21.93	10.29.03	0.83	180
Eskişehir – ESGAZ*	1994	10.01.96	0.23	180
Kayseri – KAYSERİGAZ	06.19.03	10.01.04	0.08	180
Konya – GAZNET	07.31.03	10.21.04	0.06	180
Erzurum – PALEN	08.13.03	11.08.04	0.05	180
Çorlu – ÇORDAŞ	08.28.03	06.25.05	0.04	180
Gebze – PALGAZ	09.11.03	12.01.04	0.05	180
İnegöl – İNGAZ	09.18.03	10.24.04	0.06	180
Çatalca – TRAKYADAŞ	09.25.03	10.25.05	0.04	180
Bandırma – BADAŞ	10.09.03	01.27.05	0.17	180
Balıkesir – BALGAZ	10.16.03	01.05.05	0.11	180
Sivas – SİDAŞ	10.30.03	10.21.05	0.16	180
Kütahya – ÇİNİGAZ	11.06.03	01.04.05	0.12	180
Ereğli (Konya) – NETGAZ	12.04.03	10.16.05	0.17	180
Çorum – ÇORUMGAZ	12.18.03	10.15.04	0.08	180
Kırıkkale Kırşehir – KIRGAZ	01.08.04	09.29.05	0.16	180
Samsun – SAMGAZ	01.22.04	10.29.05	0.06	180
Aksaray – AKSARAYGAZ	02.12.04	11.22.05	0.24	180
Düzce Karadeniz Ereğli – DERGAZ	04.08.04	11.30.05	0.03	180
Gemlik – GEMDAŞ	04.22.04	12.08.05	0.24	180
Yalova – ARMAGAZ	07.01.04	11.19.05	0.03	180
Uşak – UDAŞ	12.02.04	10.26.05	0.06	180
Polatlı – POLGAZ	01.13.05	02.09.06	0.23	180
İzmir – İZMİRGAZ	01.27.05	06.01.06	0.01	180
Manisa – MANİSAGAZ	02.24.05	10.13.06	0.02	180
Niğde Nevşehir – KAPADOKYAGAZ	03.17.05	09.23.06	0.10	180
Bilecik Bolu – BEYGAZ	06.09.05	03.01.06	0.02	180
Karabük Kastamonu Çankırı – KARGAZ	06.16.05	-	0.07	180

Table 2-4 (continued): Some Characteristics of Turkish Natural Gas Distribution Companies

Company	**Tender Date**	**Gas Delivery Date**	**Distribution Margin (¢/kWh)**	**Connection Charge (USD)**
Edirne Kırklareli Tekirdağ – TRAKYAGAZ	06.23.05	04.01.06	0.00	0
Yozgat – SÜRMELİGAZ	06.30.05	11.17.06	0.18	180
Malatya – PEGAZ	07.07.05	08.22.06	0.04	180
Kahramanmaraş – ARMADAŞ	07.14.05	12.22.06	0.01	180
Denizli – KENTGAZ	07.21.05	10.26.06	0.00	149
Gaziantep Kilis – GAZDAŞ	07.28.05	10.10.07	0.00	30
Şanlıurfa – GÜRGAZ	11.09.05	12.17.07	0.10	180
Çanakkale - ÇANAKKALEGAZ	12.16.05	12.22.06	0.00	180
Isparta Burdur - TOROSGAZ	12.23.05	09.01.08	0.02	180
Afyonkarahisar - AFYONGAZ	01.06.06	11.09.07	0.00	174
Kars Ardahan - KARGAZ Kars Ardahan	01.20.06	06.18.08	0.28	180
Erzincan – ERZİNGAZ	01.27.06	11.20.07	0.09	180
Karaman – DOĞANGAZ	02.03.06	09.08.07	0.14	180
Amasya Tokat Turhal – TAMDAŞ	02.10.06	01.02.08	0.00	163
Antalya – OLİMPOSGAZ	02.17.06	10.14.08	0.00	5
K.bey M.Kemalpaşa Susurluk - OVAGAZ	02.24.06	11.17.07	0.08	180
Elazığ - ELAZIĞGAZ	07.21.06	03.27.08	0.00	5
Trabzon Rize – KARADENİZGAZ	09.15.06	09.01.08	0.01	180
Gümüşhane Bayburt	09.22.06	10.04.08	0.25	180
Diyarbakır – DİYARGAZ	11.03.06	09.12.08	0.29	180
Adıyaman – AKMERCANGAZ	12.01.06	-	0.01	180
Ordu Giresun – FINDIKGAZ	12.08.06	11.20.08	0.00	169
Van	03.16.07	03.12.08	0.30	180
Seydişehir Çumra – SELÇUKGAZ	03.23.07	12.01.08	0.06	180
Çukurova – AKSAGAZ	07.20.07	-	0.00	167
Siirt Batman	12.28.07	-	0.24	180
Aydın	02.08.08	-	0.00	165

* These companies were set up before the enactment of NGML; the dates in the tender date column are setup date for these companies

Source: Author generated from EMRA (2009h)

The distribution companies have the sole right to sell gas to non-eligible consumers based on the regulated retail sale prices by EMRA and have the right to sell eligible consumers if an eligible consumer prefers to buy gas from the relevant distribution company (EMRA, 2009a). On the other hand, an eligible consumer who chooses a different supplier has to pay distribution charge to the relevant distribution company (EMRA, 2009d). The eligibility threshold is 1 million cubic meters for the non-tender companies (EMRA, 2009l) and more than 5 years of operation for the tender companies. However, this threshold is 15 million cubic meters for other tender companies (EMRA, 2009h). To determine the revenues and costs of each sub-activity separately, a distribution company is obliged to do account unbundling (EMRA, 2009m).

The retail sale prices and distribution fee tariffs of distribution companies are regulated by EMRA based on the rules and conditions set by the Article 11 of NGML. The retail sale prices and tariff principles consisting of unit purchase price of the natural gas, unit service cost, depreciation costs of the distribution company and other factors, shall be determined by EMRA. The retail sale tariffs can be revised by taking into consideration the inflation and other issues, upon application of the distribution companies to EMRA. In tariff setting process, the service cost, reasonable profitability that provides opportunity for investment, current natural gas purchase prices in the market and similar factors will be taken into consideration (EMRA, 2009a).

CHAPTER 3

METHODOLOGY AND LITERATURE SURVEY

Efficiency estimation methods have been developed to measure the performance of firm(s) or an industry in the process of production by analyzing inputs and outputs of the process.

The efficiency analysis studies have been based basically on the paper by Farrell (1957). Koopmans (1951) and Debreu (1951) studied efficiency, but Farrell systematized these studies and decomposed efficiency into AE and TE. Following Farrell, efficiency analysis has been developed by the studies of Fare (1975), Fare and Grosskopf (1983a and 1983b), Fare and Grosskopf (1985), Fare and Lovell (1978), Forsund and Hjalmarson (1974) and Zieschang (1984).

Efficiency analysis methods are generally classified as parametric and non-parametric. The parametric methods, namely Ordinary Least Squares (OLS), COLS, MOLS and SFA are based on econometrics. These methods produce equality with random part and coefficients and are used to measure the gap between estimate value and real value to determine the efficiency level.

The non-parametric methods are Total Factor Productivity (TFP) and DEA. These methods do not assume any functional form and produce efficiency scores for a firm by comparing the performance of the relevant firm in the past or the performance of the other firms.

DEA is based on the theoretical context established by the above mentioned studies. Charnes, Cooper and Rhodes (1978) proposed DEA method by determining input oriented efficiency scores. This model is assuming CRS in production. After this paper, many studies were conducted in the following years. Fare, Grosskopf and

Lovell (1983), Byrnes, Fare and Grosskopf (1984) and Banker, Charnes and Cooper (1984) developed DEA model assuming VRS.

Applied work decides between non-parametric and parametric efficiency measurement and considers the tradeoffs. In this study, we employ the non-parametric frontier approach to analyze economic efficiency of natural gas distribution firms, thus avoiding the specification errors that can result from making parametric assumptions about technology. As a consequence, in this section we will give some detailed information about DEA and the models based on this method.

3.1 Data Envelopment Analysis

DEA is a non-parametric method which measures efficiency level of a DMU by comparing this DMU with other DMUs. The goal of DEA is to find an efficient frontier composed of the best performer units of the data set under consideration, and then use that frontier to calculate the changes that can be made to the non-efficient DMUs. Linear programming is used to construct a non-parametric piece-wise surface over the data. To get efficiency score for a DMU, a separate model is solved for each DMU.

DEA has some valuable advantages compared to other efficiency analysis methods. First, DEA is superior thanks to its simplicity to implement, so it does not need complex mathematical formulas. Secondly, DEA can be used to calculate efficiency scores by handling both multiple inputs and outputs. The third advantage is that DEA does not need any functional form assumption. In addition to these, DEA considers all inputs and outputs as a group, eliminating the situation where every DMU claims to be a best performer on the basis of a limited view of a single input or output. Last but not the least; inefficient firms are compared to actual firms rather than some statistical measure (Jacobs, 2001 and Ruggiero, 2007).

On the other hand, DEA has some shortcomings. First of all, it considers all factors causing a DMU to divert frontier as inefficiency, i.e., it does not take into account the uncontrolled random factors. Further, as more variables are included in model, the number of firms on the frontier increases. Therefore, it is important to examine the sensitivity of the efficiency scores and the rank order of firms to analyze model specifications. Thirdly, as sample size increases, average efficiency scores decreases. To put it in a different way, the efficiency scores are sensitive to the number of DMUs. Lastly, the measures of efficiency or inefficiency are only relative to the available data set; there is no attempt to calculate theoretical efficiencies (Jacobs, 2001 and Ruggiero, 2007).

In this chapter, the analytical framework of DEA method is discussed. First, the comparison of input and output orientation is made. Then, basic information about four different DEA models, namely CRS DEA model, VRS DEA model, NIRS DEA model and cost minimization DEA model are given. Furthermore, how and why environmental factors are added into DEA models is described. Lastly, we provide a literature survey on the empirical studies which used DEA method to analyze the performance of DMU operating in distribution sectors, namely electricity and natural gas distribution sectors.

3.1.1 Input and Output Orientation

Efficiency scores can be calculated by using an input-oriented or an output-oriented model. The input-oriented models consider output to be fixed so that the input has to be adjusted in order to maximize efficiency. This approach is used by Farrell (1957) to measure TE. On the other hand, in the output-oriented models, inputs are considered to be fixed and the objective is the maximization of output. In other words, the input-oriented TE tries to give an answer to the question that "how much should input quantities be reduced without changing the output level?", whereas output-oriented TE tries to answer the question "how much should output quantities be increased without changing the input level?"

An important point about the relation between input and output oriented models is that if a firm operates at an optimal scale, there is no need to solve two models separately, on the grounds that the output-oriented and input-oriented TE scores become equal if return type is CRS (Fare and Lovell 1978).

The output oriented DEA models are very similar to their input oriented counterparts that will be explained in the following part. For example, consider the following output oriented VRS model (LP 3.1) which is counterpart of input oriented VRS model, explained in section 3.1.3.

$$
\begin{aligned}
&\mathrm{Min}_{\phi,\lambda}\ \phi, \\
&\text{st.} \quad -\phi q_i + Q\lambda >= 0, \\
&\qquad x_i - X\lambda >= 0, \\
&\qquad I1'\lambda = 1, \\
&\qquad \lambda >= 0,
\end{aligned}
\tag{3.1}
$$

where ϕ is a scalar measuring efficiency level, λ is a Ix1 vector of constants, q_i is the output vector of ith firm, Q, the MxI matrix, is the output matrix containing all firms' output data, x_i is the input vector of ith firm, X, the NxI matrix, is the input matrix containing all input data. In the model, TE is calculated by taking inverse ofϕ.

The selection of input or output oriented model depends on the structure of the industry. If the relevant firm is operating in an environment where the objective is to maximize output with a fixed quantity of resources, output oriented models should be used. However, if the management of the relevant firm has no effect on the level of output, input oriented measures become more meaningful. In natural gas distribution sector, distribution companies have to serve every customer who resides in a defined license area. Therefore, a natural gas distribution company does not have any control over the level of outputs. Such a firm can only increase its efficiency by decreasing the amount of inputs. Accordingly, efficiency analyses about the regulated distribution sector use input orientation. As a result, in this study, input oriented models are used to calculate efficiency scores of Turkish natural gas distribution companies.

3.1.2 Constant Returns to Scale Model and Technical Efficiency

The CRS DEA Model is proposed by Charnes, Cooper and Rhodes (1978) to determine input oriented efficiency scores. This model assumes CRS in production, and is used to find TE scores of the firms under the assumption that all firms are operating at the optimal scale. For I firms, N inputs and M outputs, we can use the LP 3.2 (Coelli et al., 2005):

$$\text{Min}_{\theta,\lambda}\ \theta,$$

$$\begin{aligned} \text{st.} \quad & -q_i + Q\lambda >= 0, \\ & \theta x_i - X\lambda >= 0, \\ & \lambda >= 0, \end{aligned} \tag{3.2}$$

where θ is a scalar measuring efficiency level, λ is a Ix1 vector of constants, q_i is the output vector of ith firm, Q, the MxI matrix, is the output matrix containing all firms' output data, x_i is the input vector of ith firm, X, the NxI matrix, is the input matrix containing all input data. This linear programming (LP) model will be solved for each firm to find efficiency level θ. The firms whose θ equals 1 will be deemed as efficient, others whose θ is lower than 1 will be deemed as inefficient.

The production technology associated with LP 3.2 can be defined as $T = \{(x,q): q<=Q\lambda, x>=X\lambda\}$. This technology defines a production set that is closed, convex and exhibits a CRS and strong disposability (Fare et al., 1994).

The CRS models may underestimate the company's pure technical efficiency by benchmarking it against dissimilar and, presumably, more scale-efficient comparators (Giannakis et al., 2005). To eliminate this shortcoming we should loose the restriction on returns to scale.

3.1.3 Variable Returns to Scale Model and Scale Efficiency

The CRS Model can be used if all firms operate at optimal scale. However, some problems like regulation, imperfect competition etc. may cause a firm not to be operated at optimal scale. Banker, Charnes, and Cooper (1984) proposed VRS model by noting that using a CRS model when not all DMUs are operating at optimal scale would produce incorrect measures of TE. VRS Model constructs a convex hull for the efficient frontier that is a tighter fit to the data points, increasing the TE scores for the DMUs. Thus, if the VRS TE is greater than the CRS TE, then scale inefficiencies exist.

The output for a VRS model is the same as the output for the CRS model described above, with the addition of the scale efficiency calculation. A measure of TE, based on a VRS input-orientated DEA model, can be summarized as follows:

$$CRS\ TE = VRS\ TE * SE \tag{3.3}$$

where CRS TE is decomposed into "pure" technical efficiency (VRS TE) and scale efficiency (SE) components. The nature of the scale inefficiency can be due to increasing (IRS) or decreasing (DRS) returns to scale (Hollas et al, 2002).

LP 3.4 will be used to find TE and scale efficiency scores of the firms under the assumption that all firms are not operating at the optimal scale (Coelli et al., 2005).

$$
\begin{aligned}
& \text{Min}_{\theta,\lambda}\ \theta, \\
\text{st.}\quad & -q_i + Q\lambda >= 0, \\
& \theta x_i - X\lambda >= 0, \\
& I1'\lambda = 1, \\
& \lambda >= 0,
\end{aligned} \tag{3.4}
$$

where I1' is an Ix1 vector of ones. This LP model will be solved for each firm to find efficiency level θ under the assumption of VRS production. In VRS models a convexity constraint $I1'\lambda = 1$ is added to the model which ensures that the firm is compared against other firms with similar size (Giannakis et al., 2005). In this model, frontier envelopes all data more tightly, so the efficiency scores become equal or bigger than the efficiency scores calculated under the assumption of CRS production.

By using TE scores of CRS DEA model and VRS DEA model, the scale efficiency score can be calculated for each firm with Equation 3.5:

$$SE_i = TE_{CRSi}/TE_{VRSi} \tag{3.5}$$

3.1.4 Non-increasing Returns to Scale Model and Nature of Technology

The scale efficiency scores only show whether the relevant firm operates at optimal scale or not, it does not say anything about whether the firm is in the increasing returns or the decreasing returns part of the production frontier. To find the scale type of a firm LP 3.6 should be solved:

$$
\begin{aligned}
&\mathrm{Min}_{\theta,\lambda}\ \theta,\\
\text{st.}\quad & -q_i + Q\lambda >= 0,\\
& \theta x_i - X\lambda >= 0,\\
& I1'\lambda <= 1,\\
& \lambda >= 0, \qquad (3.6)
\end{aligned}
$$

By restricting $I1'\lambda$ to be equal or lower than one, we are able to find TE score under the assumption of NIRS. This constraint ($I1'\lambda <= 1$) ensures that the ith firm is compared with firms smaller than itself. If TE score (θ) obtained from NIRS DEA model equals to θ produced by solving VRS DEA model, the firm is in the decreasing returns to scale part; otherwise, it is in the increasing returns to scale part (Coelli et al., 2005).

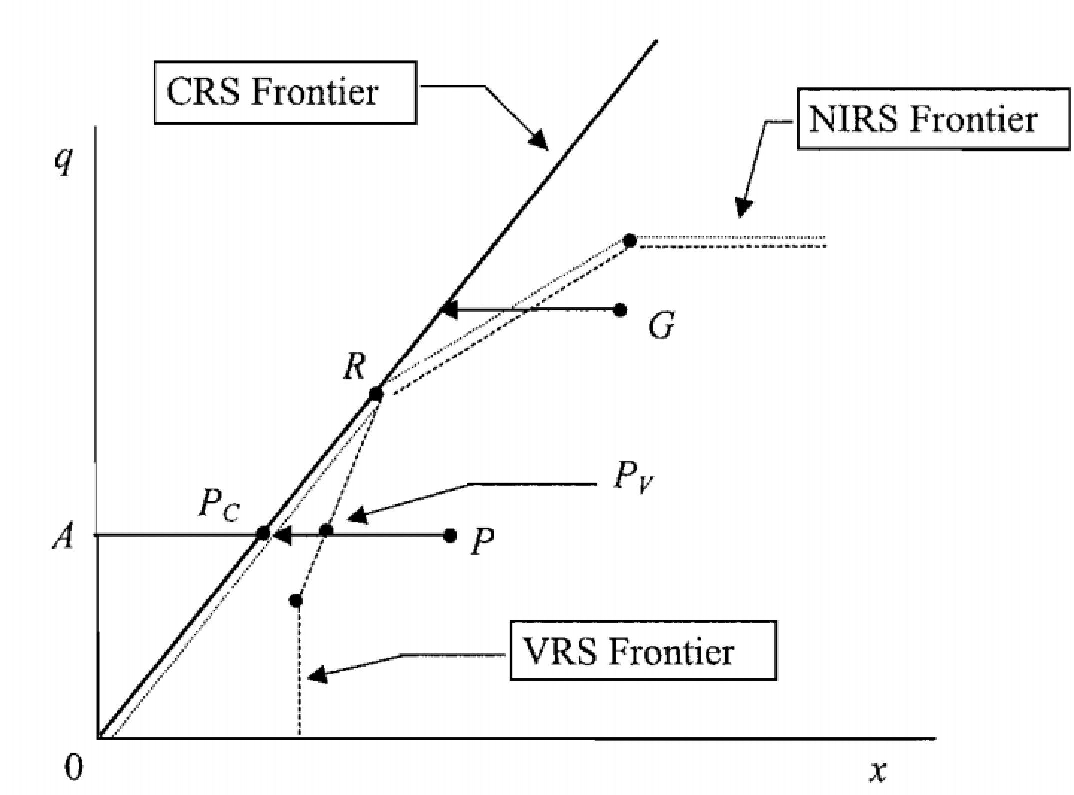

Figure 3-1: Scale Efficiency Measurement in DEA

Source: Coelli et al. (2005)

CRS, VRS and NIRS DEA frontiers are depicted in Figure 3-1. If all three scores of a firm are equal (firm R in Figure 3-1), this firm is scale efficient; otherwise there exist scale inefficiency. The nature of the scale inefficiency of a firm can be determined by comparing NIRS score with VRS score. If two scores are equal (firm G in Figure 3-1), the nature of technology of this firm is DRS. In contrast, in the event that two scores are not equal (firm P in Figure 3-1), then IRS exist.

3.1.5 Cost Minimization Model and Allocative Efficiency

Total economic efficiency for a system is composed of TE and AE. TE is defined as the ability of a DMU to use the minimum inputs to produce a determined level of output. Nonetheless, AE defines a DMU's ability to use inputs in optimal proportions so that to minimize the cost of production (Hollas et al., 2002).

TE scores and scale efficiency scores calculated by using input oriented CRS DEA, VRS DEA and NIRS DEA models can be used to analyze the distribution companies' production efficiency and to assess maturity level of these companies, but it does not say anything about their CE and AE. For this aim, LP 3.7 which assumes variable returns will be solved (Coelli et al., 2005):

$$\begin{aligned}
&\text{Min}_{\lambda,x_i^*}\ w_i' x_i^*,\\
&\text{st.}\quad -q_i + Q\lambda >= 0,\\
&\qquad x_i^* - X\lambda >= 0,\\
&\qquad I1'\lambda = 1,\\
&\qquad \lambda >= 0,
\end{aligned} \tag{3.7}$$

where w_i is an Nx1 vector of input prices for the i^{th} firm and x_i^* (which is calculated by the LP) is the cost-minimizing vector of input quantities for the i^{th} firm.

The results of this model will be used to calculate CE and AE scores.

$$CE = (w_i' x_i^*) / w_i' x_i \tag{3.8}$$

$$AE = CE/TE_{VRS} \tag{3.9}$$

That is, CE is the ratio of optimal cost ($w_i' x_i^*$) to observed cost ($w_i' x_i$). TE value used in the calculation of AE scores will be calculated from the DEA VRS model.

3.1.6 Environmental Factors

Environmental factors are the factors that could affect the efficiency level of a DMU and are not under the control of the firm management. These factors are not inputs and are not used to produce outputs, but affect the level of inputs and outputs exogenously. Some of environmental factors can be measured like population density, income per capita and network density. Conversely, some can not be measured including ownership structure and location. There are four widespread methods that are developed to accommodate environmental factors in a DEA analysis (Coelli et al., 2005).

Two of these four methods are used when the environmental factors can not be measured. (1) First, if the environmental factor is not measured but can be ordered from the least favorable to the most favorable, firms can be classified according to the favorability level and the firms that operate under the same environment are compared with each other or the ones that have less favorable environment. (2) Second, in the event that the environmental variable is neither measured nor ordered, the sample is divided into subsamples according to the characteristic of DMUs in terms of the relevant environmental factor. Then, DEA is solved for both of these subsamples and the whole sample.

The other two methods are developed for the measurable environmental methods. (3) The first method that is used if the environmental factors are measurable is a two-stage method (Coelli et al., 2005). In the first stage, a DEA model is solved without the addition of the environmental factors. Afterwards, the efficiency scores from the first stage are regressed upon the environmental variables. (4) In the last method, the measurable environmental variables are included in the LP model as outputs or non-discretionary variables[2]. In this option, the direction of the influence has to be determined first. (4.1) Then, if the influence is positive and there are L positive environmental variables, LP 3.10 will be used:

$$\mathrm{Min}_{\theta,\lambda}\ \theta,$$

$$\begin{aligned} \text{st.} \quad & -q_i + Q\lambda >= 0, \\ & \theta x_i - X\lambda >= 0, \\ & z_i - Z\lambda >= 0, \\ & I1'\lambda = 1, \\ & \lambda >= 0, \end{aligned} \qquad (3.10)$$

where z_i is the environmental variable vector of i^{th} firm, and Z, the LxI matrix, is the environmental variable matrix containing all firms' data (Coelli et al., 2005). Furthermore, if the influence is negative, the environmental factors can be added to the model as outputs and LP 3.11 will be used:

[2] A non-discretionary variable is a variable that is not under the control of the management of a firm.

$\text{Min}_{\theta,\lambda}\ \theta,$

$$\begin{aligned} \text{st.}\quad & -q_i + Q\lambda >= 0, \\ & \theta x_i - X\lambda >= 0, \\ & -z_i + Z\lambda >= 0, \\ & I1'\lambda = 1, \\ & \lambda >= 0, \end{aligned} \qquad (3.11)$$

If a model includes both kinds of environmental variables, the mixture of the models will be used (Coelli et al., 2005).

In this study, only the second alternative of the fourth method (4.2) is used to measure the effect of two environmental factors on the efficiency level of each DMU because the environmental variables are measurable and have negative influence on efficiency. Then, the scores generated by the models with environmental factors are compared with the ones that do not include any environmental factor.

3.2 Literature Survey on Empirical Studies

DEA has been widely used all over the world to analyze performance efficiency of DMUs including non-profit organizations and some activities like corporate governance efficiency. This method has been used especially in the performance analysis of hospitals, education institutions, banks, manufacturing firms, farms and ports. Furthermore, DEA has been used in efficiency analysis of regulated distribution firms in electricity and gas, but the number of these studies is not much for natural gas distribution. These two different distribution sectors belonging to different markets, namely electricity and gas have the same characteristics. Therefore, we will discuss the studies related to the efficiency analysis of both natural gas and electricity distribution sectors by focusing on sample size, input-output selection, methodology and conclusion.

The literature on economic efficiency analysis about gas distribution companies is scarce. Some of the studies are based on econometric estimation of cost or production functions and some use DEA for this aim. Among these studies that estimate efficiency scores of natural gas distribution companies by using econometric methods, we can mention Hollas and Stansell (1988), Kim and Lee (1996), Bernard et al. (1998), Fabbri et al. (2000), Granderson (2000), Rossi (2001)[3] and Farsi et al (2006).

In terms of the studies that use DEA in gas distribution sector, Granderson and Linvill (1999) use both parametric and nonparametric methods with an eleven-year panel data of 20 U.S. interstate natural gas transmission companies to produce a benchmark for regulation. They specify labor, fuel, weight of transmission pipelines and capacity of compressor stations as inputs and total costs as output. They use DEA to get non-parametric estimates of inefficiency and compare the results with the results of parametric methods. Although the results show that when using the nonparametric approach, the inefficiency estimates are lower, the inefficiency ranking stays more or less the same. The paper concludes that relative firm performance with standard CE scores is essentially identical to relative firm performance with regulated CE scores, i.e. there would not be a substantial change in the relative performances of firms under deregulation.

Carrington et al. (2002) measures the efficiency of Australian gas distributors relative to each other and relative to US counterparts with the sample size of 59. In this paper, several techniques are used such as partial productivity indicators, regression analysis, COLS, SFA and DEA. In preferred model, the inputs are length of pipelines and operating expenses; the outputs are gas delivery amount, number of residential customers and number of other customers; and the environmental factors are winter average degree and average age of pipelines. It is concluded that all techniques generated similar results which show that there was a scope for most local distributors to increase the efficiency.

The other paper about natural gas distribution companies is written by Hollas et al. (2002) in which the effect of different policies on economic efficiency of natural gas companies is analyzed. TE, SE and productivity changes are examined through DEA for 33 US natural gas distribution firms over a 20-year period from 1975 to 1994. The outputs are residential, commercial and industrial consumptions and the inputs

[3] See Farsi et al (2007) for detail information about these studies.

are capital, labor and volume of purchased gas. Their results suggest little or no support for the hypothesis that enhanced competition has altered economic efficiency of gas distributors. However, the most significant effect of federal policy during the examined period is a general reduction in scale due to industry restructuring and the promotion of competition.

Silveira and Legey (2007) also use DEA to evaluate the performance of the nine natural gas distribution firms in Brazil. The model consisting of two inputs (length of network and number of employees) and one output (gas delivery amount) is solved to estimate TE scores by using the data of 2004. The paper concludes that the main source of inefficiencies in Brazilian gas distribution companies is related to their scale of operation.

Another study in gas sector is about the determination of the nature of returns to scale in the Italian gas distribution industry by Erbetta et al. (2008). In the paper, 46 gas distributors' technical and scale efficiencies are analyzed over the period 1994–1999 with the single input as total cost and the outputs as the number of customers and the delivered volumes. According to this study, technology shows increasing returns for small companies that have customers less than 65,000 and delivery volumes less than 150 million cubic meters. As a result, they propose that merging of the small companies will increase the scale efficiency and social welfare[4].

[4] Fabbri et al. (2000) also analyze the efficiency of Italian natural gas distribution firms by using econometric methods and conclude that the economies of scale are not significant at the output levels, but economies of density appear to be considerable.

Table 3-1: Empirical Studies on Electricity Distribution Sector

Authors	Inputs	Outputs	Sample Size	Main Findings
Førsund et al. (1998)	- hours of labor - capital cost - material cost - energy loss	- customers - units sold - distance index	150 firms in Norway	- a positive productivity growth averaging nearly 2% per year, mainly due to frontier technology shift
Giannakis et al. (2005)	- Operation and Maintenance cost - total cost - security of supply - reliability of supply	- customers - units sold - total grid size	14 firms in the UK	- cost-efficient firms do not necessarily exhibit high service quality - efficiency scores of cost-only models do not show high correlation with those of quality-based models - improvements in service quality have made a significant contribution to the sector's total productivity change
Korhonen et al. (2003)	- Operation and Maintenance cost - cost of capital - dispersion of customers - # of customers - forest cover	- units sold - quality - winter temperature - change in the cons. - insular areas - urbanization	102 firms in Finland	- an improvement in TE after controlling for quality of service (interruption time per customer) - efficient units are distributed all over Finland and operate in different operational environments
Pahwa et al. (2003)	- energy loss - Operation and Maintenance cost - Capital expenditure - transformers - lines	- peak load - units sold - customers	50 firms in the USA	- 19 firms are efficient
Ghaderi et al. (2006)	- number of workers - total grid size - transformer capacity	- # of customers - units sold	38 firms in Iran	- the results of DEA and COLS models show a considerable variation in efficiency scores and ranks.
Von Hirschhausen et al. (2006)	- number of workers - total grid size - peak load - energy loss - aerial / cable line	- # of customers - units sold - inverse density index	307 firms in Germany	- returns to scale play but a minor role; only very small utilities have a significant cost advantage - low customer density is found to affect the efficiency score significantly - East German utilities feature a higher average efficiency then West

Table 3-1(continued): Empirical Studies on Electricity Distribution Sector

Authors	Inputs	Outputs	Sample Size	Main Findings
Hess et al. (2007)	- number of workers - total grid size - aerial line - cable line	- customers - units sold - inverse density index	304 firms in Germany	- East German firms are more efficient than West German firms
Cullmann et al. (2008)	- number of workers - total grid size	- customers - units sold - inv density index	32 firms in Poland	- while TE increased during the transition period, AE did not - the smaller utilities are on average less efficient, largely due to SE - the results derived by non-parametric and parametric analysis are consistent
Jamasb et al. (2003)	- energy loss - Operation and maintenance cost - Total cost - total grid size	- total grid size - units sold - customers	63 firms in six European countries	- the choice of benchmarking techniques, model specification, and variables can affect the efficiency scores - considerable variation in results when using network length as proxy for capital stocks instead of capital expenditures
Edvardsen et al. (2003)	- Operation and Maintenance cost - total grid size - energy loss - replacement value	- customers - units sold	122 firms from North Europe	- no country is completely dominated by another, and all countries contribute to spanning the frontier - Finland seems to be the most productive country within the common technology
Estache et al. (2004)	- number of workers - total grid size - transformer capacity - residential sales' share - GNP per capita	- customers - units sold - service area	84 firms in South America	- a regulator's information disadvantage can be mitigated by increasing international coordination and the use of comparative measures of efficiency
Hattori et al. (2005)	- total cost - load factor - customer density	- customers - units sold	21 firms in UK and Japan	- efficiency scores are higher for the UK - productivity gain is larger in the UK
Cullmann et al. (2006)	- number of workers - total grid size	- customers - units sold - inv density index	84 firms in East Europe and Germany	- Poland's distribution companies are still inefficiently small - the Czech Republic features the highest efficiency - privatization has had a positive effect on TE

Contrary to natural gas distribution sector, there are relatively more articles written about the efficiency analysis of electricity distribution companies by using DEA method. Table 3-1 lists a selection of these studies some of which include DMUs of one country and some are done to compare DMUs from a variety of countries. Amongst others, case studies for single countries are carried out by Forsund et al. (1998) who use a Malmquist Cost Index to examine the productivity of Norwegian electricity utilities. The results show a positive productivity growth averaging nearly 2% per year, mainly due to frontier technology shift. Quality is explicitly accounted for and related to benchmarking in a study by Giannakis et al. (2005) of UK electricity distribution utilities. They find that cost-efficient firms do not necessarily exhibit high service quality, while improvements in service quality make a significant contribution to the sector's total productivity change. Korhonen et al. (2003) apply DEA on Finnish distributors and find an improvement in TE after controlling for quality of service (interruption time per customer). Pahwa et al. (2003) use DEA to measure and compare the performance of 50 distribution firms in US. Ghaderi et al. (2006) carry out a study for Iranian firms by using both parametric and non-parametric models the results of which show a considerable variation in efficiency scores and ranks. Von Hirschhausen et al. (2006) and Hess et al. (2007) also chose DEA to compare East and West firms in Germany by using similar variables and both find that East German firms are more efficient than West German firms. Last, Cullmann et al. (2008) use non-parametric as well as parametric benchmarking techniques and they find that the Polish utilities feature scale inefficiency. While the TE increases over the years from 1997 to 2002 the AE decrease. In addition, they find that the smaller utilities are on average less efficient, largely due to scale inefficiency.

Moreover, comparative country studies exist but, as Jamasb and Pollitt (2003) stated in their cross-country study for six European countries, one has to account for country-specific effects in order to guarantee comparability. They focus on the capital stock variable and show the effect of measure type on efficiency. Edvardsen et al. (2003) also carry out a cross-country study for five European countries and find that no country is completely dominated by another, and all countries contribute to spanning the frontier. Estache et al. (2004) assess TE for six countries from Latin

America and reach a conclusion that a regulator's information disadvantage can be mitigated by increasing international coordination and the use of comparative measures of efficiency. Comparing distributors from the UK and Japan by applying DEA and SFA, Hattori et al. (2005) find that the firms from UK are facing higher productivity gains than the Japanese firms over the period 1985 to 1998. Cullmann et al. (2006) use non-parametric as well as parametric benchmarking techniques to compare 84 firms from East Europe and Germany. They find that the Polish utilities feature scale inefficiency because of small size. While TE increases over the years from 1997 to 2002, AE decreases.

A long list of the studies about the efficiency analysis of electricity distribution companies is given in Jamasb and Pollitt (2001). They assemble an extensive comparison of efficiency studies for the electricity sector stressing the importance of the appropriate variable choice. In their paper as well as in the literature in general, a wide variety of different specifications are employed depending on what exactly is being investigated, and what variables are being used as inputs and as outputs. Moreover, Plagnet (2006) gives a more up to date list of the studies in efficiency analysis of electricity distribution.

DEA also has been used in Turkey to analyze the performance of DMUs from several sectors. These studies are concentrated mainly on the banking sector like Bal et al. (2002), Şakar (2006), Mercan et al. (2003) and Özkan-Günay et al. (2006). Besides, DEA is used by Köksal et al. (2006) in education, by Ersoy et al. (1997) in health sector, by Düzakın et al. (2007) in the measuring the performance of manufacturing firms, by Bakırcı (2007) in textile sector and by Sarıca et al. (2007) in the efficiency assessment of Turkish power plants. Regarding distribution companies, to our knowledge, there are only two papers written by Bağdadioğlu et al. (1996) and Bağdadioğlu et al. (2007) which are outlined below. However, there is not any study using DEA in the efficiency analysis of Turkish natural gas distribution companies.

A study of Turkish electricity distribution sector is conducted by Bağdadioğlu et al. (1996) who use a non-parametric method to create a benchmark measure for the relative performance of the publicly operated organizations as well as the publicly operated organizations and their private counterparts. They conclude that the privately operated distribution companies had better technical and scale efficiency scores.

In another study, Bağdadioğlu et al. (2007) analyze the effect of the merger in Turkish electricity distribution sector on efficiency. The panel data for the period 1999 – 2003 is used to compare the actual efficiency levels of observed distribution companies with the merger of proposed aggregated companies. They consider number of customers, electricity consumed and service area as outputs and number of employees, number of transformers, transformer capacity, network length and network losses as inputs and prefer input-oriented DEA model. They claim that the merger will provide considerable efficiency improvement, but for the potential efficiency enhancement at either individual level or at merged level to be realized, an appropriate incentive mechanism is necessary.

To sum up, there is a considerable literature about the efficiency analysis of DMUs from several sectors including electricity distribution sector by applying DEA. However, things are less developed in natural gas distribution sector, especially in Turkish natural gas distribution sector as shown by the fact that, to the best of our knowledge, this paper is the first effort to generate this type of assessment for a set of Turkish natural gas distribution companies.

CHAPTER 4

DATA AND ESTIMATION

In this chapter, we first introduce the data set by describing the selected inputs and outputs. Then, three partial productivity indicators, namely penetration rate, labor productivity and capital productivity are discussed. Furthermore, the specification of the models set up to measure the efficiency levels for the companies is explained. In addition, the effect of the different model specifications on efficiency in terms of the input-output selection, the number of variables and the environmental factors are analyzed. Besides, the efficiency scores are analyzed to compare the performance of public versus private, new versus old, tender versus non-tender and small versus big firms. Lastly, the common characteristics of the most inefficient firms are discussed.

4.1 Data

In this study, Turkish natural gas distribution companies are analyzed in terms of their technical, scale, cost and allocative efficiency. To determine these efficiency scores we collected data for 38 firms. Cross sectional data belonging to 2008 is used in the analysis.

The sample size has an important role in the level of TE scores of DMUs when DEA method is used in estimation. According to Diewert (1993), the average TE score of the analyzed companies will decrease as the number of DMUs increases. The reason is that as the number of firms increases, the chance of encountering firms close to the true production frontier increases. Namely, the frontier constructed by DEA approaches the true frontier asymptotically as the number of firms in an industry increases (Banker, 1989). In DEA models, number of constraints is equal to the number of firms, i.e., more firms mean more constraints. Thus, if the number of firms increases, the number of constraints increases and the feasible solution set becomes smaller. As a result, TE score of any firm in the study becomes equal or smaller than the one estimated from a model with fewer firms.

In this study, 38 of 60 distribution companies are used. Our sample size is limited due to the fact that only the data of these 38 companies are proper for efficiency analysis. Other 22 firms are excluded because of two reasons. First, some of these firms started to construct their distribution network within the last two to three years and started to distribute natural gas in 2007 or 2008. These companies generally have completed a little part of the network and only connected few customers to the network. Secondly, some of the firms are not included in the data set because reliable data can not be obtained for these firms.

In addition to the number of firms, the number of variables affects the level of efficiency score of a firm. Contrary to the sample size, as the number of variables increases, the efficiency scores tend to increase, i.e., if we reduce the number of variables, efficiency score of a firm decreases or remains the same, but never increases. With the addition of more variables, each firm tends to become unique in some aspects and has less benchmarking partners. Inclusion of more variables causes two problems. First, when the number of inputs and outputs is large, the imprecision of the results is reflected in large bias, large variances and wide confidence intervals (Simar and Wilson, 2007). Second problem is that a very large number of variables can increase the number of efficient firms and makes the analysis useless (Pahwa et al., 2003). Thus, as the number of outputs increases, the number of observations must increase at an exponential rate. To determine whether the number of variables is high, we can use a rule-of-thumb that the sample size should be greater than or equal to three times the sum of the number of inputs and outputs (Pahwa et al., 2003).

Considering the effect of the number of variables on the efficiency scores, we try to limit the number of variables and only use major inputs and outputs. Consequently, given the relatively low sample size in the study, we use 9 variables at most in one model and 4 variables at least in two models.

To get reliable results, it is also necessary to use proper variables in the model on the grounds that the efficiency analysis depends on input – output selection. In the selection of inputs and outputs two problems have to be solved which are the classification of variables as inputs and outputs and the inclusion of proper variables.

In the classification of variables, we can use a general guideline that a variable that is preferred to have low value when all other variables are fixed should be considered as an input. On the other hand, a variable that is desirable to have high value when all other variables are fixed should be considered as an output (Pahwa et al., 2003).

Choosing the right variables is difficult in an analysis of distribution companies since there are many environmental factors affecting the efficiency of distribution firms. Hence, there is no firm consensus on which variables best describe the operation of distribution companies (Giannakis et al., 2005) and there are many different variable portfolio in different studies. Jamasb and Pollitt (2001) determine the most widely used variables in efficiency analysis studies of electricity distribution utilities. According to this study, the most frequently used inputs are operating costs, number of employees, transformer capacity, and network length, whilst the most widely used outputs are units of energy delivered, number of customers, and the size of service area. In addition to these, peak load, purchased power, loss, capital expenditure, network density and revenues are other widespread variables used in the efficiency analysis of distribution companies (Jamasb and Pollitt, 2001).

The outputs can be determined easily compared to inputs. The widespread outputs that have been used in the studies conducted on natural gas and electricity distribution companies' efficiency analysis are consumption, consumer number and peak load which are also used in this study.

Four input variables which are operating expenditure, capital expenditure, network length and number of employees are selected to analyze Turkish natural gas distribution companies' economic efficiency. In some models, we use operating expenditure and capital expenditure directly, whereas in some other models we use network length as a proxy for capital and number of employees as a proxy for operating expenditure.

The last group of variables is environmental factors. For distribution companies, there are many environmental factors that affect the efficiency level of a firm. The important ones are service area, climate, inverse apartments per building ratio, income per capita, altitude, purchase price and land characteristics. We analyze all of these factors and decide to use the most important factors which are climate and inverse apartments per building ratio in the study. As mentioned before, as the number of variables used increases, the analysis becomes useless due to the fact that each firm becomes unique in some aspects. Therefore, two environmental factors are considered to be sufficient for this study. If sample size were large, we would select more environmental factors.

The companies included in this analysis are regulated and monitored by EMRA, so that there are reliable and properly classified data regarding the companies. Accordingly, the data about the inputs, outputs and the costs of the companies are obtained from EMRA.

In this section, some details related to the mentioned inputs and outputs will be given.

4.1.1 Inputs

There are two broad classes of inputs in any economic activity: capital costs and operating costs. However, these costs have been used seldomly in efficiency analysis; instead some physical measures like length of pipelines, number of employees and transformer capacity are preferred generally owing to the difficulty to obtain accurate measures of operating and capital costs (Jamasb and Pollitt, 2001).

Capital which is the major input for network companies can be used in monetary terms or physical terms. Because of the difficulty to get the correct monetary measure, physical terms have been used intensely. Nevertheless, this approach has some disadvantages. First, it can not capture all fixed assets. Secondly, it does not account for differences in some important characteristics like quality and age. As a consequence, to use monetary measures produces correct results, but it is difficult to generate monetary measures. First, it is impossible to get consistent values since accounting methods and revaluation policies are different for each company. There is not a consensus on the right method of calculating the monetary values (Carrington et al, 2002). As a result, we use monetary measure only in one model by taking annual depreciation amount as capital costs; in other models we use physical measures. In some models, the lengths of steel pipelines and polyethylene pipelines are used as two different inputs as proxies for capital costs and in some others only one variable that is total length of pipelines is used.

Contrary to capital costs, operating costs can be more easily determined. However, we use operating costs directly only in two models, in others we prefer to use number of employees instead of operating costs. The most important reason is to get a chance of calculating cost and allocative efficiencies on the grounds that these efficiency scores could only be calculated with physical amounts and prices of inputs. Also, we use physical measures for operating costs in line with capital. For the number of employees, we use both the number of employees of the relevant firm and the number of employees of subcontractors that provide some services to the distribution companies because of the fact that some firms execute some subservices like meter reading by using its own employees and some others use subcontractors.

4.1.2 Outputs

Residential consumption, industrial consumption, total consumption, number of customers and peak demand are outputs that are used in this study. Consumption and number of consumers are common outputs that are considered as main variables nearly in all efficiency analysis studies concerning distribution firms. However, peak demand is included only in a few studies like Klein et al. (1992) and IPART (1999).

The amount of natural gas delivered by a distribution company is the fundamental output of gas distribution in view of the fact that the main aim of construction of distribution networks is consumption. Parallel to other studies, we classify consumption as residential and industrial consumption and in some models we take total consumption and in others we use residential and industrial consumptions as two different variables.

Contrary to consumption, we use total number of consumers in all analyses. We did not take industrial and residential consumers as different variables on the grounds that the number of industrial customers is generally low. Furthermore, rather than the number, the consumption amount of these consumers is important. For example, one industrial consumer in some distribution area can consume much more than residential consumption of the relevant distribution area.

The last output is daily peak demand of the network. Since a network is designed and set up to satisfy peak demand, this output has an important role on the efficiency level of a distribution company.

4.1.3 Environmental Factors

AGLGN (1999) listed environmental factors that could affect the efficiency level of a natural gas distribution company as soil type, topography, pipeline materials, climate, age of pipelines, urbanization level and ratio of industrial consumption within the network. In addition to these factors, inverse apartments per building ratio, population density and income per capita can be considered as other environmental factors.

Most of the above mentioned factors can be used in this study, but taking into account the small sample size, it is restricted to only two environmental factors. Hence, we prefer two most important environmental factors which are climate and inverse apartments per building ratio. To reflect the effect of climate, we use average temperature in winter by assigning 1 to the lowest value. Climate is important because it affects both consumption and investment and operating costs. In hard climate areas, it is costly to operate a distribution network. Moreover, in cold climate areas people consume more gas in winter.

On the other hand, inverse apartments per building ratio is chosen because it is easy to calculate and reflects the effects of more than one environmental factor including population density and urbanization level.

4.1.4 Descriptive Findings

In this section, the characteristics of the variables will be analyzed by using some basic statistical measures. In this context, sum, mean, median, standard deviation, minimum and maximum values for each variable are calculated and results are given in Table 4-1.

The amount of natural gas delivered by these 38 companies in 2008 is about 18 billion cubic meters and 23% of this amount is delivered by only one company, İstanbul Gaz Dağıtım A.Ş. (İGDAŞ). Conversely, the minimum amount delivered by a company is about 3 million cubic meters which is about 0.02 percent of total consumption. This large difference between the maximum and the minimum amounts is also observed in the standard deviation values.

In 2008, industrial customers consumed more than 12 billion cubic meters (70% of total amount) and the other 5.5 billion cubic meters was consumed by residential customers. İGDAŞ, the biggest distribution company, delivered 3.4 billion cubic meters to households and became the number one in terms of residential consumption. In contrast, the maximum natural gas delivered to industrial customers was realized by Adapazarı Gaz Dağıtım A.Ş. (AGDAŞ) with 2.5 billion cubic meters. The minimum residential and industrial consumptions which are 2.8 million and 0, respectively, took place in the same distribution area.

Total number of customers of all 38 distribution firms is 4 million and the number of customers deviates among the firms. The maximum number of customers that belongs to one company (İGDAŞ) is 2.5 million, whereas the minimum is only 4,450. The mean value of this variable is 108,726, the median is 25,640 and the standard deviation is 412,969.

Table 4-1: Descriptive Statistics of Variables (2008)

	Sum	Mean	Median	Std Dev	Min	Max
OUTPUTS						
Total Consumption (million m^3)	17,747,428,134	467,037,582	103,881,422	847,284,514	2,805,615	4,014,357,013
Residential Consumption (million m^3)	5,415,295,989	142,507,789	34,468,987	543,505,788	2,805,615	3,369,989,267
Industrial Consumption (million m^3)	12,332,132,145	324,529,793	56,106,747	580,502,307	0	2,453,733,591
Total Number of Customers	4,131,587	108,726	25,640	412,969	4,450	2,559,399
Peak Demand (m^3/day)	94,953,173	2,498,768	692,135	5,816,964	46,893	34,175,049
INPUTS						
Total Length of Network (km)	42,709,982	1,123,947	447,703	2,743,568	84,123	16,790,622
Length of Steel Pipeline (km)	3,972,511	104,540	42,383	238,179	6,358	1,464,923
Length of PE Pipeline (km)	38,737,470	1,019,407	394,923	2,506,755	75,525	15,325,699
Number of Employees	5,866	154	47	491	20	3,058
Total Costs (TL)	560,556,609	14,751,490	3,745,719	49,076,651	1,389,309	301,167,923
Operating Costs (TL)	348,698,550	9,176,278	2,237,851	30,961,555	889,413	191,367,923
Capital Costs (TL)	211,858,059	5,575,212	1,270,127	18,247,782	82,040	109,800,000
ENVIRONMENTAL FACTORS						
Average Winter Temp (^{0}C)		4	5	4	-3	17
Inverse Apr. per Building Ratio (building/apr.)		0,24	0,22	0,12	0,09	0,67

The fifth output variable analyzed in Table 4-1 is daily peak demand. These 38 firms' total peak demand which is maximum daily consumption in a defined area became 95 million cubic meters in 2008. Taking into account the annual consumption of 17.7 billion cubic meters for these 38 firms, we can find average daily consumption as 48 million cubic meters and load factor as 51%. This means average capacity usage is about 51 percent for distribution sector in 2008. If we consider that residential customers consume nearly 90% - 95% of the total annual natural gas in winter, it can be claimed that this load factor is high enough. Nevertheless, load factor differs among companies according to the weight of industrial consumption. For example, the load factor of İGDAŞ in 2008 is only 32% since industrial consumption is only 16 percent of total consumption. In contrast, load factor is 63% for AGDAŞ which has the highest industrial consumption in 2008.

Concerning network's physical capital, the length of network will be used in models. Total length of networks of these 38 companies is more than 42 million meters and length of steel pipelines and polyethylene pipelines are 4 million meters and 38.5 million meters, respectively. The ratio of steel pipeline length to total length is around 9%. The maximum length of pipelines belonging to İGDAŞ is 16.8 million meters, whereas the minimum is 84,123 meters. Mean values for total, steel and polyethylene pipelines are 1.1 million meters, 0.1 million meters and 1 million meters, respectively.

The other input variable is labor which is considered as a proxy for operating expenditure in some models where operating expenditure can not be used. The total number of employees is around 5,866. The maximum number of employees existed in İGDAŞ which is 3,058 employees. The low level of mean and median which are 154 and 47 respectively shows that other firms have very small number of employees.

Total cost variable includes only operating costs and depreciation as capital costs. If the costs of these firms are examined, it is obvious that operating costs are generally higher than capital costs for the sector. That is to say, total costs of all 38 companies are 560 million TL and 350 million TL of this amount is operating costs. Besides, there exist different values between firms' costs. For example, as total costs of one company are above 300 million TL which consists of more than 50 percent of total costs of all firms, the minimum total costs are about 1.4 million TL. Furthermore, the mean values of total costs, operating costs and capital costs are 15 million TL, 9 million TL and 5.5 million TL, respectively.

The last two variables are environmental factors which are average winter temperature and inverse apartments per building ratio. Total amount can not be calculated for these two variables because of the fact that the addition of the values does not give any meaningful information. However, other statistical measures are calculated. The mean, median and standard deviation of average winter temperature are close to each other and their values are 4 ^{0}C, 5 ^{0}C and 4 ^{0}C degrees, respectively. On the other hand, the same values for inverse apartments per building are 0.24, 0.22 and 0.12, respectively. The differences between maximum and minimum values are high, so these environmental factors may affect the efficiency levels of the firms.

In addition to the analysis of variables by using some basic statistical measures, the correlation between the variables are also calculated and correlation coefficients are given in Table 4-2. General conclusion is that all variables have high correlations with each other. In spite of the fact that total consumption has relatively low values compared to other variables, the smallest correlation coefficient of this variable is over 0.7. All other variables except total consumption have high correlations with each other and the smallest correlations are between total number of customers with peak demand and capital costs with peak demand, both having the value of 0.93.

Table 4-2: Correlation Coefficients between Selected Variables

	Total Consumption	Total Number of Customers	Peak Demand (m^3/day)	Total Length of Network	Number of Employees	Operating Costs	Capital Costs
Total Consumption	1.00						
Total Number of Customers	0.74	1.00					
Peak Demand (m^3/day)	0.93	0.93	1.00				
Total Length of Network	0.82	0.98	0.96	1.00			
Number of Employees	0.77	1.00	0.94	0.99	1.00		
Operating Costs	0.78	0.99	0.94	0.99	1.00	1.00	
Capital Costs	0.79	0.97	0.93	0.97	0.98	0.99	1.00

4.2 Partial Productivity Indicators

Partial productivity measures are simple ratios that are used to help to form judgments about the efficiency level of firms[5]. Although many ratios can be calculated for this aim, we focus on three of them which are penetration rate, labor productivity and capital productivity. Labor productivity and capital productivity measure the level of technical efficiency, whereas penetration rate shows marketing strategy and investment strategy efficiencies.

These indicators give some useful information about the efficiency of firms, but these measures need to be interpreted carefully. These productivity measures do not show a complete view of the performance of the firms because of some reasons. First, they focus on only one property and do not consider the various relationships or trade-offs between inputs and outputs of gas distribution. Therefore, partial productivity measures can potentially mislead and misrepresent the performance of a firm. Also, these factors do not take into account the environmental factors which

[5] For details, see Coelli et al. (2005) and Carrington et al. (2002).

may cause unattractive results for some firms operating in an adverse environment (Carrington et al, 2002).

4.2.1 Penetration Rate

Penetration rate is calculated by dividing the number of customers that are connected to network and started to consume natural gas to the potential number of customers that are connected to network but not started to consume natural gas. It is expected to be low for the firms that are in the early stage of network investment. However, firms can manage this rate successfully if network investment and marketing activities are successfully coordinated.

Penetration rate has direct relations with outputs and a high value for penetration rate means high outputs as inputs are fixed. Consequently higher penetration rates produce higher efficiency scores.

Penetration rate indicates whether a firm efficiently utilizes its capital; therefore, it can be considered as a capital productivity indicator. However, we analyze it as a different productivity indicator since it only measures the potential of the firm, not the actual productivity.

The penetration rates of the 38 firms covered in our study are given in Table 4-3. The maximum value is 89% and minimum is 20%. Nonetheless, the mean penetration rate is 63%, which means these distribution firms can increase the number of customers by about 43% without any additional investment costs. Besides, the average penetration rate of the old companies and new companies are calculated and as expected the average value of old ones is turned out to be higher than the value of new ones; which are 79% and 60%, respectively. The difference between the values of these two groups stems from the maturity levels of the firms.

Table 4-3: Partial Productivity Indicators

	Penetration Rate	Labor Productivity		Capital Productivity	
		Indicator 1	**Indicator 2**	**Capital 1**	**Capital 2**
DMU1	58%	1,377,527	431	125	0.039
DMU2	46%	628,190	331	69	0.037
DMU3	61%	4,093,345	366	523	0.047
DMU4	43%	1,740,130	803	154	0.071
DMU5	82%	563,980	301	181	0.096
DMU6	62%	9,990,461	204	1,323	0.027
DMU7	60%	4,738,946	600	304	0.038
DMU8	75%	1,721,574	352	279	0.057
DMU9	83%	2,191,761	737	452	0.152
DMU10	84%	1,474,873	428	196	0.057
DMU11	61%	2,957,079	941	223	0.071
DMU12	79%	1,312,739	837	239	0.152
DMU13	84%	4,108,347	475	532	0.061
DMU14	20%	16,065,638	290	1,771	0.032
DMU15	43%	1,707,331	283	241	0.040
DMU16	48%	932,611	566	95	0.058
DMU17	74%	596,065	501	81	0.068
DMU18	81%	1,347,086	1,028	131	0.100
DMU19	53%	85,019	135	24	0.039
DMU20	83%	1,179,972	501	198	0.084
DMU21	43%	315,382	255	89	0.072
DMU22	85%	2,136,632	869	228	0.093
DMU23	58%	8,487,283	653	774	0.060
DMU24	54%	2,247,294	770	314	0.107
DMU25	84%	2,103,046	1,053	186	0.093
DMU26	20%	3,459,293	46	826	0.011
DMU27	87%	1,179,293	169	220	0.031
DMU28	62%	1,919,158	1,024	99	0.053
DMU29	83%	843,891	413	114	0.056
DMU30	27%	4,954,582	388	672	0.053
DMU31	32%	8,212,839	407	858	0.042
DMU32	51%	923,388	315	160	0.054
DMU33	79%	3,964,085	889	342	0.077
DMU34	76%	3,578,775	629	355	0.062
DMU35	76%	18,530,414	299	1,659	0.027
DMU36	75%	5,521,628	1,523	324	0.089
DMU37	51%	9,858,006	696	583	0.041
DMU38	89%	2,451,882	413	372	0.063

The penetration rates are generally higher than 50%, which can be seen in Figure 4-1. The number of firms in the upper intervals increases and arrives at 11 firms in the interval 80% - 90%. While the new firms take place in every interval, the old firms have penetration rates concentrated between 70% and 90%.

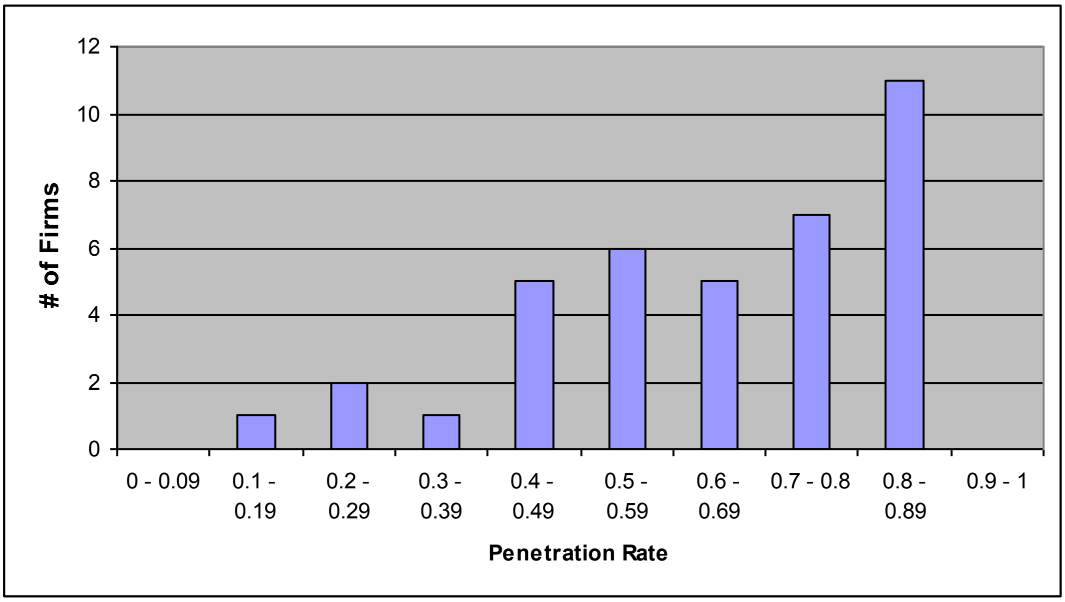

Figure 4-1: Dispersion of Penetration Rates.

4.2.2 Labor Productivity

Two ratios of labor productivity are calculated to measure whether a firm uses its labor efficiently or not. The first labor productivity indicator is calculated by dividing total natural gas delivered in 2008 to number of employees and the second indicator is calculated by dividing number of customers to number of employees. The results for each DMU are given in Table 4-3.

As it can be seen from Table 4-3, there are big differences between firms in terms of these two labor productivity measures. Regarding the first labor productivity indicator, the maximum value is 18.5 million cubic meters, while the minimum is 85,019 cubic meters. The mean labor productivity of these 38 firms is 3.7 million cubic meters and standard deviation is 4 million cubic meters, higher than the mean value. Only 8 companies' labor productivity is less than 1 million cubic meters. If these companies are carefully analyzed, one can understand that these low productivity measures stem from diseconomies of scale on the grounds that every distribution company needs some personnel to operate a network independent of its delivery amount. This situation can be seen in Figure 4-2 where number of firms is given according to number of employees. Half of 38 firms have number of employees between 26 and 50 and only 7 firms have more than 100 employees. As a result, if the consumption amount is low, labor productivity inevitably becomes lower.

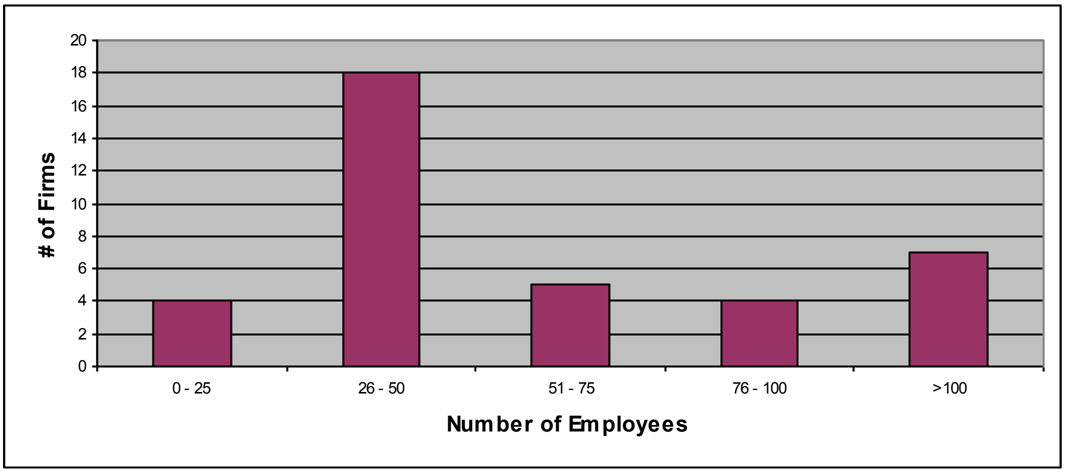

Figure 4-2: Dispersion of Number of Employees

If the life time of the firms is used as a comparison criterion, it can be concluded that the old distribution companies are more productive than the new ones. The mean of the old firms' labor productivity is 5.7 million cubic meters, whereas the new firms' mean consumption per employee is 3.3 million cubic meters. The most important reason is that the old companies are more mature and get closer to their potential in terms of delivery amount level.

The second labor productivity measure which is calculated by dividing number of customers to number of employees also shows high variety. However, this measure has less deviation compared to the first one. The mean value is 551 customers per employee and standard deviation is 313. The maximum value is 1,523, and the minimum is 46.

Like the first labor productivity measure, the old firms have higher values on average compared to the new ones. The mean value of the old firms is 721 customers per employee, whereas the mean value of the new firms is 519.

Regarding the comparison of the results of these two productivity measures, it can be seen from Table 4-3 that there is a high inconsistency between the values of these measures. For example, only one of the first 10 companies that have higher values in terms of the first labor productivity indicator also is a member of the group of the first 10 companies that have higher values in terms of the second labor productivity indicator. If the lowest 8 values of two measures are compared, it can be seen that only 2 firms belong to both groups. This situation proves that high and low productivity values do not only depend on the efficiency or inefficiency of relevant firms, but also the structure of the customer portfolio. For instance, the firm that has maximum delivery per employee is the 31st in rank in terms of numbers of customer per employee value since this firm has a customer that consumes more than 90 percent of the annual natural gas distributed by this company. It can be checked whether this conclusion about the inconsistency is correct by calculating the correlation coefficients. The value of correlation coefficient in between two labor productivity measures is -0.09 as it can be seen from Table 4-4. This finding is matching with the conclusion mentioned above.

Table 4-4: Productivity Indicators' Correlations

	Labor Prod 1	**Labor Prod 2**	**Capital Prod 1**	**Capital Prod 2**
Labor Prod 1	1.00			
Labor Prod 2	-0.09	1.00		
Capital Prod 1	0.93	-0.27	1.00	
Capital Prod 2	-0.36	0.59	-0.37	1.00

4.2.3 Capital Productivity

Like labor productivity, two different measures are calculated for capital productivity to analyze whether a firm uses its capital efficiently. The first capital productivity indicator is calculated by dividing total natural gas consumption to length of network and the second measure is calculated by dividing number of customers to length of network. The results are given in Table 4-3.

The differences between firms in terms of the two capital productivity indicators are less compared to the labor productivity measures, but there is still wide variety. If the results for the first measure are analyzed, it can be seen that the maximum value is 1,771 cubic meters/km and the minimum is 24 cubic meters/km. On the other hand, the mean capital productivity is 403 cubic meters/km and standard deviation is 414 cubic meters/km. There are three firms whose capital productivity is higher than 1,000 cubic meters/km and seven firms whose capital productivity is higher than 500 cubic meters/km and lower than 1,000 cubic meters/km. Eight of these 10 firms are also among the firms that have the highest 10 ranks in terms of the labor productivity. Six of the last 8 firms with lowest capital productivities are also among the last 8 firms that have the lowest labor productivities. These comparisons prove that there is a high consistency between labor and capital productivity in terms of consumption. To measure the level of consistency, the correlation coefficient is calculated which is found to be considerably high (0.93) as expected.

Similar to labor productivity, the mean of the capital productivity values of the old firms is higher than that of new firms. The mean of the former and the latter are 546 cubic meters/km and 376 cubic meters/km, respectively. This is probably due to the high penetration rate of the old firms.

The other capital productivity measure which is calculated by dividing the number of customers to length of network is used in order to observe whether a firm uses its capital efficiently. This measure has the least variety among these four productivity measures. Its standard deviation which is 0.031 is half of the mean. The most productive firm's score is 0.152 customer/km, whereas the least productive firm's score is 0.011 customer/km. This measure has positive correlation with the second labor productivity measure, but the coefficient is not high. This correlation coefficient is 0.59 which is less than the correlation coefficient between the first labor productivity and the first capital productivity measures. The high correlations between labor and capital productivity measures show that the length of network is the most important factor affecting the number of employees of a firm.

When the productivity levels of these firms are analyzed in terms of their life time, like all other partial productivity indicators, the old firms have higher values on average compared to the new ones. The mean value of the old firms is 0.084 customer/km, whereas the mean value of the new firms is 0.60 customer/km.

Lastly, two capital productivity indicators are compared. Like the labor productivity measures, these measures also have negative correlation, but the level of this negative correlation is much higher. The firm that has maximum productivity in terms of first capital productivity measure has the 34th rank in terms of the second capital productivity measure.

4.3 Estimation

To estimate efficiency scores of distribution companies input-oriented models are used by taking into account the service obligation of the distribution firms to all customers in their defined area. For this aim, seven models with different input-output sets are formed and TE_{CRS}, TE_{VRS}, SE, CE and AE scores are calculated for each of them.

In this section, first of all these seven models will be explained in terms of the selected variables and the logic behind this selection. Then, the results of these models will be analyzed for TE, SE, AE and CE scores by comparing the scores generated by different models. Moreover, impact of environmental factors, different model specifications and variable selections on efficiency will be investigated. Then, results will be analyzed by comparing public firms with private firms, new firms with old firms, tender firms with others and small firms with big firms. Lastly, this study examines reasons for the inefficiency of some firms under investigation.

4.3.1 Models

Seven models which employ different combinations of the variables introduced in Section 4.1 are constructed. Some characteristics of these models are summarized in Table 4-5.

Model 1 includes all important variables that affect the efficiency level of the distribution companies. Inputs of the model are steel pipeline length, polyethylene pipeline length and number of employees; outputs are residential consumption, industrial consumption, number of customers and peak demand; environmental factors are average winter temperature and inverse apartments per building ratio. Four DEA models, namely CRS DEA, VRS DEA, NIRS DEA and CE DEA are used to calculate TE, SE, AE and CE scores. However, high variable number is the blind side of this model because having more variables may increase the efficiency scores of the inefficient firms.

Model 2 consists of the same inputs and environmental factors as Model 1, but outputs are different. This model is developed to measure the effect of the classification of consumption on efficiency. Like in Model 1, all four DEA models will be used to calculate four efficiency scores and nature of technology of the companies.

Model 3 is a version of Model 2. Contrary to Model 2, the number of inputs are decreased by taking length of network as total, not dividing it into two parts as steel and polyethylene. This model will be used to measure the effect of the classification of pipeline on efficiency.

Model 4 is a different model compared to Model 3 in terms of the outputs. In this model, only the outputs that are connected with residential customers are considered under the assumption that the network is used only to provide service to residential customers. This model aims to reveal the effect of the industrial customers who consume natural gas with low unit costs on the efficiency levels of the firms. Thus, DMUs that have high efficiency scores can be detected, thanks to high amount of industrial consumption instead of conducting distribution service in an efficient way.

Table 4-5: Model Specifications

Model	Inputs	Outputs	Environmental Factors	Efficiency Models	Efficiency Scores
Model 1	• Steel Pipeline Length, • PE Pipeline Length • Number of Employees	• Residential Consumption, • Industrial Consumption, • Number of Customers, • Peak Demand	• Average Winter Temperature, • Inverse Apartments per Building Ratio	• CRS DEA • VRS DEA • NIRS DEA • CE DEA	• TE • SE • AE • CE
Model 2	• Steel Pipeline Length • PE Pipeline Length • Number of Employees	• Total Consumption, • Number of Customers, • Peak Demand	• Average Winter Temperature, • Inverse Apartments per Building Ratio	• CRS DEA • VRS DEA • NIRS DEA • CE DEA	• TE • SE • AE • CE
Model 3	• Total Pipeline Length • Number of Employees	• Total Consumption • Number of Customers, • Peak Demand	• Average Winter Temperature, • Inverse Apartments per Building Ratio	• CRS DEA • VRS DEA • NIRS DEA • CE DEA	• TE • SE • AE • CE
Model 4	• Total Pipeline Length • Number of Employees	• Residential Consumption, • Number of Residential Customers, • Peak Demand	• Average Winter Temperature, • Inverse Apartments per Building Ratio	• CRS DEA • VRS DEA • NIRS DEA • CE DEA	• TE • SE • AE • CE
Model 5	• Total Pipeline Length • Number of Employees	• Total Consumption, • Number of Customers, • Peak Demand		• CRS DEA • VRS DEA • NIRS DEA • CE DEA	• TE • SE • AE • CE
Model 6	• Operating expenditure	• Total Consumption, • Number of Customers, • Total Pipeline Length		• CRS DEA • VRS DEA	• TE • SE
Model 7	• Total expenditure	• Total Consumption, • Number of Customers, • Total Pipeline Length		• CRS DEA • VRS DEA	• TE • SE

Model 5 is developed to measure the effect of environmental factors on the efficiency levels of the firms. For this purpose, the efficiency scores and the ranks of the firms that have low efficiency scores will be analyzed by comparing the results of Model 3 and Model 5. Model 5 has only five variables whereas all the variables are the same as Model 3 except the environmental variables which are excluded.

The last two models which are similar to each other are included in the study to analyze the expenditure efficiencies of the firms and therefore base on the expenditures of the firms. In the previous models, we use physical terms like number of employees and length of network as inputs, but monetary terms are used as inputs in these last two models. Outputs which are total consumption, number of customers and length of network are the same in both models, but inputs are different. Regarding inputs, only operating expenditure is considered in Model 6, whereas total expenditure which consists of both operating expenditure and depreciation is included in Model 7. Contrary to the previous five models, these two models consider length of network as output on the grounds that the level of this variable affects the amount of expenditure. In addition to the selection of variables, these two models are different in terms of the usage of efficiency models. Only CRS DEA and VRS DEA are used to analyze the efficiency levels of the firms and two scores, TE and SE, are determined.

4.3.2 Results

The seven efficiency models explained in section 4.3.1 are processed by DEAP 2.1 (CEPA, 2001) to estimate the efficiency scores of the natural gas distribution companies. First, TE scores both under the assumption of CRS and VRS are measured for all efficiency models. Then, scale efficiency scores and the nature of returns to scale for each DMU are determined for all seven efficiency models. Lastly, CE and AE scores are calculated under the assumption of VRS technology. However, these last two scores are found only for the first five efficiency models because of the reason that the 6th and 7th efficiency models have inputs in monetary terms.

In this section, the results of the models are given and explained by using basic statistical measures. Furthermore, the correlation coefficients between models are calculated for each efficiency measure.

4.3.2.1 Technical Efficiency Scores

If the TE has a value of 1, then the DMU is one of the best performers and lies on the efficient frontier for that data set. On the other hand, a TE score that is less than 1 shows that the relevant DMU works inefficiently. TE score can be used to calculate the percentage by which all inputs can be decreased without decreasing the outputs. These decreased input levels are referred to as targets, and define the projected performance point that would cause the DMU to fall on the efficient frontier. As we are calculating input-oriented models, our efficiency scores relate to changes in the inputs, so no measure of percentage changes related to outputs is calculated.

The CRS TE scores of all seven efficiency models are given in Table 4-6. Model 1 containing the maximum number of variables has the highest efficiency scores with an average score of 83%. On the other hand, Model 6 one of the models that has the lowest number of variables has the lowest scores as the mean of the 38 DMUs is only 56%. Similar to mean values, the highest minimum efficiency score exists in Model 1 and Model 2 (49%) and the lowest in Model 6 (11%). However, the minimum efficiency score of each model does not belong to the same firm. As the DMU with the minimum score is the same in Model 1, 2, 3 and 4 (DMU1), the minimum scores belong to DMU5 in Model 6 and 7 and DMU19 in Model 5. Regarding variance, the differences between models are low. When the variance of Model 1, 2, 3 and 4 is 4%, it is 5% in Model 5, 6% in Model 7 and 7% in Model 6.

In addition to basic statistical measures, the number of efficient firms differs from one model to another. As expected, the number of efficient firms is highly correlated with the average efficiency score level. If the average score is high, the number of efficient firms also becomes high. Therefore, Model 1 has the highest value with 15 firms, whereas Model 6 has the lowest value with 4 firms.

Table 4-6: TE Scores under the Assumption of CRS Technology

Firm	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
DMU1	49%	49%	47%	47%	44%	40%	58%
DMU2	93%	93%	93%	93%	32%	28%	43%
DMU3	61%	61%	61%	57%	54%	77%	93%
DMU4	100%	100%	100%	100%	68%	21%	31%
DMU5	100%	100%	100%	100%	63%	11%	22%
DMU6	100%	100%	96%	93%	81%	61%	61%
DMU7	66%	65%	63%	58%	51%	51%	54%
DMU8	57%	57%	56%	56%	48%	74%	94%
DMU9	100%	100%	100%	100%	100%	89%	100%
DMU10	65%	65%	62%	62%	54%	43%	55%
DMU11	89%	84%	82%	88%	78%	96%	100%
DMU12	100%	100%	100%	100%	100%	41%	42%
DMU13	66%	66%	65%	56%	65%	26%	25%
DMU14	100%	100%	100%	88%	100%	72%	60%
DMU15	97%	97%	57%	54%	37%	27%	39%
DMU16	57%	57%	56%	56%	52%	74%	92%
DMU17	59%	59%	58%	58%	53%	48%	67%
DMU18	100%	100%	100%	100%	92%	74%	77%
DMU19	100%	100%	100%	100%	25%	27%	43%
DMU20	71%	71%	70%	71%	60%	30%	47%
DMU21	62%	62%	61%	61%	47%	20%	31%
DMU22	100%	87%	86%	100%	85%	100%	98%
DMU23	95%	95%	94%	87%	84%	100%	79%
DMU24	100%	100%	100%	100%	86%	80%	74%
DMU25	92%	92%	92%	92%	89%	57%	82%
DMU26	57%	56%	54%	50%	48%	73%	100%
DMU27	50%	49%	49%	47%	27%	43%	57%
DMU28	97%	97%	97%	97%	67%	74%	80%
DMU29	50%	50%	50%	50%	43%	100%	100%
DMU30	100%	100%	93%	83%	63%	55%	61%
DMU31	100%	100%	100%	100%	79%	54%	68%
DMU32	77%	59%	47%	69%	42%	29%	42%
DMU33	83%	83%	81%	81%	81%	56%	73%
DMU34	68%	67%	65%	61%	65%	33%	53%
DMU35	100%	100%	100%	100%	100%	100%	100%
DMU36	100%	100%	100%	100%	100%	45%	64%
DMU37	98%	97%	97%	89%	80%	75%	92%
DMU38	100%	100%	100%	100%	63%	23%	34%
Mean	83%	82%	80%	79%	66%	56%	65%
Minimum	49%	49%	47%	47%	25%	11%	22%
Maximum	100%	100%	100%	100%	100%	100%	100%
Variance	4%	4%	4%	4%	5%	7%	6%
# of Efficient Firms	15	14	12	12	5	4	5

Lastly, the correlation coefficient table is constructed for these seven efficiency models in terms of CRS TE efficiency scores (Table 4-7). If we analyze the coefficients, we can see that there are high correlations among the first four models and among the last two models. Nevertheless, Model 5 has low correlation with all other models. In addition, the last two models have low correlation scores with all other models. Even Model 7 has negative correlation with the first four models. However, the correlations of these models with Model 5 are relatively high, possibly due to similar variable structures.

Table 4-7: Correlation Coefficients between CRS TE Scores of the Models

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Model 1	1,00						
Model 2	0,98	1,00					
Model 3	0,92	0,94	1,00				
Model 4	0,92	0,91	0,96	1,00			
Model 5	0,61	0,61	0,68	0,66	1,00		
Model 6	0,07	0,05	0,12	0,12	0,44	1,00	
Model 7	-0,09	-0,10	-0,02	-0,01	0,31	0,92	1,00

The CRS models may underestimate the company’s pure technical efficiency by benchmarking it against dissimilar and, presumably, more scale efficient comparators. On the other hand, in VRS assumption, firms are benchmarked against other firms that are comparable in size. As a result, the efficiency scores in VRS technology assumption either remain at the same level or increase relative to the CRS scores (Coelli et al., 2005). In this study, when we use the VRS assumption for these seven efficiency models instead of CRS, we find that the efficiency scores are increasing significantly as it can be seen from Table 4-8: 101 of the 266 efficiency scores are hundred percent under the assumption of VRS while 67 of the 266 efficiency scores are hundred percent under the assumption of CRS. This can be explained by the fact that now DMUs of similar size are compared with each other, not with the best ones in the sample. With VRS, the average efficiency increases to

83%, 10 percentage points higher than the results under the CRS assumption. For individual DMUs, this improvement is significantly higher, in particular for the smaller DMUs.

The VRS TE scores and basic statistical measures for all seven efficiency models are given in Table 4-8. The mean TE scores are considerably high compared to the mean of CRS TE scores. It is 89% for Model 1 that has the highest score and 71% for Model 6 which has the lowest score. However, the rankings of the models are similar in CRS and VRS. In a similar way, the rankings are alike in terms of minimum TE scores.

Variances of TE scores are also calculated for each model. The highest variance belongs to Model 6 as 5%, while the variance of all other models is 3%. As we compare variances of VRS technology with CRS technology, we can see that the variances are lower in VRS technology.

Beside basic statistical measures, the number of efficient firms differs from one model to another. As the maximum number of efficient firms exists in Model 1 (22 firms), the minimum belongs to Model 6 (7 firms).

The correlation coefficient table is generated for seven efficiency models in terms of VRS TE efficiency scores (Table 4-9). Contrary to CRS technology results, there is not any negative correlation between the models. Besides, the levels of coefficients are higher in VRS technology except for the correlation between Model 6 and Model 7. The lowest correlation among the first four models exceeds 0.95 and the correlations between the first four models and Model 5 are over 0.85.

Table 4-8: TE Scores under the Assumption of VRS Technology

Firm	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
DMU1	74%	70%	70%	73%	70%	41%	59%
DMU2	100%	100%	100%	100%	57%	30%	44%
DMU3	64%	63%	61%	57%	57%	79%	94%
DMU4	100%	100%	100%	100%	100%	31%	43%
DMU5	100%	100%	100%	100%	100%	40%	62%
DMU6	100%	100%	97%	93%	91%	67%	74%
DMU7	79%	75%	73%	70%	73%	54%	54%
DMU8	60%	60%	60%	60%	51%	76%	95%
DMU9	100%	100%	100%	100%	100%	96%	100%
DMU10	67%	67%	64%	64%	61%	44%	55%
DMU11	89%	84%	82%	88%	80%	100%	100%
DMU12	100%	100%	100%	100%	100%	100%	100%
DMU13	66%	66%	66%	56%	65%	45%	33%
DMU14	100%	100%	100%	90%	100%	73%	61%
DMU15	100%	100%	99%	99%	99%	59%	73%
DMU16	78%	78%	71%	71%	71%	79%	96%
DMU17	76%	76%	74%	74%	74%	61%	82%
DMU18	100%	100%	100%	100%	100%	78%	77%
DMU19	100%	100%	100%	100%	80%	83%	100%
DMU20	100%	100%	100%	100%	100%	67%	88%
DMU21	79%	79%	78%	78%	78%	55%	71%
DMU22	100%	91%	91%	100%	91%	100%	99%
DMU23	95%	95%	95%	88%	91%	100%	80%
DMU24	100%	100%	100%	100%	87%	85%	78%
DMU25	100%	100%	99%	100%	99%	58%	82%
DMU26	58%	57%	56%	51%	55%	78%	100%
DMU27	57%	55%	54%	49%	45%	51%	64%
DMU28	100%	100%	100%	100%	91%	79%	81%
DMU29	59%	59%	59%	59%	59%	100%	100%
DMU30	100%	100%	94%	84%	90%	97%	89%
DMU31	100%	100%	100%	100%	91%	63%	75%
DMU32	100%	90%	80%	93%	80%	59%	73%
DMU33	100%	100%	100%	100%	100%	100%	100%
DMU34	69%	67%	65%	62%	65%	50%	64%
DMU35	100%	100%	100%	100%	100%	100%	100%
DMU36	100%	100%	100%	100%	100%	76%	87%
DMU37	98%	98%	98%	89%	97%	80%	92%
DMU38	100%	100%	100%	100%	100%	54%	68%
Mean	89%	88%	86%	85%	83%	71%	79%
Minimum	57%	55%	54%	49%	45%	30%	33%
Maximum	100%	100%	100%	100%	100%	100%	100%
Variance	3%	3%	3%	3%	3%	5%	3%
# of Efficient Firms	22	20	16	17	11	7	8

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Table 4-9: Correlation Coefficients between VRS TE Scores of the Models

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Model 1	1,00						
Model 2	0,99	1,00					
Model 3	0,97	0,99	1,00				
Model 4	0,97	0,97	0,96	1,00			
Model 5	0,88	0,89	0,89	0,86	1,00		
Model 6	0,18	0,18	0,17	0,17	0,26	1,00	
Model 7	0,09	0,08	0,07	0,12	0,16	0,86	1,00

In conclusion, there are important differences between efficiency scores under the assumption of CRS technology and VRS technology. Furthermore, the number of efficient firms considerably increases in VRS DEA models. As a result, it can be inferred that the low technical CRS efficiency scores combined with a notable difference in the VRS scores indicate that the Turkish natural gas distribution companies are too small to be efficient.

4.3.2.2 Scale Efficiency Scores and Type of Returns

In parts 4.3.2.1 and 4.3.2.2, the efficiency scores of the firms under the assumption of both CRS and VRS technology are analyzed and this analysis shows that there are high differences between the scores calculated by using these two technologies. This inference means that Turkish natural gas distribution firms generally work inefficiently in terms of scale. As a consequence, we expect that the number of firms which operate under CRS is low compared to the ones which are under IRS or DRS.

To find the scale efficiency scores we use CRS TE and VRS TE scores by applying Equation 3.5. Furthermore, to determine the nature of scale inefficiency, we solve NIRS DEA model for the seven efficiency models. The results considering scale efficiency scores and the nature of returns to scale are given in Table 4-10.

Table 4-10: SE Scores and Nature of Technology

Firm	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	SE	**RTS**	**SE**	**RTS**	**SE**	**RTS**	**SE**	**RTS**	**SE**	**RTS**	**SE**	**RTS**	**SE**	**RTS**
DMU1	66,0%	IRS	69,1%	IRS	66,6%	IRS	64,4%	IRS	62,0%	IRS	97,7%	IRS	98,5%	IRS
DMU2	92,6%	DRS	92,6%	DRS	92,5%	DRS	92,5%	DRS	56,3%	IRS	96,1%	IRS	97,4%	IRS
DMU3	96,5%	DRS	96,5%	DRS	99,9%	CRS	99,5%	DRS	94,9%	IRS	97,3%	DRS	98,7%	IRS
DMU4	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	68,1%	IRS	67,7%	IRS	72,8%	IRS
DMU5	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	63,4%	IRS	27,9%	IRS	34,9%	IRS
DMU6	100,0%	CRS	100,0%	CRS	99,1%	IRS	99,8%	IRS	89,1%	IRS	91,2%	IRS	81,9%	IRS
DMU7	83,8%	IRS	86,0%	IRS	85,4%	IRS	83,1%	IRS	69,9%	IRS	95,8%	DRS	99,9%	CRS
DMU8	94,0%	DRS	94,0%	DRS	93,7%	DRS	93,7%	DRS	93,7%	IRS	97,4%	DRS	98,7%	IRS
DMU9	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	92,9%	IRS	100,0%	CRS
DMU10	97,7%	IRS	97,7%	IRS	97,2%	IRS	96,9%	IRS	88,8%	IRS	97,7%	DRS	99,9%	IRS
DMU11	99,9%	IRS	99,2%	IRS	99,8%	IRS	99,8%	IRS	97,7%	IRS	96,3%	DRS	100,0%	CRS
DMU12	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	40,9%	DRS	42,3%	DRS
DMU13	99,8%	DRS	99,7%	DRS	99,1%	DRS	99,0%	DRS	100,0%	CRS	56,5%	DRS	75,9%	DRS
DMU14	100,0%	CRS	100,0%	CRS	100,0%	CRS	98,1%	DRS	100,0%	CRS	98,8%	DRS	99,1%	DRS
DMU15	97,1%	IRS	97,1%	IRS	57,9%	IRS	54,3%	IRS	37,0%	IRS	45,4%	IRS	53,5%	IRS
DMU16	73,3%	IRS	73,3%	IRS	78,3%	IRS	78,3%	IRS	72,8%	IRS	93,7%	IRS	95,2%	IRS
DMU17	78,1%	IRS	78,1%	IRS	78,5%	IRS	78,5%	IRS	71,6%	IRS	78,7%	IRS	81,8%	IRS
DMU18	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	91,7%	IRS	93,8%	DRS	100,0%	CRS
DMU19	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	31,7%	IRS	33,1%	IRS	42,9%	IRS
DMU20	70,8%	IRS	70,8%	IRS	70,3%	IRS	70,5%	IRS	60,2%	IRS	44,5%	IRS	53,9%	IRS
DMU21	78,9%	IRS	78,9%	IRS	78,9%	IRS	78,7%	IRS	60,8%	IRS	36,3%	IRS	43,8%	IRS
DMU22	100,0%	CRS	95,1%	IRS	94,7%	IRS	100,0%	CRS	93,6%	IRS	100,0%	CRS	99,1%	IRS
DMU23	100,0%	CRS	99,9%	CRS	99,5%	DRS	99,4%	DRS	92,8%	IRS	100,0%	CRS	98,3%	IRS
DMU24	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	98,8%	IRS	93,9%	DRS	95,6%	DRS

Table 4-10 (continued): SE Scores and Nature of Technology

Firm	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	SE	**Return**	**SE**	**Return**	**SE**	**Return**	**SE**	**Return**	**SE**	**Return**	**SE**	**Return**	**SE**	**Return**
DMU25	92,1%	IRS	92,2%	IRS	92,8%	IRS	92,4%	IRS	89,9%	IRS	97,8%	DRS	99,3%	IRS
DMU26	97,4%	IRS	97,5%	IRS	97,2%	IRS	96,6%	IRS	87,0%	IRS	92,8%	DRS	100,0%	CRS
DMU27	87,7%	DRS	89,3%	DRS	91,0%	DRS	95,6%	DRS	59,0%	IRS	84,0%	IRS	88,7%	IRS
DMU28	97,0%	DRS	97,0%	DRS	97,0%	DRS	96,9%	DRS	74,1%	IRS	93,8%	DRS	99,4%	DRS
DMU29	85,0%	IRS	85,0%	IRS	84,8%	IRS	84,7%	IRS	74,1%	IRS	100,0%	CRS	100,0%	CRS
DMU30	100,0%	CRS	100,0%	CRS	99,3%	DRS	99,5%	IRS	69,7%	IRS	56,5%	IRS	68,0%	IRS
DMU31	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	87,5%	IRS	85,4%	IRS	90,6%	IRS
DMU32	77,0%	IRS	65,6%	IRS	58,8%	IRS	74,3%	IRS	52,2%	IRS	48,5%	IRS	57,5%	IRS
DMU33	82,6%	DRS	82,6%	DRS	80,6%	DRS	80,6%	DRS	80,6%	DRS	55,9%	DRS	72,8%	DRS
DMU34	98,9%	DRS	99,9%	IRS	100,0%	CRS	98,8%	DRS	100,0%	CRS	66,9%	DRS	81,4%	DRS
DMU35	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS
DMU36	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	59,7%	DRS	73,4%	DRS
DMU37	99,6%	DRS	99,6%	DRS	99,6%	DRS	99,4%	DRS	82,3%	IRS	94,3%	DRS	99,4%	IRS
DMU38	100,0%	CRS	100,0%	CRS	100,0%	CRS	100,0%	CRS	62,5%	IRS	42,3%	IRS	49,4%	IRS
Mean	93,3%		93,1%		91,9%		92,2%		79,3%		77,7%		82,7%	
Minimum	66,0%		65,6%		57,9%		54,3%		31,7%		27,9%		34,9%	
Maximum	100,0%		100,0%		100,0%		100,0%		100,0%		100,0%		100,0%	
Variance	1,0%		1,0%		1,5%		1,4%		3,5%		5,7%		4,4%	
# of Efficient Firm	19		18		17		16		7		4		8	

The scale efficiency scores are higher in the first four models in a way that the mean values are over 90% compared to the other models which have mean values around 80%. According to the results of Model 1, 16 DMUs are operating at optimal scale and 12 of 22 inefficient DMUs is close to the optimal scale with more than 90% scale efficiency. In addition, 9 of the 22 scale inefficient firms are in DRS part. If we consider the immaturity characteristic of these firms, this large number of firms which either have CRS or DRS is contrary to the expectations. These problems are also relevant for all other models except Model 5 which has only one company having DRS technology. Regarding Model 6, the number of DMUs that have DRS technology increases to 17.

In addition to mean values, minimum, maximum and variance are calculated for the scale efficiency scores. In all models, there are some scale efficient firms, so the maximum score is 100% for all models. Regarding the minimum scores, Model 6 has the lowest minimum score with 28% and Model 1 and Model 2 have the highest minimum score with 66%. Variance values are relatively low for the models. The lowest values belong to the first four models with 1%.

In addition to statistical measures, the number of scale efficient firms is given in Table 4-10. As expected, the number of scale efficient firms has parallelism with the number of technically efficient firms under the assumption of CRS technology. The number of scale efficient firms is high in the first four models with 19, 18, 17 and 16 firms, respectively and low for the others.

Moreover, the number of DRS, CRS and IRS technology for each firm is calculated (Table 4-11). It is obvious that the number of DMUs with IRS is very high. As a result, we can conclude that Turkish natural gas distribution companies generally operate at the scale below the optimal level.

Lastly, the correlation coefficients are calculated to show the relations between the models (Table 4-12). Contrary to the correlations in TE scores, correlation coefficients are only high between Model 2 and Model 4, and Model 6 and Model 7.

Table 4-11: Nature of Returns to Scale for Each Firm

Firm	# of IRS	# of DRS	# of CRS
DMU1	7	0	0
DMU2	3	4	0
DMU3	2	4	1
DMU4	3	0	4
DMU5	3	0	4
DMU6	5	0	2
DMU7	5	1	1
DMU8	2	5	0
DMU9	1	0	6
DMU10	6	1	0
DMU11	5	1	1
DMU12	0	2	5
DMU13	0	6	1
DMU14	0	3	4
DMU15	7	0	0
DMU16	7	0	0
DMU17	7	0	0
DMU18	1	1	5
DMU19	3	0	4
DMU20	7	0	0
DMU21	7	0	0
DMU22	4	0	3
DMU23	2	2	3
DMU24	1	2	4
DMU25	6	1	0
DMU26	5	1	1
DMU27	3	4	0
DMU28	1	6	0
DMU29	5	0	2
DMU30	4	1	2
DMU31	3	0	4
DMU32	7	0	0
DMU33	0	7	0
DMU34	1	4	2
DMU35	0	0	7
DMU36	0	2	5
DMU37	2	5	0
DMU38	3	0	4
Total	**128**	**63**	**75**

Table 4-12: Correlation Coefficients between SE Scores

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Model 1	1.00						
Model 2	0.30	1.00					
Model 3	0.46	0.49	1.00				
Model 4	0.22	0.93	0.56	1.00			
Model 5	0.28	0.17	0.57	0.18	1.00		
Model 6	0.11	0.38	0.36	0.50	0.09	1.00	
Model 7	0.10	0.41	0.35	0.53	0.11	0.98	1.00

4.3.2.3 Cost Efficiency Scores

In addition to the estimation of TE and SE scores, CE and AE scores are determined for Turkish natural gas distribution companies by solving cost minimization DEA model. However, CE and AE scores are estimated only for the first five models, not for Model 6 and Model 7 since in Model 6 and Model 7 inputs are used in monetary terms.

In cost minimization DEA model, two important assumptions are used. First, because of the difficulty to find the reliable data about network investment and labor costs of these companies, average prices are used instead of firm specific input prices. For this purpose, we calculate average prices by using the cost data of the five oldest companies. Second, we solve cost minimization DEA model under the assumption of VRS technology. This technology is chosen due to the fact that these companies do not have the right to decide on the level of outputs and the size of the network. They have to serve all customers in their defined license area.

Table 4-13: CE Scores under the Assumption of VRS Technology

Firm	Model 1	Model 2	Model 3	Model 4	Model 5	Mean
DMU1	41%	41%	45%	45%	45%	43%
DMU2	80%	80%	78%	78%	36%	70%
DMU3	61%	61%	61%	57%	51%	58%
DMU4	100%	100%	100%	100%	64%	93%
DMU5	100%	100%	100%	100%	100%	100%
DMU6	87%	87%	97%	91%	91%	90%
DMU7	42%	42%	41%	36%	40%	40%
DMU8	58%	58%	59%	59%	47%	56%
DMU9	100%	100%	100%	100%	100%	100%
DMU10	49%	49%	56%	56%	52%	52%
DMU11	63%	56%	60%	67%	58%	61%
DMU12	100%	100%	100%	100%	100%	100%
DMU13	62%	62%	63%	52%	61%	60%
DMU14	100%	100%	100%	89%	100%	98%
DMU15	83%	80%	74%	69%	69%	75%
DMU16	49%	49%	49%	49%	49%	49%
DMU17	53%	53%	57%	57%	57%	55%
DMU18	74%	74%	76%	76%	71%	74%
DMU19	100%	100%	100%	100%	75%	95%
DMU20	83%	82%	81%	80%	80%	81%
DMU21	76%	76%	75%	75%	75%	75%
DMU22	100%	64%	67%	100%	67%	80%
DMU23	73%	73%	77%	70%	71%	73%
DMU24	100%	100%	100%	100%	75%	95%
DMU25	66%	66%	67%	67%	67%	66%
DMU26	50%	50%	52%	47%	51%	50%
DMU27	53%	52%	53%	49%	40%	49%
DMU28	43%	43%	45%	45%	40%	43%
DMU29	46%	46%	48%	48%	45%	46%
DMU30	85%	85%	77%	64%	77%	77%
DMU31	98%	98%	91%	91%	83%	92%
DMU32	80%	69%	64%	77%	64%	71%
DMU33	67%	67%	65%	64%	65%	66%
DMU34	57%	51%	55%	53%	55%	54%
DMU35	100%	100%	100%	100%	100%	100%
DMU36	81%	73%	72%	75%	72%	75%
DMU37	51%	51%	54%	49%	54%	52%
DMU38	100%	100%	100%	100%	89%	98%
Mean	74%	72%	73%	72%	67%	71%
Minimum	41%	41%	41%	36%	36%	40%
Maximum	100%	100%	100%	100%	100%	100%
Variance	4%	4%	4%	4%	4%	4%
# of Efficient Firms	10	9	9	9	5	4

The results of cost minimization DEA model for the first five efficiency models are examined in this section (Table 4-13). There is a high consistency between a firm's different scores generated by different efficiency models except for a few firms. Therefore, the mean values of the five models are close to each other: the highest value is 74%, whereas the lowest value is 67%. If the difference between the highest and lowest mean values (7 percentage points) is compared with the differences in CRS DEA model (Table 4-6) and VRS DEA model (Table 4-8) which are 27 percentage points and 18 percentage points respectively, the effect of low deviation can be realized more truly.

Beside basic statistical measures, the number of efficient firms is depicted in Table 4-13. This number differs from model to model and deviates between 5 and 10. Like CRS DEA and VRS DEA models, Model 1 has the highest efficiency scores among the first five models in terms of CE analysis.

The correlation coefficients are calculated to show the relations between the models (Table 4-14). Like the correlations in TE scores, the correlation coefficient values are very high among the first four models.

Table 4-14: Correlation Coefficients between CE Scores

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Model 1	1,00				
Model 2	0,96	1,00			
Model 3	0,94	0,99	1,00		
Model 4	0,97	0,92	0,94	1,00	
Model 5	0,83	0,85	0,86	0,81	1,00

4.3.2.4 Allocative Efficiency Scores

Total economic efficiency for a firm is composed of TE and AE. TE score which shows the ability of a DMU to use minimum amount of inputs to produce a determined level of output is estimated for all seven models and the results of these models are explained in section 4.3.2.1. In contrast, AE score that defines the ability of a firm to use inputs in optimal proportions so as to minimize the cost of production is estimated for the first five models and the results are analyzed in this section.

AE score is calculated by using Equation 3.9 and the results are given in Table 4-15. AE scores produced by different models for a firm have little deviation. The difference between maximum and minimum scores does not exceed 15 percentage points except for DMU2, DMU4, DMU10 and DMU22. This high consistency is also relevant for the mean values which deviate around 83% with 81% as minimum (Model 5) and 84% as maximum (Model 3 and Model 4). In addition to mean values, minimum values of the five efficiency models are close to each other. As the highest minimum score is 45% (Model 3 and Model 4), the lowest minimum AE score is 43% (Model 1 and Model 2). The minimum scores of all models belong to the same DMU which is DMU28. Similar to the mean values, the variances are low and it is 2% for Model 3 and Model 5 and 3% for the other three models.

Not only AE scores, but also the number of allocatively efficient firms is given in Table 4-15. As expected, the number of allocatively efficient firms has similarities with the number of cost efficient firms. The number of allocatively efficient firms is high in the first four models compared to Model 5.

The correlation coefficients are calculated to observe the degree of relations between the models (Table 4-16). Like the correlation coefficients in TE and CE, the AE scores of all models have higher correlations with each other, especially among the first four models.

Table 4-15: AE Scores under the Assumption of VRS Technology

Firm	Model 1	Model 2	Model 3	Model 4	Model 5	Mean
DMU1	55%	58%	64%	61%	64%	60%
DMU2	80%	80%	78%	78%	64%	76%
DMU3	97%	97%	100%	100%	89%	96%
DMU4	100%	100%	100%	100%	64%	93%
DMU5	100%	100%	100%	100%	100%	100%
DMU6	87%	87%	100%	98%	100%	94%
DMU7	53%	55%	57%	51%	55%	54%
DMU8	97%	97%	99%	99%	93%	97%
DMU9	100%	100%	100%	100%	100%	100%
DMU10	73%	73%	88%	87%	85%	81%
DMU11	70%	66%	73%	77%	73%	72%
DMU12	100%	100%	100%	100%	100%	100%
DMU13	94%	94%	96%	92%	94%	94%
DMU14	100%	100%	100%	99%	100%	100%
DMU15	83%	80%	74%	70%	70%	75%
DMU16	63%	63%	69%	69%	69%	66%
DMU17	70%	70%	77%	77%	77%	74%
DMU18	74%	74%	76%	76%	71%	74%
DMU19	100%	100%	100%	100%	94%	99%
DMU20	83%	82%	81%	80%	80%	81%
DMU21	96%	96%	96%	96%	96%	96%
DMU22	100%	70%	74%	100%	74%	84%
DMU23	77%	77%	82%	80%	78%	79%
DMU24	100%	100%	100%	100%	87%	97%
DMU25	66%	66%	67%	67%	67%	67%
DMU26	86%	87%	92%	92%	93%	90%
DMU27	94%	94%	99%	100%	88%	95%
DMU28	43%	43%	45%	45%	44%	44%
DMU29	77%	77%	81%	81%	77%	79%
DMU30	85%	85%	81%	77%	85%	83%
DMU31	98%	98%	91%	91%	91%	94%
DMU32	80%	77%	80%	82%	80%	80%
DMU33	67%	67%	65%	64%	65%	66%
DMU34	83%	77%	84%	86%	84%	83%
DMU35	100%	100%	100%	100%	100%	100%
DMU36	81%	73%	72%	75%	72%	75%
DMU37	52%	52%	56%	55%	55%	54%
DMU38	100%	100%	100%	100%	89%	98%
Mean	83%	82%	84%	84%	81%	83%
Minimum	43%	43%	45%	45%	44%	44%
Maximum	100%	100%	100%	100%	100%	100%
Variance	3%	3%	2%	3%	2%	2%
# of Efficient Firms	10	9	11	11	6	5

Table 4-16: Correlation Coefficients between AE Scores

	Model 1	Model 2	Model 3	Model 4	Model 5
Model 1	1,00				
Model 2	0,95	1,00			
Model 3	0,92	0,96	1,00		
Model 4	0,95	0,91	0,95	1,00	
Model 5	0,82	0,85	0,90	0,86	1,00

4.3.3 Analysis of Model Specification

Models with different specifications produce different efficiency scores for a DMU. Therefore, in some specifications an inefficient firm can have high efficiency scores because of the incorrect specification. To eliminate or at least mitigate this risk and determine the most reliable model specification, we should analyze the results of the models. In this study, we construct seven models with different specifications. We analyze these models in terms of the number of variables, the addition of environmental variables, the input-output selection and the effect of the exclusion of the outlier. These four factors are analyzed in this section by comparing the results of the relevant models with each other.

4.3.3.1 Effect of Number of Variables and Environmental Factors

In this section, we compare the results of Model 3 and Model 5 to measure the effect two factors, namely the effect of number of variables and the effect of environmental variables on efficiency. Firstly, the effect of two extra variables (environmental variables) on efficiency is analyzed in terms of the increase in mean scores and the number of firms having higher scores. Then, the effect of the addition of the environmental variables on efficiency is measured by analyzing the rankings of DMUs in each model and the degree of this effect for each DMU.

A consequence of DEA’s mathematical formulation is that DMUs can only receive higher TE or CE scores or maintain the relevant scores as the number of variables increases. However, this rule is relevant only if the model with higher number of variables contains all variables of the model with lower number of variables. In this study, we have specified seven models with different number of variables, but only two of them have this relation. In this context, Model 3 has two more variables than Model 5 which does not include the environmental variables. To determine whether additional variables provide a DMU more power in terms of getting higher scores or leading to no change in terms of their scores we will analyze the results of these two models.

The effect of extra variables is given in Table 4-17. We compare Model 3 with Model 5 in terms of CRS TE, VRS TE and CE scores. Model 5 has five variables three of which are outputs and the others are inputs. Yet, there are extra two environmental variables in Model 3. The means of CRS TE, VRS TE and CE scores for Model 5 are 66%, 83% and 67%, respectively and the mean increases to 80%, 86% and 73%, respectively in Model 3 with the addition of two environmental variables. These extra variables increase the efficiency scores of 30 DMUs in CRS TE, 16 in VRS TE and 18 in CE. Considering the number of efficient firms which are 5, 11 and 5, respectively in Model 5, the inefficient DMUs in Model 5 that can not get higher scores in Model 3 are only 3 in CRS TE, 11 in VRS TE and 15 in CE. This indicates the trade-off between a model's details and its explanatory power. While Model 3 captures more features of DMUs, it somewhat limits our ability to draw conclusions on their performance relative to their peers because the efficiency scores increase.

Table 4-17: Effect of Extra Variables on Efficiency

	Mean of Differences (percentage points)	**# of DMUs Having Higher Scores**
CRS TE	14	30
VRS TE	3	16
CE	6	18

The results of this comparison which measure the effect of the extra variables on efficiency show that all efficiency scores increase or be the same as the number of variables increases. This finding is in line with the theory.

In addition to measure the effect of number of variable, we can also determine the effect of the addition of environmental factors on efficiency by comparing the results of Model 3 and Model 5. Average daily temperature in winter and inverse apartments per building ratio are added in the first four models as environmental factors to reflect the circumstances in which firms operate, whereas these factors are eliminated in Model 5 to measure the effect of these factors on efficiency. Except environmental factors, all variables of Model 3 and Model 5 are the same. The models that contain the environmental factors generate higher scores in view of high number of variables, so the firms' rankings and correlation coefficients across models are used to analyze the effect of environmental factors instead of the comparison of the scores.

First, the correlation coefficients between Model 3 and Model 5 are calculated for CRS TE, VRS TE, SE, CE and AE as 0.68, 0.89, 0.59, 0.86 and 0.90 respectively. The correlations are high for VRS TE, CE and AE, whereas they are low for CRS TE and SE. The existence of low correlation coefficients between some scores shows that the environmental factors affected the efficiency scores of some firms.

Beside the correlation coefficients between models, the rankings are also analyzed (Table 4-18). The number "1" indicates the first rank and the number "38" shows the lowest rank in Table 4-18. The rankings of DMUs are analyzed for SE which has the lowest correlations and for AE which has the highest correlations. It is expected that the DMUs that operate in unfavorable environments get lower scores with the addition of environmental factors. In line with the expectations, generally the DMUs in cooler areas get lower rankings in models with environmental factors.

In addition to climate, inverse apartments per building ratio has positive effect on efficiency. The DMUs that operate in favorable environments with high buildings (low inverse apartments per building ratio) get lower rankings when we add the environmental factors into the model. Also, the DMUs that operate in unfavorable environment with low buildings get higher scores when we add the environmental factors in Model 3. Seven of eight DMUs operating in unfavorable environment get higher rankings or the same rankings with the addition of the environmental factors. Therefore, these factors should be added since they compensate for the unfavorable environment of distribution companies. As a result, Model 3 that has two environmental factors is preferred over Model 5.

4.3.3.2 Effect of Variable Selection

Efficiency scores depend on the choice of input and output variables. Two models consisting of different variables generate different scores; even two models have the same number of variables. In this study, we construct seven models with different variables and in this section the effect of different variables are analyzed.

There are four basic different model specifications in terms of variable selection. First, Model 2 takes consumption as total while Model 1 considers residential consumption and industrial consumption as two different variables. We can measure the effect of the classification of consumption by comparing the results of these two models. Second, Model 2 and Model 3 have different specification in terms of pipeline. While Model 3 includes only one variable for pipelines as total length of network, Model 2 contains two variables for pipelines as steel and polyethylene. Third, Model 4 differs from Model 3 in terms of consumer groups. Model 4 that takes only residential consumption and number of residential customers, as Model 3 takes into account total consumption and total number of customers. Fourth, we compare the results of Model 6 and Model 7: the former include only operating costs while the latter takes into account total costs consisting of operating and capital costs.

Table 4-18: Rankings of DMUs in Model 3 and Model 5

	Rankings for SE			Rankings for AE		
	Model 3	**Model 5**	**Difference (Model 5- Model 3)**	**Model 3**	**Model 5**	**Difference (Model 5- Model 3)**
DMU01	37	31	-6	35	33	-2
DMU02	27	35	8	25	33	8
DMU03	1	10	9	1	13	12
DMU04	1	28	27	1	33	32
DMU05	1	29	28	1	1	0
DMU06	1	16	15	1	1	0
DMU07	30	26	-4	36	36	0
DMU08	26	11	-15	12	10	-2
DMU09	1	1	0	1	1	0
DMU10	22	16	-6	18	17	-1
DMU11	1	9	8	30	26	-4
DMU12	1	1	0	1	1	0
DMU13	17	1	-16	14	8	-6
DMU14	21	1	-20	1	1	0
DMU15	38	37	-1	28	29	1
DMU16	34	24	-10	32	30	-2
DMU17	32	25	-7	26	23	-3
DMU18	1	14	13	27	28	1
DMU19	1	38	37	1	8	7
DMU20	36	33	-3	21	20	-1
DMU21	32	32	0	14	7	-7
DMU22	1	11	10	28	25	-3
DMU23	17	13	-4	20	22	2
DMU24	1	8	7	1	16	15
DMU25	28	15	-13	33	31	-2
DMU26	22	19	-3	16	10	-6
DMU27	25	34	9	12	15	3
DMU28	22	22	0	38	38	0
DMU29	29	22	-7	21	23	2
DMU30	1	26	25	21	17	-4
DMU31	1	18	17	17	12	-5
DMU32	35	36	1	24	20	-4
DMU33	31	21	-10	34	32	-2
DMU34	17	1	-16	19	19	0
DMU35	1	1	0	1	1	0
DMU36	1	1	0	31	27	-4
DMU37	17	20	3	37	36	-1
DMU38	1	29	28	1	13	12

To measure the effect of specification related to consumption, the efficiency scores of Model 1 and Model 2 are analyzed in terms of TE, SE, CE and AE. Regarding CRS TE scores of these two models, we find that the scores are very close to each other for 6 DMUs and the same for 30 DMUs (Table 4-6). The differences between CRS TE scores are high only for DMU22 and DMU32 which are 13 and 18 percentage points, respectively. Secondly, VRS TE scores are compared and it is seen that the highest difference which belongs to DMU32 is only 10 percentage points (Table 4-8). Similar to TE, the differences between SE scores are also lower; for 27 out of 38 DMUs there are no differences between the scores for Model 1 and Model 2. In addition, the nature of returns to scale is the same for 36 DMUs (Table 4-10). Besides, the differences between CE and AE are analyzed. For CE, there are two high values which belong to DMU22 and DMU32 as 36 and 11 percentage points, respectively (Table 4-13). Nonetheless, in terms of AE there exist only one high difference which belongs to DMU22 as 30 percentage points (Table 4-15). As a result, it is obvious that the different specifications of consumption and length of network may have only little effect on efficiency. If we consider that the efficiency scores become higher when a model includes more variables, these differences seem negligible. Therefore, it will be more convenient to take these variables as total. Thus, the negative effect of higher number of variables can be eliminated and it becomes possible to include different variables into the model instead of these redundant ones.

In addition to the effect of the classification of consumption on efficiency, we analyze the effect of the classification of pipelines. In this context, the efficiency scores of Model 2 and Model 3 are compared. First, we calculate the differences between CRS TE scores and find that the differences are low except for DMU15 and DMU32 as 40 and 12 percentage points, respectively (Table 4-6). Regarding VRS TE, the difference between the scores becomes much lower. The highest difference belongs to DMU32 with 10 percentage points (Table-8). Moreover, the differences between SE scores of Model 2 and Model 3 are lower than 8 percentage points except DMU15 that has 39 percentage points (Table-10). The same analyses are also relevant for CE and AE scores. As a result, like the classification of consumption the classification of pipelines does not provide more accurate results, so taking pipelines as total seems reasonable.

The third different specification exists between Model 3 and Model 4 which are compared to see the changes in efficiency scores if only residential customers are considered. These two models have the same number of variables but two of these variables are different. In Model 3, total consumption and total number of customers are taken whereas residential consumption and number of residential customers are included in Model 4. The results of Model 3 and Model 4 are compared for TE, SE, CE and AE scores. The differences which are calculated by subtracting the scores of Model 4 from Model 3 are given in Table 4-19. In terms of CRS TE and VRS TE scores, the differences are higher than 10 percentage points only for four DMUs which are DMU14, DMU22, DMU30 and DMU32. The differences between SE scores are lower than or equal to 5 percentage points for 37 DMUs and 16 percentage points for DMU32. The four DMUs that have higher differences in terms of TE scores have also higher differences (higher than 10 percentage points) for CE scores. Additionally, DMU13 has a high difference in SE score which is equal to 11 percentage points. Lastly, when we examine the differences of AE scores, we can see that there is only one DMU (DMU22) that has a high difference between the models.

There are four DMUs which have considerably different scores for Model 3 and Model 4. As the scores of DMU14 and DMU30 are higher in Model 3, the scores are higher in Model 4 for DMU22 and DMU32. We expect that DMU14 and DMU30 should have higher industrial consumption because the scores of these DMUs decrease in Model 4 which excludes the industrial consumption. Similarly, DMU22 and DMU32 should have lower industrial consumption because they get higher scores in Model 4. When we examine the industrial consumption, we see that DMU14 and DMU30 have high industrial consumption relative to their residential consumption as DMU22 and DMU32 have low industrial consumption, even zero for DMU22. Hence, both models should be used to analyze economic efficiency of the Turkish natural gas companies. However, if we take into consideration the fact that a distribution company has to bear investment and operating costs to provide service for both industrial and residential consumption, we prefer Model 3 over Model 4.

Table 4-19: Differences between Model 3 and Model 4 (Model 3 – Model 4)

	CRS TE	VRS TE	SE	CE	AE
DMU1	-1	-3	2	0	3
DMU2	0	0	0	0	0
DMU3	4	3	0	3	0
DMU4	0	0	0	0	0
DMU5	0	0	0	0	0
DMU6	3	4	-1	6	1
DMU7	5	4	2	6	5
DMU8	0	0	0	0	0
DMU9	0	0	0	0	0
DMU10	0	0	0	0	0
DMU11	-6	-6	0	-8	-4
DMU12	0	0	0	0	0
DMU13	9	9	0	11	4
DMU14	12	10	2	11	1
DMU15	3	0	4	5	5
DMU16	0	0	0	0	0
DMU17	0	0	0	0	0
DMU18	0	0	0	0	0
DMU19	0	0	0	0	0
DMU20	0	0	0	0	0
DMU21	0	0	0	0	0
DMU22	-14	-10	-5	-33	-26
DMU23	7	7	0	7	1
DMU24	0	0	0	0	0
DMU25	0	-1	0	0	0
DMU26	5	5	1	4	0
DMU27	3	5	-5	5	-1
DMU28	0	0	0	0	0
DMU29	0	0	0	0	0
DMU30	10	11	0	12	5
DMU31	0	0	0	0	0
DMU32	-23	-14	-16	-13	-2
DMU33	0	0	0	1	1
DMU34	4	3	1	1	-2
DMU35	0	0	0	0	0
DMU36	0	0	0	-3	-3
DMU37	9	9	0	6	1
DMU38	0	0	0	0	0
Mean	1	1	0	1	0

Beside the comparison of different model specifications of the first five models, Model 6 and Model 7 which have three common variables (outputs) and one different variable (input) are compared to measure the effect of this different specification of one variable on efficiency. In Model 6, only operating costs are considered as inputs, whereas in Model 7 total costs consisting of operating and capital costs are used instead. In this analysis, TE and SE scores will be compared to decide which model produces more reliable results. TE scores of Model 7 generally are higher than the ones belonging to Model 6 despite the fact that two models have the same number of variables. Only three DMUs get the same scores in both models and five get lower scores in Model 7 while other thirty DMUs get higher scores in Model 7 under the assumption of CRS (see Table 4-6). On the other hand, the number of DMUs that have the same scores in both models is 6 and the number of DMUs that get lower scores in Model 7 is 7 under the assumption of VRS technology (see Table 4-8). Furthermore, SE scores are higher in Model 7: SE scores are higher 5 percentage points on average in Model 7 (see Table 4-10). Moreover, regarding CRS TE, as minimum score is 11% in Model 6, it is 22% in Model 7. These scores are 30% and 33% for VRS TE and 28 % and 35 % for SE, respectively. Similar results are also relevant for the number of DMUs that have efficiency scores lower than 50 %: 17 firms in Model 6 and 11 firms in Model 7 under the assumption of CRS technology (see Table 4-6).

These results show that the DMUs that get lower scores in Model 6 have higher operating costs, but have lower capital costs, relatively. When total costs are taken into account, the companies' scores show an overall improvement. As a result, the sector displays a smaller performance gap than operating costs-based model would suggest, which indicates that Model 6 can penalize firms that are efficient in capital costs. For example, CRS TE of DMU8 in Model 7 is 94%, while it is only 74% in Model 6. As a result, if monetary variables are used, Model 7 should be preferred since it has more reliable efficiency scores and takes into account total costs.

In conclusion, when we analyze the results of seven models in terms of input-output selection we reach a conclusion that Model 3 among the first five models and Model 7 among the last two models generate more reasonable results.

To sum up, if we consider the results of all three criteria, namely the effect of extra variables and the effect of the addition of environmental factors (Section 4.3.3.1) and the effect of input-output selection (Section 4.3.3.2), we can reach a conclusion that Model 3 generates more reliable scores and should be used to analyze and compare the efficiency scores of the distribution companies investigated in this study.

4.3.3.3 Outlier Effect

Outliers may affect the efficiency scores and lead to incorrect interpretation of the results. In our data set, DMU12 (İGDAŞ) is the most probable candidate to be an outlier because DMU12 distribute 23% of total amounts of natural gas delivered by these 38 companies in 2008. In addition, 2.5 million of 4 million customers belong to DMU12. Therefore, we processed the most preferred model (Model 3) by excluding DMU12 from the data set so that we measure the effect of the outlier on efficiency scores. The results for CRS TE, VRS TE and SE scores and type of returns with and without the outlier are given in Table 4-20 for the remaining 37 DMUs. CRS TE scores are the same for all DMUs in both cases and VRS TE scores are the same except for DMU13 and DMU34. For SE DMU13, DMU16 and DMU34 have different scores. On the other hand, the nature of returns differs only for DMU34 which has CRS technology when the outlier included. If we examine these DMUs, we can see that they also have high delivery amounts like DMU12. As a result, the model containing DMU12 generates more reliable results because the inclusion of DMU12 does not change the scores of 34 DMUs and the number of DMUs sharing some similar characteristics increases with the inclusion of the relevant DMU.

Table 4-20: Effect of Outlier on Efficiency Scores

	CRS TE		VRS TE		SE		Type of Return	
	With Outlier	Without Outlier	With Outlier	Without Outlier	With Outlier	Without Outlier	With Outlier	Without Outlier
DMU01	47%	47%	70%	70%	67%	67%	IRS	IRS
DMU02	93%	93%	100%	100%	93%	93%	DRS	DRS
DMU03	61%	61%	61%	61%	100%	100%	CRS	CRS
DMU04	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU05	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU06	96%	96%	97%	97%	99%	99%	IRS	IRS
DMU07	63%	63%	73%	73%	85%	85%	IRS	IRS
DMU08	56%	56%	60%	60%	94%	94%	DRS	DRS
DMU09	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU10	62%	62%	64%	64%	97%	97%	IRS	IRS
DMU11	82%	82%	82%	82%	100%	100%	IRS	IRS
DMU13	65%	65%	66%	91%	99%	72%	DRS	DRS
DMU14	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU15	57%	57%	99%	99%	58%	58%	IRS	IRS
DMU16	56%	56%	71%	71%	78%	79%	IRS	IRS
DMU17	58%	58%	74%	74%	79%	79%	IRS	IRS
DMU18	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU19	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU20	70%	70%	100%	100%	70%	70%	IRS	IRS
DMU21	61%	61%	78%	78%	79%	79%	IRS	IRS
DMU22	86%	86%	91%	91%	95%	95%	IRS	IRS
DMU23	94%	94%	95%	95%	100%	100%	DRS	DRS
DMU24	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU25	92%	92%	99%	99%	93%	93%	IRS	IRS
DMU26	54%	54%	56%	56%	97%	97%	IRS	IRS
DMU27	49%	49%	54%	54%	91%	91%	DRS	DRS
DMU28	97%	97%	100%	100%	97%	97%	DRS	DRS
DMU29	50%	50%	59%	59%	85%	85%	IRS	IRS
DMU30	93%	93%	94%	94%	99%	99%	DRS	DRS
DMU31	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU32	47%	47%	80%	80%	59%	59%	IRS	IRS
DMU33	81%	81%	100%	100%	81%	81%	DRS	DRS
DMU34	65%	65%	65%	73%	100%	89%	CRS	DRS
DMU35	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU36	100%	100%	100%	100%	100%	100%	CRS	CRS
DMU37	97%	97%	98%	98%	100%	100%	DRS	DRS
DMU38	100%	100%	100%	100%	100%	100%	CRS	CRS

4.3.4 Analysis of Results

In Section 4.3.3, the results of seven DEA models are analyzed to evaluate different model specifications by considering all DMUs' scores without constructing subgroups. On the other hand, in this section we discuss the results by creating and comparing some subgroups. First, we discuss whether public or private companies have higher efficiency scores. Thus, the common belief proposing that private companies operate more efficiently is tested. Second, the new companies which started to distribute natural gas after 2005 and the old ones are compared to measure the effect of the maturity level on efficiency. Third, the success of tenders is analyzed by comparing the companies that get the right by tender and the others. Tenders created a competitive environment and the bidders competed for the monopoly right, so these firms are expected to be more efficient. Fourth, the effect of size is analyzed by comparing small firms which delivered less than 100 million cubic meters of natural gas in 2008 with the large ones which delivered more than 100 million cubic meters in 2008. Fifth, we compare the firms in terms of the Socio-economic Development Index (SDI) calculated by SPO (2003). All these comparisons are analyzed by taking into account the scores generated by Model 3, which was chosen as the best one among the seven alternative models in the previous part of this study. Also, the scores of Model 5 are used to measure the robustness of the inferences that are based on Model 3. Lastly, we construct an OLS model to evaluate whether the mentioned criteria have effect on the performance of these 38 companies.

4.3.4.1 Public versus Private Companies

In Turkish natural gas distribution sector, there were three public distribution companies in 2008, namely İGDAŞ, İZGAZ and BAŞKENTGAZ. İZGAZ was privatized at the end of 2008, but we consider it as a public company because it was publicly owned during 2008. BAŞKENTGAZ does not take place among 38 DMUs because we can not get reliable data for that company. Therefore, 2 public companies are compared with 36 private companies to test whether the claim about private companies' efficiency is relevant for Turkish natural gas distribution sector.

For this comparison, average scores of each group are calculated for TE, SE, CE and AE (Table 4-21). The average scores tabulated in Table 4-21 show that the public firms get higher average scores compared to the private firms.

Table 4-21: Average Efficiency Scores of Public Firms versus Private Firms

	Model 3			Model 5		
	Public	**Private**	**Total**	**Public**	**Private**	**Total**
CRS TE	82%	80%	80%	82%	65%	66%
VRS TE	83%	87%	86%	82%	83%	83%
SE	100%	91%	92%	100%	78%	79%
CE	82%	72%	73%	81%	66%	67%
AE	98%	83%	84%	97%	80%	81%

According to the results of this study, the public distribution companies both utilize the resources more effectively and manage the costs more successfully. This conclusion means that the claim about the efficiency of private companies fails in Turkish natural gas distribution sector case. This is consistent with Kwoka (2005) who shows that public ownership is often associated with greater efficiency in US electric utilities and Bağdadioğlu et al. (2007) who reach the same conclusion for Turkish electricity distribution sector. This conclusion is also supported by the results of Model 5. Nevertheless, taking into consideration the low number of public firms in this study and the high maturity level of these two companies, we need to conduct more detailed studies.

4.3.4.2 New Firms versus Old Firms

Turkish natural gas distribution sector consists of a few old firms which existed before NGML and many young firms that started to distribute natural gas after the enactment of the law. In this study, to split the firms as old and new, the criteria of first natural gas delivery date is used. The firms that started to distribute natural gas before 2006 are labeled as old and the others are considered as new. Efficiency scores of these two subgroups are calculated and compared with the expectation that new firms would have lower efficiency scores.

The average efficiency scores for CRS TE, VRS TE, SE, CE and AE are given in Table 4-22. Contrary to the expectations, the old firms do not have higher average efficiency scores for all these 5 criteria in Model 3. They have higher scores for CRS TE and SE, but the new ones have higher average scores for three efficiency criteria, namely VRS TE, CE and AE. However, the structure is different for Model 5 in which the old firms get higher average scores. Therefore, we can say that the old firms may operate more efficiently.

Table 4-22: Average Efficiency Scores of New versus Old Firms

	Model 3			Model 5		
	New	Old	Total	New	Old	Total
CRS TE	79%	80%	80%	58%	71%	66%
VRS TE	88%	86%	86%	81%	84%	83%
SE	90%	93%	92%	71%	84%	79%
CE	74%	72%	73%	66%	67%	67%
AE	85%	84%	84%	82%	80%	81%

4.3.4.3 Getting License with Tenders versus Others

In Turkish natural gas distribution sector, 60 companies are engaged in distribution activity and 53 of them have obtained license that gives them concession rights to operate in a defined area by means of tender. However, other 7 companies got licenses without competition in that they obtained their concession rights before the enactment of the law. In this study, 6 of 7 non-tender firms and 32 of 53 tender firms are included. Accordingly, to test whether these tenders have become successful in terms of economic efficiency, we compare the efficiency scores of these two subgroups.

The average scores that are calculated for two subgroups are given in Table 4-23. The results show that the tender firms are less efficient relatively in all aspects of economic efficiency. Consequently, it can be inferred that the tender firms have not succeeded to increase social welfare which means that they have utilized the resources ineffectively. However, if we consider the maturity stage of the non-tender firms with high penetration rate, to reach an accurate conclusion this comparison should be repeated a few years later. In addition to Model 3, the results of Model 5 also show that the non-tender firms use the resources more efficiently as they manage their costs more effectively.

Table 4-23: Average Efficiency Scores of Tender Firms versus Non-tender Firms

	Model 3			**Model 5**		
	Tender	**Non-tender**	**Total**	**Tender**	**Non-tender**	**Total**
CRS TE	78%	91%	80%	63%	85%	66%
VRS TE	86%	94%	86%	82%	94%	83%
SE	92%	97%	92%	77%	91%	79%
CE	70%	83%	73%	63%	83%	67%
AE	82%	89%	84%	78%	89%	81%

In addition to efficiency scores, the nature of technology is also analyzed. Non-tender firms generally have CRS technology. Two of six firms have DRS technology and the rest (4 firms) have CRS technology. On the other hand, 15 of 32 tender firms have IRS technology. This result shows that the tender firms are operating below the optimal scale, so they get lower efficiency scores compared to non-tender firms. In other words, the most important problem for the tender firms is the low penetration levels. If these companies have higher penetration rates and increase delivery amounts, they can increase their efficiency scores.

4.3.4.4 Small Firms versus Large Firms

Small firms and large firms should also be compared in terms of their economic efficiency. The distribution area of a company is determined by EMRA without interference of the relevant distribution company. As a consequence, if small distribution companies suffer from the size, they should merge and decrease operating costs to increase their efficiency.

Table 4-24: Average Efficiency Scores of Small Firms versus Large Firms

	Model 3			Model 5		
	Small	**Large**	**Total**	**Small**	**Large**	**Total**
CRS TE	74%	85%	80%	53%	77%	66%
VRS TE	86%	87%	86%	81%	84%	83%
SE	86%	97%	92%	65%	92%	79%
CE	70%	75%	73%	62%	71%	67%
AE	82%	86%	84%	77%	84%	81%

Distribution companies are classified as small and large according to the criteria of consumption amounts as it is used in Cullmann et al. (2008). The firms which distribute less than 100 million cubic meters are categorized as small. According to this classification, the number of small companies is 18, nearly half of the sample size. As expected, the average scores of the small companies are lower for all efficiency scores and the difference is considerably high for SE (Table 4-24). Regarding the nature of technology, the similar situation exists: small companies generally have IRS technology. These results are in line with the results of Cullmann et al. (2008) who carried out the similar analysis for Polish electricity distribution companies. As a result, it is obvious that the small companies are inefficient. Therefore, merger between the small companies that are close to each other should be promoted in order to eliminate the inefficiency that comes from the small scale. The merger dos not provide a decrease in investment costs, but it can supply a decrease in operating costs.

4.3.4.5 Comparison Based on Socio-Economic Development Index

The distribution companies investigated in this study operate in various distribution areas that have different SDI values. SDI is calculated by using several economic, social and cultural factors to indicate the socio-economic development level of a city or a region. In this section, we compare the performance of DMUs that have SDI more than zero with the ones having SDI values less than zero. There are 12 DMUs with SDI lower than zero (Table 4-25).

Table 4-25: Socio-Economic Development Index Values

Firm	SDI	Firm	SDI	Firm	SDI
DMU01	-0,452	DMU14	2,524	DMU27	4,808
DMU02	-0,350	DMU15	-0,099	DMU28	0,565
DMU03	0,935	DMU16	0,059	DMU29	-0,717
DMU04	0,565	DMU17	-0,229	DMU30	0,169
DMU05	4,808	DMU18	-0,226	DMU31	0,342
DMU06	0,609	DMU19	1,679	DMU32	3,315
DMU07	-0,207	DMU20	0,253	DMU33	1,679
DMU08	1,059	DMU21	-0,356	DMU34	0,477
DMU09	-0,328	DMU22	-0,533	DMU35	0,404
DMU10	0,716	DMU23	1,943	DMU36	1,104
DMU11	0,253	DMU24	0,088	DMU37	-0,280
DMU12	4,808	DMU25	-0,406	DMU38	1,679
DMU13	1,943	DMU26	0,828		

Source: SPO (2003)

For this comparison, average scores of each group are calculated for TE, SE, CE and AE. The average scores tabulated in Table 4-26 show that the DMUs with positive index scores get higher average scores compared to the others.

Table 4-26: Average Efficiency Scores of Firms in Terms of SDI

	Model 3			Model 5		
	Neg. SDI	**Pos. SDI**	**Total**	**Neg. SDI**	**Pos. SDI**	**Total**
CRS TE	75%	82%	80%	63%	67%	66%
VRS TE	87%	86%	86%	83%	83%	83%
SE	86%	95%	92%	74%	82%	79%
CE	65%	76%	73%	60%	70%	67%
AE	75%	88%	84%	73%	84%	81%

According to the results of this study, the companies with positive SDI values both utilize the resources more effectively and manage the costs successfully. This structure is relevant not only for Model 3 but also for Model 5.

4.3.4.6 Test of Robustness of Comparison Criteria by Using OLS

We construct an OLS model to measure the effects of ownership (public/private), licensing procedure (tender/non-tender), age of the DMU and socio-economic development level of the area on efficiency. The dependent variable of the model is efficiency scores generated by Model 3 and the independent variables are SDI, age and two dummy variables which are used for the type of ownership and the type of licensing procedure. We use five criteria in Section 4.3.4 to compare the results, but we include only four of them. The consumption is not included because it is one of the variables that are used to estimate efficiency scores (dependent variables in OLS models). The OLS model is given in Equation 4.1.

$$y = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \beta_3 A + \beta_5 SDI \qquad (4.1)$$

where;

D_1 : Dummy Variable used for the type of ownership (1 = public, 0 = private),

D_2 : Dummy Variable used for tender and non-tender (0 = tender, 1 = non-tender),

A : Age of the company,

SDI : Socio-Economic Development Index.

We run the model by Excel for each efficiency score, namely CRS TE, VRS TE, SE, CE and AE. The results are used to test whether the coefficients of independent variables are significantly different from zero or not. We conduct t-test for each coefficient and F-test for the significance of all coefficients. F-test is failed for CRS TE, VRS TE, SE and CE; in other words, the null hypothesis of zero coefficients is not rejected for these efficiency criteria. The null hypothesis is only rejected for AE OLS model. The results of AE OLS model is given in Table 4-27. The coefficients of SDI, D1 and D2 are positive as expected, but the value of the coefficient of age is negative. When t-stat and p-values are analyzed, it is seen that only the coefficient of D1 fails in t-test.

Tablo 4-27: The Results of AE OLS Model (Dependant Variable: AE)

Indipendant Variables	Coefficient	t-stat	p-value
Intercept	0,883	16,010	0%
SDI	0,046	2,701	1%
Age	-0,032	-2,290	3%
D1	0,144	1,211	23%
D2	0,262	1,911	6%
R2	0,550		
F	3,574		
# of Observations	38		

4.3.5 Analysis of Inefficient Firms

In order to detect some regularities of inefficiency, a short summary of technical characteristics for the most inefficient firms will be given. For this purpose the CRS TE scores of Model 3 from Table 4-6 are considered. We prefer CRS TE scores because these scores contain both technical and scale inefficiency. To find the common characteristics, 9 most inefficient firms which have TE scores lower than 60% are sorted out (Table 4-28).

Table 4-28: The Most Inefficient Firms

Firm	Score
DMU01	47%
DMU32	47%
DMU27	49%
DMU29	50%
DMU26	54%
DMU16	56%
DMU08	56%
DMU15	57%
DMU17	58%

When the data of these nine firms are examined to find the reasons why these firms are inefficient, some common characteristics are determined. First, these firms have such a low natural gas distribution amount that five of them are distributing less than

50 million cubic meters annually. Additionally, seven of these nine companies have IRS technology. Second, the number of customers is low for these companies: 4 out of 8 firms that have customers less than 10,000 are among these 10 companies. As a result, the number of customers per employee and gas delivery amount per employee ratio is low for these companies. Third, the most inefficient firms have proportionally a higher share of network length with respect to their number of customers.

CHAPTER 5

CONCLUSION

Turkish natural gas market has developed very rapidly since 2002 by the enactment of NGML in 2001. The most impressive developments have been carried out in the distribution sector. Natural gas usage in Turkey started in the mid 1980s and until 2003 distribution network had been constructed only in six cities. After 2003 the number of cities has increased abruptly and the number of distribution companies has reached sixty as of 2009.

The distribution companies have monopoly rights in their designated areas, so their prices are subject to regulation. Parallel to the regulatory practices in other countries, EMRA determines the prices based on operating and investment costs of the distribution companies. This regulatory structure does not encourage the companies to operate efficiently, on the contrary the guarantee of covering costs by the tariffs leads to an increase in the costs. Hence, during the last few years, some regulators have started to evaluate the economic efficiency of the regulated companies by using efficiency analysis techniques and used the results in tariff calculation and implementation procedures, especially related to the operating costs. This study supplies some insights about the economic efficiency levels of Turkish natural gas distribution companies and provides some models which can be used in order to evaluate the economic efficiency of the distribution companies by the aim to use the results in tariff setting.

To analyze performance of the companies, one of the efficiency analysis methods, DEA is used. As explained in detail, the economic efficiency analyses have been based on the early works of Farrell (1957) who systematized the ideas of Koopmans (1951) and Debreu (1951). Farrell (1957) decomposed efficiency into AE and TE. Then, to estimate efficiency scores of DMUs, DEA was developed by Charnes, Cooper and Rhodes (1978). This method has been used extensively in the efficiency analysis of firms, hospitals, banks, farms and other activities all over the world. Also some studies have been carried out about the distribution companies.

In Turkey, efficiency analysis methods have been used to analyze the performance of DMUs belonging to various areas. However, there is not any study about the economic efficiency analysis of Turkish natural gas distribution companies. This study is the first in the evaluation of efficiency levels of these companies and in that sense it contributes to efficiency analysis and regulation literature in Turkey.

To analyze the performance of Turkish natural gas distribution companies, seven models with different specifications are constructed. In the first five models, physical inputs, namely length of network and number of employees are used. In contrast, in the sixth model operating expenditure is used as input while total expenditure is the single input of the seventh model. Moreover, in the first four models, two environmental factors are added in order to measure the effect of these factors on efficiency. The other difference between the models is the classification of pipeline as steel and polyethylene pipeline and consumption as industrial and residential consumption or taking these two variables as total in terms of pipeline length and consumption.

These seven models are processed by using DEAP 2.1 (CEPA, 2001) to estimate the efficiency scores. The results show that there is a high variation between firms in terms of efficiency under the assumption of both CRS and VRS technology. It means that the firms can increase the amount of outputs at the same level as inputs if they operate more effectively. However, the most important reason for the inefficiency of the sector is that most of the distribution firms are young and can not get high penetration. Namely, investment costs are high in the sector and the majority of the firms can not increase the number of customers and the delivery amounts because of the short operating period. To eliminate this adverse effect, this study should be repeated a few years later when these firms will increase the penetration rate.

In addition to the variety in efficiency scores within a model, the variety among the efficiency scores of the firms generated by different models are high. This indicates that some model specifications produces more accurate scores compared to others.

To detect the most plausible model specification, we analyze the results in terms of the nature of technology, the number of variables, the input-output selection and the inclusion of the environmental factors. This analysis shows that Model 3 among the first five models and Model 7 compared to Model 6 generates more reliable results.

The results are also analyzed to compare the firms in terms of the type of ownership (public versus private), the maturity level (new versus old), the licensing process (tender versus non-tender), the scale (big versus old) and SDI. First of all, the comparison of private and public companies indicates that the public distribution companies utilize the resources and manage the costs more efficiently. It means that the claim about the efficiency of private companies fails in Turkish natural gas distribution sector case. Nevertheless, taking into consideration the small number of public firms in this study and the high maturity level of these two companies, we need to conduct more detailed studies to get a more reliable conclusion. Second, the results show that the old firms operate more efficiently compared to the new ones in terms of the cost management, but we can not reach a certain conclusion about the utilization of physical resources. Third, to test whether the tenders have become successful in terms of economic efficiency, we compare the performance of tender firms with non-tender firms and find that non-tender firms are more efficient contrary to the expectations. However, if we consider the maturity stage of the non-tender firms with higher penetration rate compared to the tender firms, this conclusion seems normal. To reach an accurate conclusion, this comparison should be repeated after a few years when the penetration rates of the tender firms increase. Fourth, the efficiency scores of the small firms are analyzed to see whether these firms operate less efficiently than the large firms. We reach a conclusion that large firms have higher average scores than small ones for all efficiency measures. Fifth, we compare the average scores of DMUs that have positive SDI with the average scores of DMUs having negative SDI and find that DMUs operating in more developed areas get higher scores. Lastly, OLS models are constructed for all efficiency score types to test whether the mentioned five criteria significantly affect the level of efficiency.

In addition to determine whether a firm is efficient or inefficient, the exploration of the reasons behind the inefficiency is important. For this aim we analyze the inefficient firms and find two common characteristics of these firms. First, the most inefficient firms have small scales of operation. In other words, they deliver small amounts of gas to small number of customers. Secondly, they have higher network length per customer.

To sum up, the analysis of the results from several perspectives provide some valuable information about the Turkish natural gas distribution sector. The most important finding of this study is that most of the firms in the Turkish natural gas distribution sector operate below the optimal scale. If the distribution firms utilize their potentials more effectively and increase the number of customers, the scale problem can be solved partly. In addition, to mitigate the scale problem, mergers have to be promoted among the firms that are operating in the same geographic location. On the other hand, the immaturity of the sector limits the reliability of our inferences. Thus, we suggest that similar studies should be carried out after a few years when the majority of the firms will reach the maturity level by getting high penetration rates. Furthermore, we believe that the small size of the sample is another obstacle of this study. We could not include the other 22 firms in the study because they started to operate a short time ago. As a result, we propose that further investigations should be conducted after a few years by adding more companies to the analysis.

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