Efficiency Measurements in the Turkish Brewing Industry by Using Data Envelopment Analysis

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ABSTRACT

トルコの醸造業は未だに研究者による研究が完全には行われていない領域である。生産効率評価にデータ包絡分析 （簡略化すると DEA） を用いることが、この産業に対する新たなアプローチとなる可能性がある。この研究の動機づけとなったのは、トルコの醸造企業における生産効率評価に各使用者に特化したモデルによる DEA を用いることによる、新たな手法の構築の模索である。

トルコの醸造業は政府による独占から、民間企業の複占へと変遷してきた。近年では新規の事業者はなく、マーケットシェアにおける大きな変動もない。このマーケットは新たな顧客の需要に対しては飽和していると結論付けることができる。その上、政府による度重なる禁止措置や規制により、新規参入者にとっては不利な事業環境となっている。そのため、この産業集中の状態にあっては、生産効率の問題が重要となる。トルコの醸造業は複占企業による立場の違いが明確である。アナドル・エフェスが最大手であり、トルコ・ツボルグがそれに続き、それぞれマーケットシェアのおおよそ 80%と 20%を占める。本研究では、マーケットシェア、企業規模ならびに DEA 効率得点の相関の考察を行う。我々は DEA を使用することにより、回帰分析等の他の従来の手法では十分に解明することができない潜在的な事実や結果を得た。

今回の手法として用いた各使用者に特化したモデルは、様々な研究者が以前に行った研究から適合させたか、または、DEA 条件に相応な研究者の設計によるものである。これらのモデルには様々な目的や制約が反映されている。入力及び出力の選定基準はこれらの目的に大きく依存する。主なデータソースとして、利用可能な企業レベルの財務諸表及び比率を使用している。財務諸表データは信頼性が高く、すべての利害関係者や研究者が追跡できる点から有用であると考えられる。

本研究の結果、トルコの醸造企業は、売上高ならびに収益の創出、株式市場における取引または生産要素の割当を目的として自らの資産および負債を活用している点で、高い生産効率を示している。トルコ・ツボルグは 6 から 7 のビール製造工場で必要な最小効率規模 （MES） に達していないにもかかわらず、生産可能性辺境線上で操業している。集権的組織構造ならびに高級製品ラインへの特化がツボルグの効率得点が満点である理由であるとの結論に至った。対してアナドル・エフェスは、その規模の大きさをより効率の良い営業へと生かすことができていないように見える。アナドル・エフェスはトルコ以外の他国に工場を所有し、コカコーラの独占販売頒布権も保有している。大規模でありながら、非集権的な組織構造であることが高い生産性を維持しての操業を困難なものとしている。
本実証研究の 2 つ目の部分では、ヨーロッパ市場におけるトルコの醸造企業の DEA 効率評価を行っている。トルコ・ツボルグは効率得点が満点である一方で、アナドル・エフェスは平均的な得点で順位も中程度となっている。ヨーロッパの醸造企業の DEA 得点では、ビール製造最大手のアンハイザー・ブッシュ・インベブが効率得点が満点であり、生産可能性辺境線上で操業している。アンハイザー・ブッシュ・インベブが大規模であり効率得点が高いことと、トルコ・ツボルグが小規模であり効率の良い操業を行っていることとは相反する。このため、市場規模と DEA 効率得点の相関を明らかにすることが未解明の今後の課題として残ることになる。

本研究の結論として、DEAは生産効率を評価するさいの他とは異なる有効な手法であることが明らかとなった。しかし、明らかになったのは相対的に効率の良い意思決定組織までであり、絶対的に効率の良い組織までには至らない。トルコ・ツボルグはトルコとヨーロッパのいずれの醸造業界においても完全な効率を示し、その結果はほぼ精確であると言える。企業の内部デ

ータを使用すればより精度の高いDEA結果を得られたものと考えられる。しかしながら、これらの情報は企業内の機密となっている。DEA条件下で各使用者に特化したモデルを用いた今回の研究手法が生産効率結果を明らかにする新たな手法であることを我々は強調したい。また、本研究の手法はデータソースが利用できるあらゆる業界の分析にも活用することが可能である

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Turkish brewing industry is a field that has not been studied yet thoroughly by researchers. Especially using Data Envelopment Analysis (abbreviated as DEA for the easiness) may be a new approach to this industry for productive efficiency measurements. My motivation in this research is to create a new process by applying DEA with user-specific models for the productive efficiency measurements in the Turkish brewing industry.

Turkish brewing industry has evolved from a government made monopoly to duopoly by private entities. Recently there are no new entries and significant fluctuations in the industry. We conclude that the market is saturated to new customer demands. Furthermore, frequent bans and regulations by the government created a hostile business environment to the new entrants. Therefore, productive efficiency issues take an important place for the industry concentration. Turkish brewing industry has well-decided roles of the duopoly companies. Anadolu Efes is the leader, and Turk Tuborg is the follower with around 80 and 20 percent market shares respectively. In this research, we study the relationship between market shares, company sizes and DEA efficiency scores. We use DEA to find out some hidden facts and results that other well-known methods like regression analysis are insufficient to reveal.

In our approach, we execute user-specific models either adapted from earlier studies of various scholars or designed by the researcher suitable to DEA assumption. These models reflect different purposes and constraints. The selection criteria of inputs and outputs highly depend on these purposes. As main data source, we prefer accessible financial statements and ratios at the corporate level. We favor financial statement data would be reliable, and trackable by any stakeholders or researchers.

Our results show that the Turkish brewing industry has highly productive efficient companies in the way they use their assets and liabilities to generate sales and revenues, trade in the stock market or allocate factors of production. Turk Tuborg is operating on the production frontier eventhough it does not reach the required minimum efficient scale (MES) of six to seven plants for beer production. We conclude centralized organization structure and concentration on the premium product line, are the reasons for Tuborg’s full efficient scores. On the contrary, Anadolu Efes does not seem to turn its bigger scale into more efficient operations. Anadolu Efes has factories in other countries besides Turkey, and exclusive rights of selling and distribution of

Coca-Cola. Its bigger scale, and decentralized organization structure makes it harder to maintain high productive efficiencies in operations.

At the second part of our empirical studies, we conduct DEA efficiency measures of Turkish brewers within the European market. Turk Tuborg has still full efficiency scores while Anadolu Efes occupies a moderate position with average scores. According to DEA scores for the European brewing industry, the largest beer company ABInbev has full efficiency scores, and it operates on the frontier. ABInbev's big scale and full efficient scores contradicts to Turk Tuborg's smaller scale and full efficient operations. Therefore, finding the relationship between the market sizes and DEA efficiency scores remains an uncompleted task for further studies.

We conclude that DEA is a unique and competent method in conducting productive efficiencies. However, we can at most find out relatively efficient decision-making units rather than absolutely efficient ones. Turk Tuborg is fully efficient both in Turkish and European brewing industries, which is closer to precision. We assume, by using internal corporate data, DEA results would be have been more accurate. However, this kind of information is kept discrete inside the companies. We claim the methodology of this research applying user-specific models under DEA assumption, is a new approach to discover productive efficiency results. Moreover, the method of this research can be applied by an analyst to any industry with accessible data sources.

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LIST OF CONTENTS

Introduction

This research is application of a specific methodology called Data Envelopment Analysis (DEA) on the Turkish brewing industry. My motive in this research concentrates on two issues: Turkish brewing industry and DEA.

The brewing industry is a suitable field for researches in many disciplines. Jim Mc Grevy, the president and CEO of Beer Institute stated: "Beer is more than our nation's favourite adult drink it is a powerhouse in job creator, commercial activity, and tax revenue". We identify the reasons of our motive for studying the brewing industry as follows: 1.Beer is a recession proof and a normal product, 2.Relationships among players are well defined and clear, 3.The brewing industry is not complicated, further than that relatively easy industry to study, 4.The brewing industry is highly regulated .80-90 percent of the data is trackable down.

Turkish brewing industry satisfies certain criteria to be the main field of our research. The industry started as a monopoly, turned into an oligopoly and finally became a duopoly. Government intervention is high and frequent through bans, regulations and licencing. The market is saturated because Islamic abolition limits total customer demand for the alcoholic beverages.

Turkish beer industry occupied as monopolistic market situation, from 1934 to 1968. During these 34 years, government's monopoly company, Tekel did not gain big access within the country. After a new regulation in 1969 allowed new firms for the market entry, Turkish Efes, and Denmark's Tuborg became the new competitors of Tekel. These two companies quickly captured big market shares in the industry. The market moved from a monopolistic structure to duopoly. The evidence supports that Efes became an industry leader with its marketing success and wider access. Efes' follower, Tuborg mainly focused on the residual demand of Efes'.

A new regulation in 1973 made a significant impact on the market. According to this regulation, under 4.2 percent of alcohol content of beer could be sold as a social beverage rather than an alcoholic drink. It was the main factor for the rapid growth of Efes. However, a new regulation in 1983 made negative impact over the companies. All broadcast and media advertising was banned and licencing became stricter. From 1983' regulation to today, the industry had been moving in a flagrant pace. Anadolu Efes and Turk Tuborg, dominate the industry with over 95 percent combined market share.

Regarding Fisher's statement Efes and Tuborg both suffered from bans and regulations more than external economic conditions[19]. The capture theory associated with Stigler (1971)[42] and Peltzman (1976)[35] states that industry performance is positively affected when regulations emerge as a reply to the industry demand. This demand for regulation is crucial in imperfectly competitive industries like beer. The government help sustains market coordination.

Recently, Efes and Tuborg produce more than 40 brands including import beers with exclusive rights. Three brands: Efes, EfesXtra, and, Tuborg capture 88 percent market share. There seems no compelling way to argue that with the rise of Islamic view and conservative wing on the government side it has been harder for brewers to succeed. Both companies reduced the risks of dependency on the Turkish market by exporting overseas.

In Turkish brewing industry competition, roles of duopoly companies are clear and well defined. Anadolu Efes is the market leader, and Turk Tuborg is the follower in a Stackelberg competition. Because of the bans on broadcast media and other tools, there are no significant opportunities for expansion locally. Moreover, we do not examine predatory advertising for companies to capture from each other's customer base. All these factors led Turkish brewing companies focus on efficiency issues rather than competitive strategies.

Data Envelopment Analysis is a non-parametric linear programming method applied to observational data that provides a new way of obtaining empirical estimates on the performance of various entries. Comparing to other well-known methods like regression analysis and stochastic frontier, DEA deals with best practices rather than the averages. In addition to this fact, there is no requirement for a priori assumption in the functional form. For these reasons we assume DEA would be a suitable method for our research. DEA reveals hidden facts that other methods are not able to and helps us finding inefficient units. Therefore, we predict with the sufficient management support and transfer of expertise these inefficient units can be improved.

Recently, Data Envelopment Analysis approach is becoming more preferable, because no company can handle the expense of having inefficient units. In this research, the DEA scores are conducted for productive, technical, pure, managerial, scale, allocative, cost and overall efficiencies. These efficiency terms help us to evaluate Turkish brewing industry by using Data Envelopment Analysis. According to the scores we conduct, we are able to comprehend clearly if the companies are efficient or not. After we identify inefficient units, we show insights to the companies for improvement with the sufficient management support and expertise. We also have motivation in finding relationships with the efficiency scores and different parameters like market size.

Previous studies on the Turkish brewing industry mainly focused on strategic and marketing approaches. A.Hamdi Demirel and Fred Miller et al. (1983)[21] examined Turkish beer market regarding the firms' competitive strategies. Their work separated Turkish brewing industry into regimes shaped by the government regulations and bans. They studied the success of Efes as the market leader at the main interest. Several lessons were taken from this study for marketing consumer goods like beer in developing countries. Another study was made by Cemhan Ozguven as a thesis of his graduate course et al.(2004)[9]. This thesis examined demand and pricing policies in Turkish beer market and whether these policies were efficient or not. This research uses a new approach to the Turkish brewing industry: we prefer a DEA efficiency-oriented approach, rather than strategic or marketing approaches mentioned above.

This research is organized as follows: **Chapter 1** is the background of the Turkish brewing Industry, which transformed from a government made monopoly into a duopoly. The first chapter describes the factors behind this transition and the success of the two companies. In this chapter, we also analyze how the government interventions affected the entire industry through bans and regulations and how the companies responded. **Chapter 2** is the analysis of Turkish beer industry in recent market circumstances. First, we introduce the external conditions surrounding both players, then we use an insider look to understand both companies' characteristics. **Chapter 3**, introduces Data Envelopment Analysis (DEA) concept. Data Envelopment Analysis abbreviated as DEA (for the easiness) had been widely used since 1978 to evaluate efficiency measures of organizations called "Decision Making Units" After an introduction and graphical explanation of DEA, we describe mathematical foundations and the models used in this research. At the end of Chapter 3, we classify the advantages and disadvantages of DEA and introduce the kind of questions an analyst can answer with DEA method. Finally, we discuss the limitations we encounter during the research. In **Chapter 4**, we introduce the models employed in DEA measurements. The beginning of Chapter 4 introduces a two-staged model of Profitability and Marketability. This approach is inspired by works of various scholars (mainly in banking). We introduce additional models to conduct DEA efficiency results for the industry regarding factors of production, marketing, scope and, scale and technical capacity usage. **Chapter 5**, addresses the sources and the preparation process of data. This chapter also gives a brief introduction to the financial statements and financial ratios. In **Chapter 6,** we conduct DEA efficiency results for the Turkish brewing industry using a sub-approach called Window Analysis. A time series analysis is required to evaluate DMUs over multiple time periods, thus DEA Window Analysis is used. This model was developed by G.Klopp et al. (1985)[22] who was using these techniques in his job for the U.S. Army. We use two staged profitability-marketability model and productivity model in DEA efficiency evaluations. We also identify, relationship between the market size and efficiency scores. At the end of Chapter 6, we summarize the results and give further suggestions for the improvements and projections. Finally, **Chapter 7** answers the question how efficient Turkish brewing companies operate comparing to peer units within the European market. Ten(10) European brewing companies from different countries (mainly beer producers including wine and spirit products' specializers) are used in the measurements. The decision-making units are a set of firms including worldwide leaders called the "big four": ABInbew, Carlsberg, SAB Miller and Heineken and mid to small size brewers. We assume fair results may be conducted by this kind of random sampling.

Chapter 1

Background of the Turkish Brewing Industry

In this chapter, we explain the development of Turkish brewing industry from government monopoly to duopoly. This approach is used to clarify the impact of government interventions (bans, regulations and strict licensing) on the market.

We analyse facts behind Efes' market leadership and Tuborg's follower position, furthermore find out reasons for the mature and saturated industry circumstances.

1.1 Industry Background

Turkish brewing industry possessed a monopolistic character from 1934 to 1969 with a government entity named Tekel. During these 35 years Tekel, suffered from low product acceptance, limited distribution channels, and productive inefficiency issues despite its monopolistic market power under government support. We do not have sufficient data to make a quantitative judgement for this stage of the industry. Furthermore, this period as government monopoly (1934-1969) does not carry any significant indicators for our research.

We introduce Turkish brewing industry in four phases according to its decisive stages. Each phase represents different industry features affected by government bans and regulations. The phases are categorized as follows: Phase 1: Growth and Competition (1969-1977), Phase 2: Market Maturity (1978-1983), Phase 3: Efes' Plans and New Regulation (1984-1990) and,Phase 4: Import Brands and M&As (1990-Todays).

1.1.1 Phase 1: Growth and Competition (1969 - 1977)

Turkish brewing industry structure changed drastically after acceptance of new entries by a government regulation in 1969. Two companies, Denmark's Tuborg[1] and Turkey's Efes Pilsen entered the market. From Figure 1.1 below we can see changes in brand sales of the industry. The industry transformed from 34 years of government monopoly (1934-1969 by Tekel) to an oligopoly (by Anadolu Efes, Turk Tuborg, Tekel) including private entities. A rapid increase of four times in brand sales occurred within following eight years' period (1969-1977). At the beginning of the figure, we examine a fierce competition in onder to capture bigger market shares.

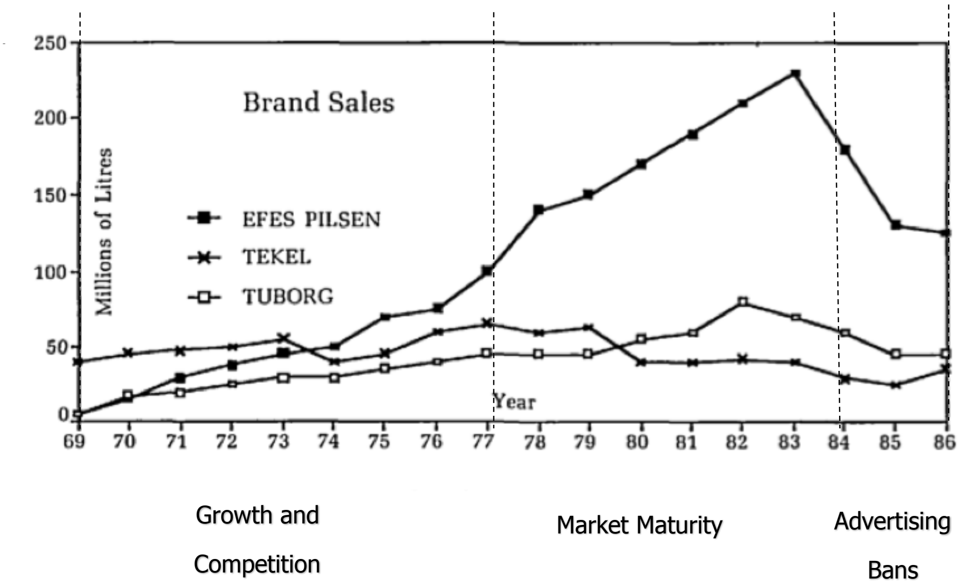

Figure 1.1: Turkish Brewing Industry and Brand Sales 1969-86

The growth and competition period took place from 1969 to 1977. Despite overall expansion of the market, growth was not evenly divided among competitors.

As seen in Figures 1.2 and 1.3 following, Tekel's market share decreased from 79.6% to 29.3% between 1969 and 1977. In this period, Efes and Tuborg achieved significant increases in market shares from 6.1% to 48.7% and from 14.3% to 22% respectively.

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[1] In this research,we use different names as : "Tuborg" or "Turk Tuborg" for Tuborg and "Efes", "Anadolu Efes" or "Efes Pilsen" for Efes .

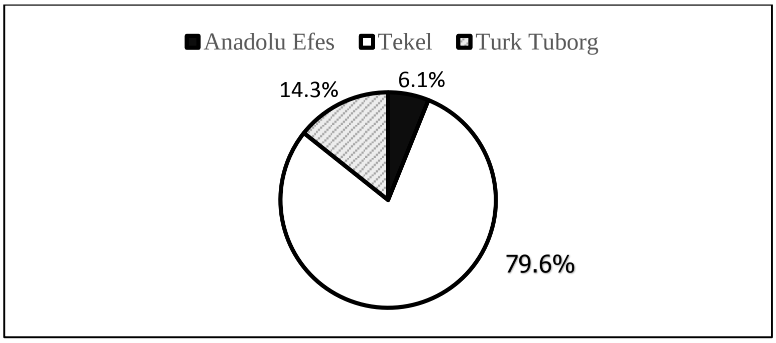


Figure 1.2: Market Shares in 1969

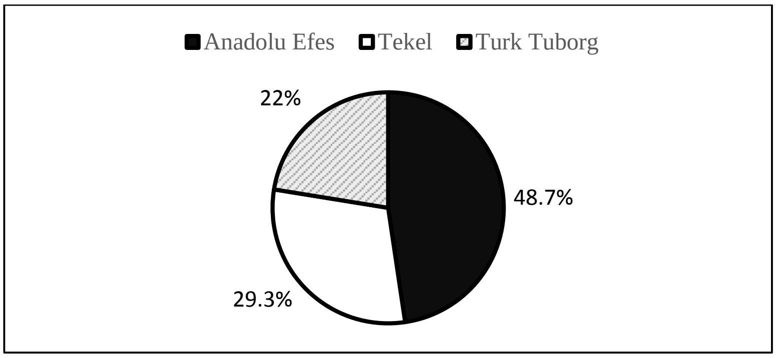


Figure 1.3: Market Shares in 1977

Efes pioneered the growth stage accompanied by Tuborg. Efes owed its market leader position to maintaining two core objectives: building product acceptance and building brand positioning.

At this section, we analyze the strategic moves which carried Efes to the market leader position. For this purpose, we use a well-known marketing model called " 4Ps marketing mix". The initials "P" stand for "product, place, promotion and price" components of the marketing mix. The concept of "the marketing mix" was reconstructed by Neil Borden[8]. In 1948, he described role of marketing manager as a "mixer of the ingredients" where the idea came from.

Another concept of 4Ps was introduced by E.Jerome Mccarthy in 1960 [31]. Table 1.1 below is the description of 4Ps concept as:

Table 1.1: Concept of 4Ps Marketing Mix

Category	Definition
Product	The product is an item that meets customer demands . It can be either in the form of a tangible good or an intangible service. Product decision is the initial decision before making any marketing plan.A firm has to answer questions for the right production mix as follows : • What product is going to be sold? • In what quality is it going to be produced? • What features will make the product different from others? • What are the secondary products or services sold together with the product?
Place	The place component refers to distribution channels. From its availability of access, products vary from consumer goods to premium products. Strategies for intensive distribution, selective distribution, exclusive distribution, and franchising can be used for the marketing.
Promotion	Promotion includes advertising, public relations, and sales promotions . Promotions also decide segmentation targeting and positioning of the product.
Price	Pricing is subject to a combination of many different variables. It also has to be updated. Some of the major elements in pricing are the cost of the product, advertising, marketing and distribution expenses and changes due to market fluctuations.

Source: Needham, Dave (1996). Business for higher awards. Oxford, England: Heinemann [34].

With 4Ps concept, we explain factors behind marketing success of Anadolu Efes as follows:

Product: Efes started its action plan with a market research that identified customers' complaints about Tekel's flagship brand under the same. Eventhough its customers liked the taste of Tekel Beer; they wanted more consistency, higher alcohol content, and thicker foam.

As a response, Efes produced a slightly higher alcohol level beer (4.2 percent against Tekel's 3.8 percent) and positioned it as a social beverage, rather than an alcoholic beverage. With this new status of beer. Efes made a rapid expansion throughout the country. On the contrary, positioning the brand as an alcoholic beverage would have run counter to Islamic prohibition[21].

Place: With the new status as a "social beverage" Efes made its rapid market penetration by selling beer in coffee houses. These places were the most popular gathering spots for Turkish men. Beer Pubs were secondary selling outlets that reflected European impression among Turkish citizens.

Promotion: Promotional programs at the trade were pioneering effects for Efes' success. However at this stage of growth and competition, only a little attention was paid to potential women customers. Because the market penetration was instituted mainly by male customers. We recognize 65/35 split as the main course for maintaining the quality control in distribution channels. Efes, shrank territories and added new distributors to achieve an increase in customer demand.

Price: At this stage, Efes positioned its beer as a social beverage at an affordable price level in between Tekel (an inexpensive beer) and Tuborg (a premium beer with price). However, it encountered a new type of competition against social beverages like soft drinks, coffee, and fruit drinks. Another obstacle for Efes was the high price elasticity due to low per capita income level in Turkey. Considering these facts, "first quality second price" policy was taken into account. This policy led Efes occupy same quality and taste level with Tuborg, yet a cheaper price level below Tuborg. Efes captured both price and quality conscious customers as a result of right timing and positioning.

We summarize Efes' successful strategic moves at the growth stage by using 4Ps of marketing mix as in Figure 1.4 below:

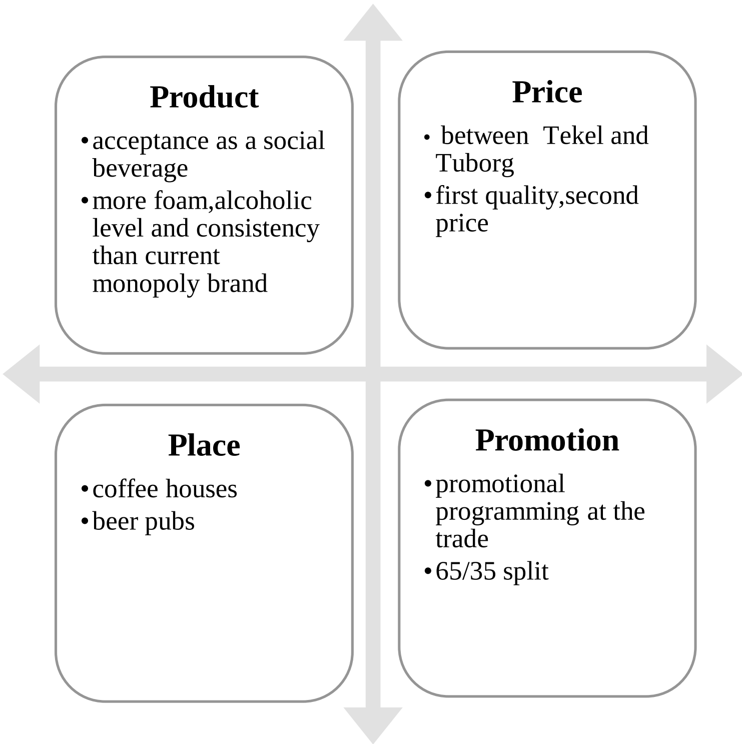


Figure 1.4: 4Ps Marketing Mix Strategy by Efes at the Growth Stage

1.1.2 Phase 2: Market Maturity (1978-1983)

Rapid growth turned into a slower trend starting from 1977. In saturated markets product acceptance and positioning are expected to be stabilized, that was what also happened in the Turkish brewing industry. However, industry sales did not follow expected patterns. Efes' sales more than doubled (see Figure 1.1) and market share increased to a level above 34 percent. Efes penetrated rural areas and gained new type of customers as a result of distributors' efforts. At this stage new beer concepts were added to the product line, like 50 cl bottle for home consumption. However, Efes' increase in market share came at the expense of Tekel, the first Turkish brewer.

1.1.3 Phase 3: Efes' Plans and the New Regulation (1984-1990)

At this stage, industry sales were stabilized. Efes had a high market share that left only a few converts to win. The offensive strategy was kept into plan targeting to assault Tuborg's brand position at the premium, with import beer brands in the market. Tuborg moved to compete against Efes with a new brand with a lower price. Efes responded this move by entering the premium beer market with a German brand called Löwenbrau. Efes targeted to capture Tuborg's 20 percent market share.

Expanding to overseas markets and developing a non-alcoholic beer for Islamic countries were other strategic moves of Anadolu Efes. However on June 22, 1984, government's announcement of beer as an alcoholic beverage again, drastically made negative impact on Turkish brewing industry. Advertising ban on broadcast media and strict licensing criterias made it harder for brewers to reach new customers. Promotional opportunities became very limited without broadcast media. Moreover, distribution to coffee houses became off-limit. Thus, a sharp decline of 38 percent in beer sales was seen in two years' time. Efes still kept its market leader position with same market share.

According to Figure 1.5 as follows, Efes' market share increased from 48.7% to 67% in between 1977 and 1983, before the government regulations. Tuborg's market share slightly fell 1 percent, from 22% to 21% level. Tekel had the biggest drop in market shares from 29.3% to 12% as a result of Efes' and Tuborg's aggressive strategies (see Figure 1.5).

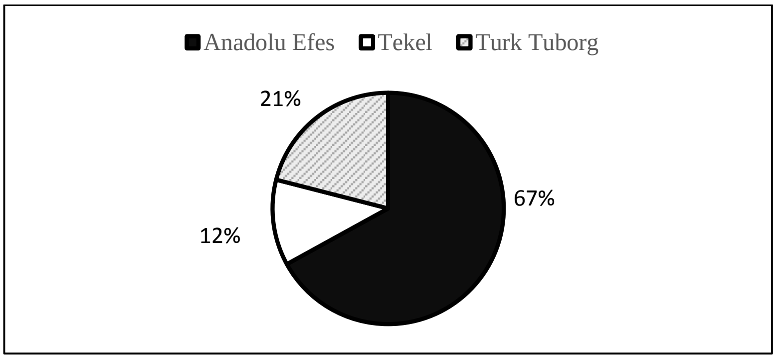


Figure 1.5: Market Shares in 1983

Instead of broadcast media, promotions through print and point-of-purchase media became new ways of advertising. Another promotional effort was done by Efes Pilsen basketball team that has been competing very successfully in Turkey and Europe. This move helped Efes enhance name recognition and even indirectly preserve broadcast media exposure [21].

In Figure 1.6 as follows we identify how industry sales increased more than six times from 1969, to 1984 when a new regulation was made by Turkish government. A rapid decrease followed after broadcast media ban and strict licensing. From Figure 1.6, we conclude that the Turkish brewing industry is significantly shaped by government interventions.

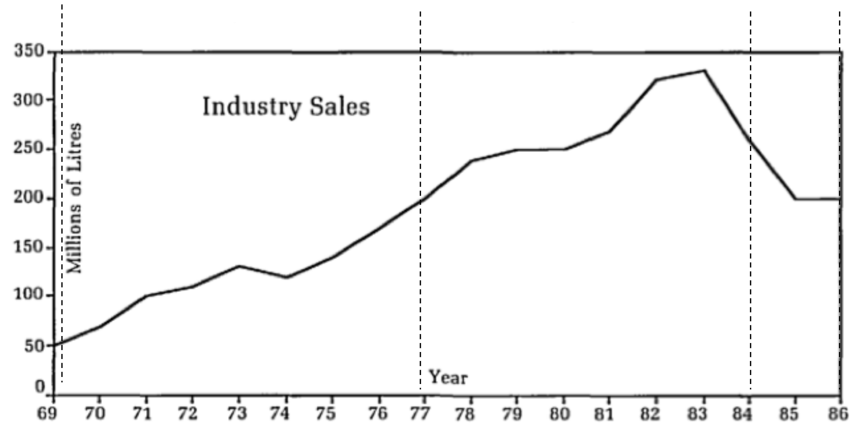


Figure 1.6: Turkish Beer Industry and Industry Sales 1969-1986

Turkish brewing industry had been focusing on product proliferation and diversification (around 40 brands including discount, popular-priced, premium and import brands) rather than a price competition. Efes has market leadership from rapid growth days of the industry. Tuborg,with follower position targets the residual demands and serves mainly to a premium customer base. From the early 70's to today's, Turkish brewing industry had completed its stabilization with two dominant companies. Despite entries of other beer companies, including "microbrewers" Anadolu Efes and Turk Tuborg capture more than 95 percent market share of the entire industry. State-owned brewer, Tekel could not use its first mover's advantage. Therefore, most of its customers switched to other brewers, mainy to Efes. At the same time, Tuborg kept its particular customer portfolio with a sense of brand loyalty, under a motto "Real men drink real beer".

A significant regulation in 1984 canalized companies expanding to new regions like overseas markets. Efes pioneered this period by opening facilities in Kazakhstan, Russia, and Romania, and grew the company into one of the main mass brewers in Europe.

1.1.4 Phase 4: Import Brands and M&A's (1990-Todays)

90's was an era for import products' entries into the Turkish brewing industry. Corona from Mexico, Heineken from Holland, Beck's from Germany, Budweiser and Miller from America and Fosters from Australia were some examples of these entrants. However, the obstacles for import brands are categorized as: complicated bureaucracy in Turkey, the limited profit margin for beer and requirement for wide distribution channeling.

2000-2001 was a period of significant change in Turkish brewing industry. Efes started holding exclusive rights for production and sales of Miller, the flagship brand of Miller, which is the 4th biggest brewer in the world. Same year Danish Carlsberg acquired Tuborg and became the biggest shareholder with a 50.01 percent of overall share.

In 2004, Tekel was acquired by another Turkish brewery called Mey Icki. Tekel had been occupying eight percent market share until the year 2006 when Mey Icki stopped its production. Turkish brewing industry transformed from oligopoly to duopoly at this stage (see Figure 1.7).In 2008, Anadolu Efes acquired Tekel Birasi Beer from Mey Icki. Today this brand has around 1 percent market share.

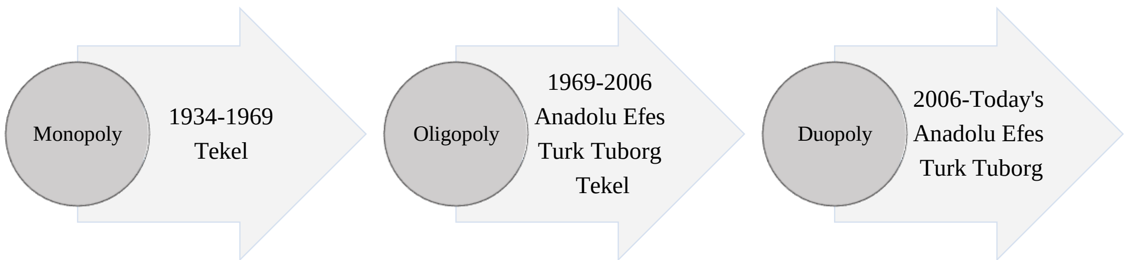


Figure 1.7: Market Evolution (1934-Todays)

Within the last 13 years, the conservative government and rise of Islamic wing brought some hardships to the brewing industry in Turkey. Very high excise taxes were imposed on beer recent years[17]. However, Anadolu Efes managed to keep its sales volume and market share at the same level until 2012, because of strategic investments and decisive initiatives. Despite a market growth of 5 % in 2012, steeper taxes and strict regulations in 2013 exerted significant pressure on the sales volumes and market shares. The effects of regulatory changes showed their impact in 2013 and 2014 as a decline trend. Taxes and regulations played crucial roles in price settings. For example, the excise tax charged on beer was increased by 15.6 % in January 2014 and by another 4.1% in July 2014. Therefore, these increases had to be reflected on prices [17].

The mature market conditions and government policies led both companies focusing on productive efficiency issues. For example as a result of these efforts from 2008 to today, 19 and 24 percent of less water is being used in beer and malt productions respectively (see Anadolu Efes annual report 2015) [1].

In Chapter 2 ,we analyze current situation of Turkish brewers and the brewing industry.

Chapter 2
Current Situation of the Turkish Brewing Industry

In this chapter, we analyze the current situation of the Turkish brewing industry. This analysis is made up of two parts. In section (2.1), we define the industry structure and categories of Turkish brewers by scales. In section (2.2), we use a well-known marketing approach called the SWOT analysis. We define strengths, weaknesses, opportunities and treats of the industry under this perspective.

2.1 Industry Structure

Beer is defined under the category of Fast Moving Consumer Goods (FMCG) as well as food, tobacco, personal care goods, and housekeeping products. On the other hand, beverages are categorized as soft drinks and alcoholic beverages. Soft drinks include carbonated soft drinks, bottled water, fruit juices and sparkling water. Alcoholic beverages include spirits like raki (traditional Turkish alcoholic beverage), vodka, wine, and beer. Finally, beer can be categorized from top to bottom as consumer goods/fast moving/food/beverage/alcoholic beverage/beer[9].

We classify breweries into five categories according to their production volumes as follows:

1) Macrobrewery: They are large and renovated breweries with a production capacity of more than 1,800,000 liters annually. This group consists of Anadolu Efes and Turk Tuborg, which compete on a nation wide level and export overseas.
2) Microbrewery: Microbreweries are the designation of breweries that produce fewer than 1,800,000 liters annually. Their marketing strategies differ from those of the large, offering products that compete by quality and diversity instead of low prices and

advertising. Most of the breweries in the Turkish brewing industry besides Anadolu Efes and Turk Tuborg fall under this category. They operate in regional levels.

3) Nanobrewery: They are scaled down breweries, often ran by a single entrepreneur that produces in very small batches.
4) Craft Brewery: This term is not only used for relatively small, independently owned breweries but also refers to traditional brewing methods and emphasize flavor and quality.
5) Brewpub: It is the combination of a brewery and pub. A brewpub can be pub or restaurant that brews beer on premises.

Until 1969 Turkey held a monopolistic market structure operated by a government entity named Tekel. Despite its monopolistic market power stimulated by the government support, its flaship brand under the same name suffered from low product acceptance, limited distribution channels, and inefficiency issues (see Chapter 1).

In 1969 a government regulation changed industry structure into an oligopoly by allowing private brewers enter the market. Since then industry concentration has increased. Today the industry holds duopoly market structure with combined market share of 95 percent. Because of high entry barriers and market saturation, there is not much space for new entrants to succeed. As we see in Table 2.1 below, Anadolu Efes is the market leader, and Turk Tuborg is the follower with around 80 and 15 percent market shares respectively. Recently, the industry has duopoly structure , and we examine a Stackelberg competition where the roles of Anadolu Efes and Turk Tuborg are well defined. Both of the firms sell homogenous products subject to same demand and cost functions. Anadolu Efes is the price and quantity setter because they are better known, and they decide first which quantity to sell. Efes owes its privileged position to the wide distribution channels established in the growth stage (see Chapter 1). Turk Tuborg focuses on residual demands of Anadolu Efes. Tuborg has a premium product portfolio including its high-quality main brand under same name as “Tuborg”.

The main product line of Anadolu Efes is Efes Pilsen (5.0% ABV) named after the ancient Turkish city of Ephesus near its Izmir brewery. Other products of Anadolu Efes are Efes Dark, Efes Light, Efes Extra, Bomonti, and Marmara. Efes also exports to markets in Europe, the Middle East, Africa and South-East Asia.

Turk Tuborg is Anadolu Efes’ main competitor. The company is a former subsidiary of the Danish Carlsberg/Tuborg group. Currently, Tuborg is owned by Israeli Central Bottling

Company (CBC). Danish Carlsberg is also popular in Turkey among other brands found internationally.

Table 2.1: Company Share Analysis (%), 2010-2011

Company	2010	2011
Anadolu Efes Biracilik ve Malt San AS	79.0%	80.2%
CBC Group(Turk Tuborg)	15.4%	14.8%
Others	5.6%	5.0%

Source: Datamonitor 2012 [15]

Anadolu Efes and Turk Tuborg operate six breweries out of eleven in total. Besides these breweries, there are five microbreweries active in the Turkish market (see Table A.1 and Table A.2,Appendix). These companies also carry out beer related operations besides the production and sale of beer such as : agricultural operations related to beer production, transportation of beer, wholesale of beer trading, the bottling and packaging of beer and production and sales of malt.

In Turkey beer is produced and consumed domestically. One percent market share of import brands takes insignificant part in the industry. They are sold through upscale hotels and cafes. Export markets of Turkish beer companies have been growing. Anadolu Efes and Turk Tuborg together sell more than 40 countries overseas. In Turkey beer production has reached to a stabilized level with compound annual growth rate (CAGR) of 14%. From the Table A.3, which includes Flavoured Alcoholic Beverages (soft drinks, pre-mixed spirits, and wine coolers) and ciders, we can identify a steady increase in production volume for beer (see Appendix).

Around 40 different brands of beer are produced in Turkish brewing industry, mostly by Anadolu Efes and Turk Tuborg. Three brands have a total market share of 88 percent as seen in Table 2.2 below. In Turkish market, the brewing companies have products in three categories: 1.Premium, 2.Mainstream and 3.Discount. Efes Pilsener and Efes Xtra of Anadolu Efes, Tuborg of Turk Tuborg fall under the “mainstream” category. The main competition takes place in this category. The average price of Turkish beer is lower than European brands and import brands sold in Turkey[1]. Under these circumstances, it is expected that firms improve their financial positions and increase disposal income. Furthermore, as a result, there should be an increase in the consumption of beer. However, bans, regulations and frequent increases in taxes and excise duties by government eliminate these opportunities.(see Appendix).

Table 2.2: Brand Share Analysis (%) 2010-2011

Company	Brand	2010	2011
Anadolu Efes Biracilik ve Malt San AS	Efes Pilsener	62.5%	62.8%
CBC Group	Tuborg	12.8%	12.7%
Anadolu Efes Biracilik ve Malt San AS	EFES Xtra	12.1%	12.6%
Anadolu Efes Biracilik ve Mallt San AS	Others	3.8%	4.3%

Source: Datamonitor 2012 [15]

Since 1969, the trends in Turkish brewing industry has existed around the popular-priced (mainstream) beer category. Despite M&As (mergers and acquisitions) and increasing disposal income per capita, we see no significant shifts to premium,super-premium, and imported brands. Today import brands have only a market share around 1 percent.

The use of agricultural products is high in beer production because beer is a natural drink. Beer is made from a malted cereal source which is mostly barley, hops, yeast and water. Barley is the most important ingredient in beer production. Eventhough Turkey is one of the major barley producers in the world, the need for high-quality barley faces some difficulties. Despite the fact that ,70 percent of barley is for industrial use in Turkey, approximately 100,000 tons of barley on a yearly basis need to be imported. In addition to agricultural products glass bottles, crown corks, labels, PET preforms, filtering products and enzymes are also used during the production process[32].

The following figures explain the breakdown of costs for beer production in the U.S. market and an average brewing plant in Europe with an annual capacity of 0.4 million hectolitres. In Turkey labor costs are almost one-fourth of the European average[18]. Turkish brewing industry has an organization of vertical integration by a three-tier distribution system. The system works as: mass brewers sell their products to wholesalers, and wholesalers sell to the retailers. The mass brewer sets the wholesale price at the brewery, but the price varies for the region in response to demand and competition factors. The following price-cost breakdown was made for the U.S. brewing industry in 1996. From Figure 2.1 below, we examine that ingredients, labor and production costs account less than 16 percent of the consumer price for a six pack beer. Tax and shipping expenses account for about 18 percent of the price for beer (see Figure 2.1).

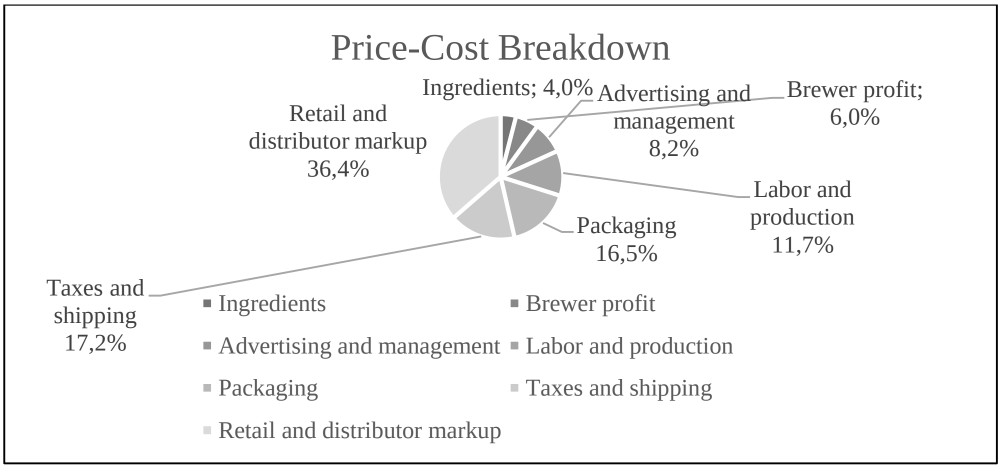


Figure 2.1: Price-Cost Breakdown of Mass Produced Beer(U.S.Industry) [49]

Item	Ratio /hl beer produced	Cost USD/hl beer produced
malt	18 kg	5
hops (cones)	0.15 kg	0.5
yeast(thick)	0.61	0
fuel	150 MJ	0.7
electricity	12kWh	1.2
water	0.7m3	0.3
waste water treatment	0.55m3	1.1
space part	lumpsum	1.2

Assumptions: capacity 0.4 ml,6.2 the h per year operation

Figure 2.2: European Standard Plant Operation Costs

Beer is the most expensive alcoholic drink to produce according to the study made by Brewers of Europe in 2009 [43]. When converted to pure alcohol, the cost of producing one liter of pure alcohol in beer is €45.20, wine is €17.90, and spirits is €18.60. After adding excise taxes, beer is still the most expensive form of alcohol to produce at retail prices. The average retail price including taxes of one liter beer is €84 compared to €77 for wine and €65 for spirits. On the contrary, when compared to other types of alcoholic beverages, beer holds the smallest net margin per liters of finished product. To add up large total margins, companies have to sell their products in big volumes.

From Figure B.7 we identify that beer has the lowest consumption per capita rate in Turkey,comparing to other European countries(see Appendix). The reasons are: a prohibition of alcohol consumption by Islam religion and customer's preference for a national alcoholic spirit called Raki.

In Turkey, brewing industry has shown growing trends from the entry of private entities in 1969 to mids of the 90s and,stagnant periods in the last decade. One of the main reasons behind changing trends in sales is government intervention by law. Alcoholic beverages are prohibited from selling closer than 200 meters to schools, mosques and hospitals. In addition to bans and regulations, granting licenses to retailers with high criteria limit distribution opportunities. Beer supply varies according to the seasonality affects. Even at the very high seasons only 35 percent of beer is distributed by retailers. Despite decreasing consumption per capita, high excise duties, taxes, and inflation rates are reflected in the prices. The expenditures made on beer per capita shows an increasing pattern of nine percent average annual rate. Eventhough the consumption per capita in Turkey stays flat, the market value increases at around 10 percent compound annual growth rate (see Appendix).

2.2 Turkish Brewing Industry under SWOT Analysis

In section 2.2, we analyze the Turkish brewing industry by using a well-known marketing approach called SWOT analysis. The term "SWOT" refers to the initials of the words "strength, weaknesses, opportunities and threats". This analysis identifies the strengths and weaknesses of a business and examines the opportunities and threats that may affect that business. This approach was first introduced by Albert S.Humprey that came from research conducted by Stanford Research Institute in 1960-1970[2]. The research was funded by Fortune 500 companies to find out reasons behind corporate failures. Table 2.3 below is the classification for the components of SWOT.

Table 2.3: Explanation of the SWOT Analysis

Strengths and Weaknesses	the internal environment- the situation inside the company or institution	i.e.: factors relating to products, pricing, cost,profitability, performance,quality, people skills,adaptability, brands, services,processes,infrastructure	These are the factors tend to be in the "present"
Opportunities and Treats	the external environment – the situation outside of the company or institution	i.e.: factors relating to markets, sectors, audience,trends, seasonality,competition, economics,politics,society,culture,technology,environment	These are the factors tend to be in the "future"

In this analysis, Strengths and Weaknesses are mapped or graphed against Opportunities and Treats. Strengths and Weaknesses are regarded distinctly as internal factors; Opportunities and Treats as external factors. During his research, Albert Humphrey advocated six categories as follows: 1.Product (what are we selling?), 2.Process (how are we selling it?), 3.Customer (to whom are we selling it?), 4.Distribution (how does it reach them?), 5.Finance (what are the prices, costs, and investments?)and, 6.Administration (how do we manage all this?)

By using the categories above, he provided a SWOT framework by which internal and external issues can be overcome with actions and new management skills. We analyze the Turkish brewing industry by using SWOT framework as follows:

STRENGTHS

Brand Awareness: Anadolu Efes' Efes Pilsener and Efes Xtra and Tuborg's Tuborg have the brand awareness among Turkish beer customers. From 1969 to today, both companies have established their corporate and brand images in the industry. Efes is well-known for its accessibility, better foam, consistency, and freshness. Tuborg focuses on its particular customer portfolio with the motto of "Real men drinks real beer". Recently regarding to the competition, capturing from each other's customer portfolio is not seen for the companies.

Company Structure: Anadolu Efes has the economy of scale and scope with a decentralized organization structure. This company has fourteen beer (five in Turkey and nine abroad) and six malt factories, Moreover it has reached MES (minimum efficient scale) amount (six to seven plants) required for the brewing industry. However, its decentralized structure may bring inefficiencies due to the large size of the organization.

On the contrary, Turk Tuborg has a centralized organization structure having Turkey's biggest brewing factory in Izmir with a production capacity of 36,000 malts and 300 million liters of beer. Under Denmark's Carlsberg Breweries Turk Tuborg has know–how and expertise in brewing. Its centralized structure makes it easier to take control in more efficient organizational structure.

Industry Structure: Turkish brewing industry is transparent, consolidated and highly regulated. Two companies dominate the industry with combined market share of 95 percent. High entry barriers make it harder for the new brewers enter the market ,however incumbent firms are protected to strength their positions. High technology and expertise is required to start up in the industry. From the year 1984, TV and radio advertisements are fully restricted. These factors make it harder for the new entrants to succeed and establish brand awareness.

Beer as a Product: Beer is a product hard to copy and imitate. The production process is technology and knowledge intense. Companies need to operate six to seven plants to reach MES in the production. Beer is most expensive to produce comparing to other alcoholic beverages. Therefore, illegal production like raki and wine is unlikely to be seen.

WEAKNESSES

Obstacles for Raw Materials: Beer is a natural drink and use of agricultural products is high. Finding suitable barley, the main ingredient, for beer production is not an easy task for brewers. Turkey is one of the major barley producers worldwide, and 70 percent of barley is for the industrial use. However, requirement for high-quality barley is an important obstacle in beer production.Turkey needs to import 100,000 tons high-quality barley annually[17].

In 2009 and 2010,because of unexpected harvests in Europe hops production decreased. Brewing companies may confront high prices in agricultural products due to similar circumstances.

Low Consumption in Turkey: Comparing to all members of European Union, beer consumption per capita in Turkey is very low. EU had averages of final product per person consumed and pure alcohol beer consumption 75.3 liters and 3.5 liters respectively in 2009. Turkey had averages in same categories as 12.7 and 0.7 respectively [43].

Reasons for low consumption may be Islamic prohibition for alcoholic drinks, tax burden, decreasing popularity of beer, economic crisis, and limited opportunities for advertising and promotions of beer in Turkey.

Hostile Business Environment: With the rise of Islamic wing in the Turkish government, the business environment has become more hostile than before for the beer companies. Excise duty levied on beer is 18 percent VAT(Value Added Tax). In addition to this tax companies have to pay,income-related taxes, social security contributions, corporate tax, property tax, environmental tax, announcement and advertising tax, stamp tax, monitoring tax, packaging tax, and fuel tax on production and sales of beer. The amount of these taxes is seven times greater than countries with similar GDP PPS per capita and three times greater than the average EU members. In addition to high excise duties and taxes, bans and regulations by the pro-Islamic government oppose to alcohol consumption and creates a hostile business environment for the brewers in Turkey [21].

OPPORTUNITIES

Young Population in Turkey: The average age range in Turkey is 30.7 and, 16.5 percent of the population is within the age range of 15-24. Because of 69 percent of the population between 18-28 do not consume alcohol, companies foresee this situation as an expansion opportunity to gain new customer base.

Expanding Overseas Markets: Expanding overseas markets can be done in two ways: Exporting to overseas market or opening facilities abroad. Because of the hostile business environment and mature market conditions, Turkish brewers have started expanding overseas. Recently, the market leader Anadolu Efes has nine facilities abroad and exports to over 50 countries. Turk Tuborg has a partnership with Carlsberg Breweries, which is operating and producing in over 140 and 40 countries respectively. Turkish brewers export more than nine percent of their production,mainly to Germany,Lebanon,Iraq and Azerbaijan. Eventhough consumers in many countries prefer to consume beer brewed domestically, European beers including Turkish brands are preferably consumed worldwide[17].

Expanding overseas can also be made in the form of M&As. M&As provide exchanges of expertise and know-how, consolidate financial strength and create synergies for brand awareness. In 2000-2001, Anadolu Efes started producing Miller the product of Miller-Coors. Same year Denmark's Carlsberg became the biggest shareholder of Tuborg with a 50.01 percent of overall share.

THREATS

The Presence of Raki: Raki is the national alcoholic drink in Turkey, and it is the main substitute for beer. Eventhough its market share is 1/25th of beer, raki may be still considered as a treat for beer. Beer and raki have annual consumptions of 900 million liters and 40 million liters respectively. Consumers of raki have high brand awareness and product loyalty. However, beer is also a complementary product for raki, because raki drinkers have the habit of drinking beer after raki to soften its strong and bitter flavor.

Besides raki, high taxes, frequent bans, and regulations, the rise of conservative wing in government, Islamic abolition may also be classified in the "Threats" category as well as "Weaknesses" category. Tuborg's premium image is a threat for Anadolu Efes while Anadolu Efes' strong presence is a threat for Turk Tuborg.

In the first two chapters, we describe the background and current situation of the Turkish brewing industry. In Chapter 3, we introduce main methodology used for productive efficiency measurements in the Turkish brewing industry which is called “Data Envelopment Analysis.”

Chapter 3

Data Envelopment Analysis

3.1 The Definition

Data Envelopment Analysis is a service management and benchmarking technique that uses a non-parametric mathematical linear programming approach. In opposition to the well-known methods like regression analysis and stochastic frontier analysis, data envelopment analysis deals with identifying optimal ways rather than averages.

Decision-making units (DMUs) are the basic elements subject to the application of the DEA (Data Envelopment Analysis) methodology. DMUs are homogenous units performing same or similar activities and converting multiple inputs to multiple outputs. A method of evaluating an appropriate efficiency index without requirement of a priori assumption was stated by Fare (et al. 1994)[38]. This formula was summed weighted outputs divided by summed weighted inputs.

The original work was made by Farrell et al.(1957)[30], and initial DEA model was improved by Charnes, Cooper and Rhodes et al.(1978)[12] which was called CCR by initials of its presenters. Seiford and Thrall [39] stated DEA as “floats like surface to the rest on the top of the observations”.

The efficiency of a DMU is calculated relatively to the group’s observed best practice. The set of peer organizations is evaluated regarding their distances to the linear surface, which “envelopes” all of the rest those are said to be relatively inefficient. By using a mathematical duality structure, DEA is composed of two parts: multiplier side from the dual model and envelopment side from the primal model.

DEA can identify the top performers, among peer groups and introduce suitable strategies for them to improve their performances. Figure 3.1 follows gives us a visual comparison between the DEA and regression analysis approaches. As seen in the figure DEA deals with the best performances rather than averages.

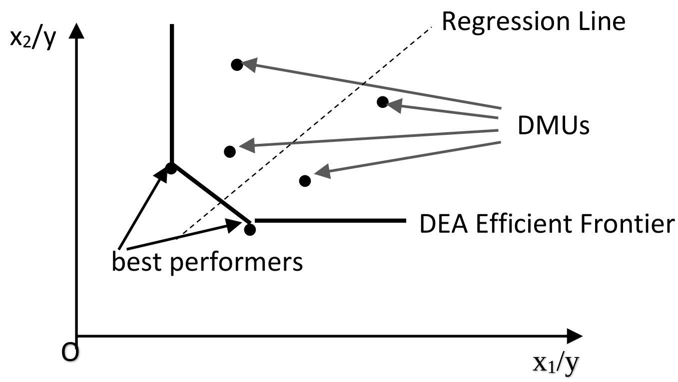


Figure 3.1: Data Envelopment Analysis versus Regression Analysis

3.2 Terminology in Data Envelopment Analysis

Data Envelopment Analysis is decomposed into various models and types, regarding their orientations, methodologies, and convexity situations.

The underlying arguments for DEA identify over 30 different models, according to the methods they exert. The first basic model of Farrell (1957)[30] was developed by Charnes, Cooper and Rhodes (1978)[12] and named after initials of their names as CCR. In their study, DEA was described as a mathematical programming model, applied to observational data. It deals with frontiers rather than central tendencies or averages. DEA is used to provide empirical estimates for decision-making units. CCR, BCC, and the additive model are widely used and most well-known methods recently for efficiency measures.

DEA is divided into two models regarding the purposes of evaluations as: 1.Input-oriented models: Outputs being kept fixed, minimization or reduction of used inputs is aimed, 2.Output oriented models: Inputs being kept fixed, maximization or augmentation of produced outputs is aimed.

The constraints and purposes for the field studied are crucial in choosing the orientation to focus. In some industries, both output augmentation and input reduction are focused simultaneously. An additive model is used in such situations providing a proportional reduction of excessive inputs (input slacks) and proportional augmentation of lacking outputs (output slacks). In either orientations, the same efficient frontier is estimated as a benchmarking process.

Convexity and returns to scale conditions address two components of DEA: constant returns to scale (CRS) and variable returns to scale (VRS).

The result of variable returns to scale is more precise and realistic than constant returns to scale. In real life situations only under optimal conditions, constant returns to scale model becomes more appropriate than variable returns to scale. Along similar lines, it is argued that imperfect competition, regulations, legal and juridical constraints and similar factors are the main reasons of non-optimal conditions. Variable returns to scale shows increasing, decreasing,non-increasing and non-decreasing patterns depending on their convexity situations.

By using DEA models and returns to scale patterns we conduct efficiency measures described as follows:

i. **Technical efficiency (TE):** It is a reduction in inputs or augmentation in outputs radially for given level of outputs and inputs respectively. Technical efficiency is a management and scale problem rather than a price and cost concern.
ii. **Scale efficiency (SE):** It is a measure how optimal a DMU or organization is in size. It is a score of the difference between variable returns to scale and constant returns to scale. New technologies and improvements in production processes are solutions for scale inefficiencies.
iii. **Allocative efficiency (AE):** It is the ability of a firm, using inputs in a very optimal proportioning. An organization, as a preliminary condition, has to be fully technically efficient to be allocative efficient.
iv. **Price efficiency (PE):** It is reached by combining process of the two measures (TE and AE). It is also called cost efficiency or total economic efficiency. An organization is cost efficient if and only if it is both technically and allocative efficient.

3.3 Graphical Illustration of the DEA Concept

Input-oriented measures indicate how much input quantities have to be proportionally reduced holding outputs at fixed levels. Output oriented measures indicate how much output quantities have to be proportionally increased holding inputs at fixed levels. Illustrating input efficiency measures under CRS and VRS assumptions would be as seen in Figure 3.2.below. The scale efficiency is conducted using both assumptions:

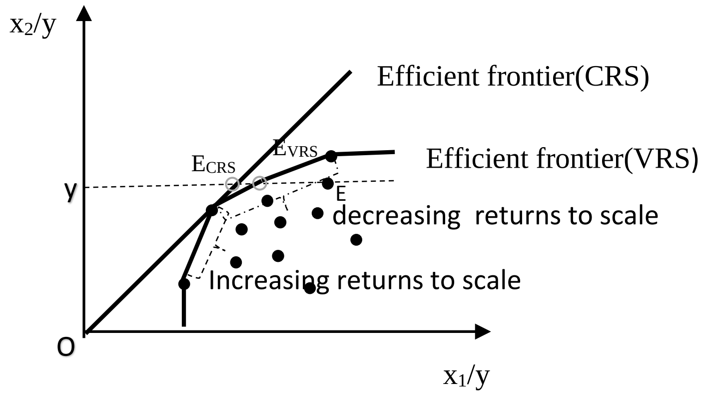


Figure 3.2: Returns to Scale Assumptions

Efficiency measures from the graph above are as follows:

Input efficiency(CRS) $= \dfrac{yE^{CRS}}{yE}$

Input efficiency(VRS) $= \dfrac{yE^{VRS}}{yE}$

Scale efficiency $= \dfrac{yE^{CRS}}{yE^{VRS}}$

The input-output combination bounded by the efficient frontier, which is formed by the best practice units, gives us the possibility set region. The borders of the production possibility set are extended using the vertical and horizontal lines from the first and last dots representing two of the efficient DMUs respectively.

The idea of illustration of the efficiency evolved from the location of a firm in a graph comes from where a piecewise linear convex isoquant represents possible production limits, and an isocost-isorevenue represents possible cost-revenue limits. Farrell’s findings lend support to claim that either this non-parametric piecewise linear convex isoquant or a parametric function that fits the data encloses all observed points as seen in Figure 3.3.

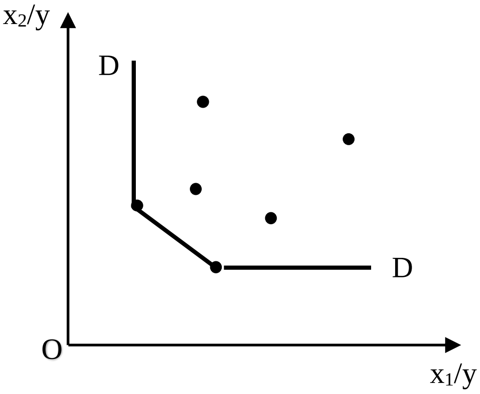


Figure 3.3: Illustration of Non-parametric Piecewise Linear Convex Isoquant

The technical, allocative and cost efficiency measures can be conducted geometrically using a proportional notion which refers distances of some important locations from the origin. These locations refer to operating coordinates of the observed decision-making unit (DMU), efficient frontier and, isocost line. The figure 3.4 below and following ratios give us the efficiency measures conducted by using these distances.

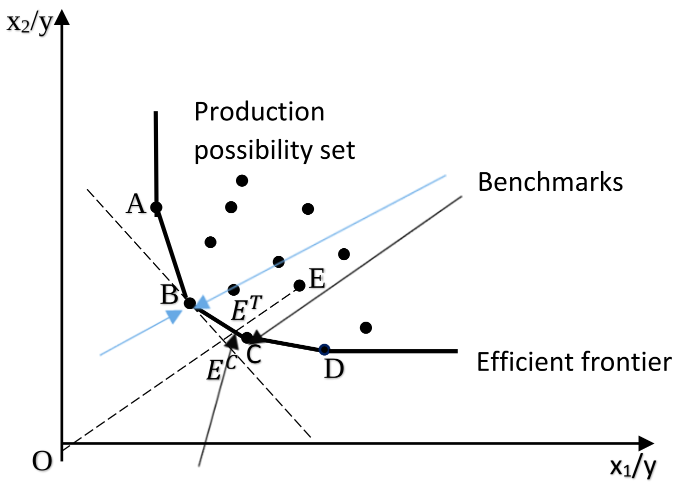


Figure 3.4: Illustration of Technical, Allocative and Cost Efficiency Measures

Technical efficiency $= \dfrac{OE^T}{OE}$

Cost efficiency $= \dfrac{OE^C}{OE}$

Allocative efficiency $= \dfrac{OE^C}{OE^T}$

Under the assumption of constant returns to scale, input-oriented model which scopes to output augmentation and, output-oriented model which scopes to input reduction as illustrated below:

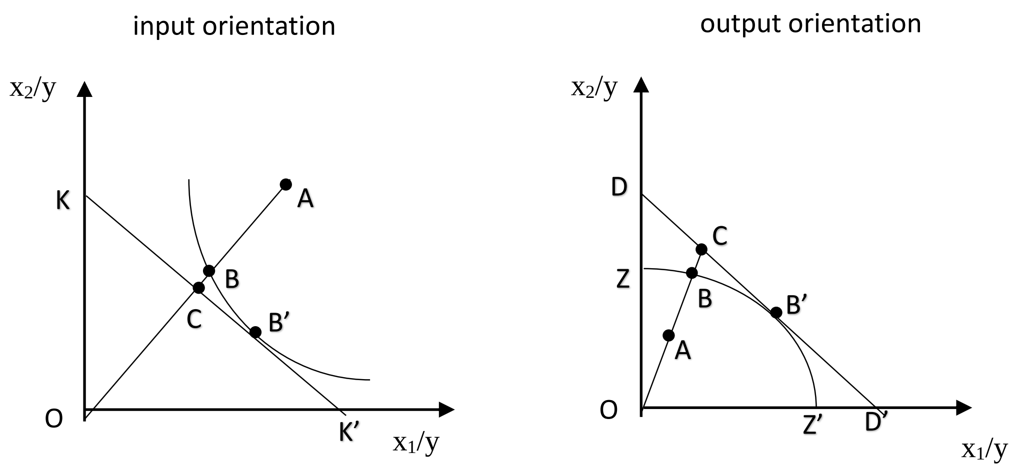


Figure 3.5: Comparison of Input and Output Orientations

In both illustrations, same capitals were used to make a comparison. The illustration on the left side represents an input-oriented model where the firm is active at point A, within the set of production possibility yet inefficient. Firm at the point of operation A would reduce its input usage radially to the point B, which is the optimum production frontier. This proportional reduction ratio of inputs (without reducing the outputs) gives us technical efficiency score of an input-oriented model. However firm at point B, being on the efficient frontier, faces a situation of optimal usage of input proportions hence cost reduction. The firm therefore tends to move to point B', where firm becomes allocative and technically efficient. The distance AB represents a radial reduction of input usage for the firm to become technically efficient. The distance CB is the reduction amount where a cost reduction represented by CB' induces the firm to contract towards the origin for reaching an efficient allocative level. The distance represented by AC shows the total distance a firm has to reduce to become both technically and, allocative efficient. C is the projection of point B' on the OA line. Point B' is the optimal operation point for the firm where isocost line and production possibility frontiers become tangent.

A similar approach can be applied to the output-oriented model; where A is the point of the firm operating, B is the point firm increases outputs without extra inputs needed, therefore reaching to a technical efficient level. With the price information a revenue line, DD' could be drawn, and a revenue increase can be shown with the segment of CB'. Similar to the previous model, C is the projection of point B' on the OA line. Point B' is the optimal operation point for the firm at where the revenue line and production possibility frontiers become tangent.

Showing all measures for the figures above are as follows:

Input Oriented Scope	Output Oriented Scope
TE = OB/OA	TE = OA/OB
AE = OC/OB	AE = OB/OC
EE = OC/OA	EE = OA/OC
= (OB/OA)x(OC/OB)	= (OB/OA)x(OC/OB)
= (OA/OB)x(OB/OC)	= (OA/OB)x(OB/OC)
= TE x AE	= TE x AE

TE: technical efficiency

AE: allocative efficiency

EE: economic efficiency

The efficiency scores from the measures bound between zero and one. Production is technically inefficient when the score is less than one and fully efficient when the score equals to one. The inefficiency scores are calculated by subtracting efficiency scores from one. An efficiency score can be interpreted by multiplying the scores with 100 for reaching a percentile notion. For example, a DMU having a 0.8 technical efficiency score tells us it is 80% technically efficient. Without changing the output, by reducing its input usage proportionally (or radially) 20% level, it can become fully efficient.

3.4 Mathematical Foundation of DEA

Data envelopment analysis uses a dual structure linear programming problem to conduct efficiency measures. The most common method was introduced by Charnes, Cooper and Rhodes et al (1978)[12] as a ratio definition of efficiency known as CCR model. This model improved the initial model of Farrell's (1957)[30]which had a failure in offering a model with various inputs and outputs.

Maximizing the efficiency scores smaller than or equal to 1, for each decision-making units an input-oriented model under CRS assumption is written as follows:

$$\text{maximize } \theta_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} = \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}$$

$$\text{subject to } \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$u_r, v_i \geq 0$ for all r and i.

This equation maximizes the numerator for the observed unit, targeting to assign the highest possible productivity score. The denominator is set as 1, relating to Charnes and Cooper's transformation. The model above is rewritten algebraically as below:

$$\text{maximize } \theta_o = \sum_{r=1}^{s} u_r y_{ro}$$

$$\text{subject to } \sum_{r=1}^{s} u_r y_j \leq \sum_{i=1}^{m} v_i x_{ij}$$

$u_r, v_i \geq 0$ for all r and i.

The fractional form targets to find the set of coefficients (u's and r's) to give the highest possible efficiency ratios for the outputs and inputs of the decision-making units being evaluated, respectively.

In the model:

j : number of decision-making units (DMUs) being compared in data envelopment analysis

θ : efficiency score of the DMU being evaluated

y_{rj} : the amount of output r used by DMU_j

x_{ij} : the amount of input i used by DMU$_j$

i : number of inputs used by the DMUs

r : number of outputs produced by the DMUs

u_r : coefficient or weight assigned by DEA to output r

v_i : efficient or weight assigned by DEA to input i

The mathematical model becomes:

Objective function :

$$\text{maximize } \theta = \frac{u_1 y_{1o} + u_2 y_{2o} + ... + u_r y_{ro}}{v_1 x_{1o} + v_2 x_{2o} + ... + v_m x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

Maximizing the efficiency score θ for the DMU being evaluated (observed) is subject to the constraint to the same set of u and v coefficients. They are applied to all of other DMUs being compared; no DMU will be more than 100% efficient as follows:

$$\text{DMU}_1 = \frac{u_1 y_{11} + u_2 y_{21} + ... + u_r y_{r1}}{v_1 x_{11} + v_2 x_{21} + ... + v_m x_{m1}} = \frac{\sum_{r=1}^{s} u_r y_{r1}}{\sum_{i=1}^{m} v_i x_{i1}} \leq 1$$

…

$$\text{DMU}_o = \frac{u_1 y_{1o} + u_2 y_{2o} + ... + u_r y_{ro}}{v_1 x_{1o} + v_2 x_{2o} + ... + v_m x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \leq 1$$

…

$$\text{DMU}_j = \frac{u_1 y_{1i} + u_2 y_{2j} + ... + u_r y_{rj}}{v_1 x_{1j} + v_2 x_{2j} + ... + v_m x_{mj}} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$u_{1,},...,u_s \geq 0$ and $v_1,...,v_m \geq 0$

The fractional form is converted to a linear programming formulation as follows:

maximize $\theta_o = \sum_{r=1}^{s} u_r y_{ro}$

subject to $\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1,...,n$

$\sum_{i=1}^{m} v_i x_{io} = 1$

$u_{r,} v_i \geq 0$

The above weights formulation (also called "multiplier model") can be completed by using a duality structure. The second part of the linear programming is called envelopment model as follows:

minimize θ_o

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io} \qquad i = 1,...,m$

$\sum_{j=1}^{n} \lambda_j y_{ri} \geq y_{ro} \qquad r = 1,...,s$

$\lambda_j \geq 0 \qquad j = 1,...,n$

With applying a dual linear programming model, minimize θ subject to the constraint:

(a) The weighted sum of inputs of other DMUs besides the being evaluated is less than or equal to the inputs of the DMU observed.
(b) The weighted sum of outputs of other DMUs is greater than or equal to the DMU observed's. The weights are λ values(lambda).

The extension of the CRS DEA model may be adopted for VRS DEA situations, by adding a convexity constraint as follows:

minimize θ_o

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io} \qquad i = 1,...,m$

$\sum_{j=1}^{n} \lambda_j y_{ri} \geq y_{ro} \qquad r = 1,...,s$

$\lambda_j \geq 0 \qquad j = 1,...,n$

$\sum_{j=1}^{n} \lambda_j = 1 \text{(convexity constraint)}$

The convexity constraint helps us to calculate of technical efficiency with devoting effects of scale efficiencies $\lambda_j (j = 1,...,n)$ are non-negative scalars such that $\sum_{j=1}^{n} \lambda_j = 1$.

In this model of DEA, which is called BCC; input orientation is focused where inputs are minimized, and outputs are kept fixed at their current levels[7]. DMU_o represents the DMU under observation and x_{io}, and y_{ro} represent the i'th input and r'th output of the DMU observed, respectively. An extended version of previous models including slacks can be defined as follows, including two staged processes of DEA:

Input orientation:

$$\min \theta - \varepsilon \left(\sum_{r=1}^{s} s_{r^+} + \sum_{r=1}^{m} s_{i^-}\right)$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = \theta x_{io} \qquad i = 1,...,m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = y_{ro} \qquad r = 1,...,s;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad j = 1,...,n$$

λ_j represents non-negative scalars, s_{r^+} and s_{i^-} represent slacks and $0 < \varepsilon$ which is non-Archimedean infinitesimal that is smaller than any positive real number.

DMU is efficient if and only if $\theta^* = 1$ and (or) $s_{i^-}* = s_{r^+}* = 0$ for all i and r (all slacks are zero) "*" mark represents the optimal values.

DMU_o is weakly efficient if $\theta^* = 1$ and (or) $s_{r^+}* \neq 0$ for some i and r.

Output orientation:

$$\max \phi + \varepsilon \left(\sum_{r=1}^{s} s_{r^+} + \sum_{r=1}^{m} s_{i^-}\right)$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = x_{io} \qquad i = 1,...,m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = \phi y_{ro} \qquad r = 1,...,s;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad j = 1,...,n$$

λ_j represents nonnegative scalars, s_{r^+} and s_{i^-} represent slacks and $0 < \varepsilon$ which is non-Archimedean infinitesimal that is smaller than any positive real number.

DMU is efficient if and only if $\phi^* = 1$ and $s_{i^-}* = s_{r^+}* = 0$ for all i and r (all slacks are zero) "*" mark represents the optimal values.

DMU_o is weakly efficient if $\phi^* = 1$ and $s_{i^-}* \neq 0$ and (or) $s_{r^+}* \neq 0$ for some i and r .

With the help of non – Archimedean ε, the minimization over for the input-oriented model and maximization over for the output-oriented model, is maintained. At the first stage of the two-stage process, maximal reduction of inputs and maximal augmentation of outputs is achieved respectively: via $\theta*$ and $\phi*$.

At the second stage movement onto the efficient frontier is achieved via slack variables.

Both input-oriented model and output-oriented model identify the same frontier.

$\theta* \leq 1$ *and* $\phi* \geq 1$ and $\theta* = 1$ if and only if $\phi* = 1$. Also $\theta* = 1/\phi*$ for the optimal solutions.

3.5 Extensions of Data Envelopment Analysis

3.5.1 Slack-Based Model

Proportional input reductions by keeping outputs at a fixed level is called input-oriented DEA model. Proportional output augmentations by keeping inputs at a fixed level is called output-oriented DEA model. Making these increases and decreases simultaneously, was the idea of the study made by Charnes, Cooper, Colony, Seiford and Stutz et al. (1985) [10].

Assuming the vector of inputs for n set of DMUs as:

$$X^j = \{x_{ij}, i = 1,2,...,m\}$$

Moreover, vector of outputs for n set of DMUs as:

$$Y^j = \{y_{ij}, i = 1,2,...,r\}$$

can be written for DMU_j .

These equations let x become (m,n) the matrix of inputs and y become (r,n) the matrix of outputs.

The DMU under evaluation for efficiency evaluation DMU $_o$, $o \in \{1,2,\ldots,n\}$ targets to reach virtual unit with inputs and outputs defined by weighted sum of inputs and outputs of other units as: $X\lambda$ and $Y\lambda$.

where $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_n), \lambda > 0$.

λ Is the vector of scalar or weights.

A linear formulation can be written as follows for targeting virtual units:

minimize θ

subject to $Y\lambda \geq y^o$

$X\lambda \leq \theta x^o$

$\lambda \geq 0$

when a virtual unit becomes identical with the observed unit, DMU is considered to be efficient.

Formulated such as:

$Y\lambda = y^o, X\lambda = x^o$ and $z = \theta = 1$

A new formulation including slack variables can be written as follows:

minimize $z = \theta - \in (e^T s^+ + e^T s^-)$

subject to $Y\lambda - s^- = y^o$

$X\lambda + s^+ = \theta x^o$

$\lambda \geq 0$

where $e^T = (1,1,\ldots,1)$ is a vector of ones and $\in$ is an infinitesimal constant.

The variables s^+ and s^- are slack variables and represent differences to reach optimal values.

If we let optimal values as $\hat{x}_o$ and $\hat{y}_o$ then new equations including slacks would be:

$$\hat{x}_o = x_o - s^{-*}$$

$$\hat{y}_o = y_o + s^{+*}$$

By this theorem an improvement projection can be made as follows:

$$\hat{x}_o \Leftarrow x_o - s^{-*}$$

$$\hat{y}_o \Leftarrow y_o + s^{+*}$$

$(\hat{x}_o, \hat{y}_o)$ also serves as the coordinates of the points on the efficient frontier used to evaluate DMU observed.

A slack based model made by Charnes, Cooper, Golany, Seiford and Stutz (1985) [10] is as follows:

$$max \sum_{j=1}^{m} s_{i^-} + \sum_{r=1}^{s} s_{r^+}$$

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = x_{io} \qquad i = 1,...,m;$

$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = y_{ro} \qquad r = 1,...,s;$

$\lambda_j, s_i^-, s_r^+ \geq 0$

including non-zero input and output slacks.

Ali , Lerme and Seiford et al. (1995) [4] made a CRS frontier type modification to this model,as follows:

$$max \sum_{i=1}^{m} w_i^- s_i^- + \sum_{r=1}^{s} w_r^+ s_r^+$$

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = x_{io} \qquad i = 1,...,m;$

$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = y_{ro} \qquad r = 1,...,s;$

$\lambda_j, s_i^-, s_r^+ \geq 0$

w_i^- and w_r^+ are specific weights applied by user's value judgement. Observed DMU is considered as efficient if and only if optimal values are equal to zero.

Slack based measure of efficiency is evaluated by K.Tone et al. (2002) [48] assigning an index as follows:

$$\rho = \frac{1 - 1/m \sum_{i=1}^{m} s_i^- / x_{io}}{1 - 1/s \sum_{r=1}^{s} s_r^+ / y_{ro}}$$

This index is reached by using the amounts of slacks and has a value between 0 and 1. The slack based measure of efficiency (SBM) is conducted from the linear model below:

$$\text{minimize} \quad \rho = \frac{1 - 1/m \sum_{i=1}^{m} s_i^- / x_{io}}{1 - 1/s \sum_{r=1}^{s} s_r^+ / y_{ro}}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = x_{io} \qquad i = 1,...,m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = y_{ro} \qquad r = 1,...,s;$$

$$\lambda_j \geq 0 \qquad \mathrm{j} = 1,..., \mathrm{n}$$

$$\lambda_j, s_i^-, s_r^+ \geq 0$$

A DMU (x_o, y_o) is CCR efficient if and only if it is SBM efficient (Tone 1997) [47]. SBM efficiency score is smaller than CCR efficiency score. SBM efficiency scores range in between 0 and 1. $\rho^* = 1$ implies a full efficiency situation where all slacks are zero and the DMU locates on the efficient frontier.SBM is also units invariant.

3.5.2 Measure Specific Model

The assumption of data envelopment analysis does not need a priori assumption or information when a preference set is chosen for the evaluation process.

With relevant subsets of inputs and outputs as $I \subseteq \{1,2,...,m\}$ and $O \subseteq \{1,2,...,s\}$ measure specific data envelopment model can be applied to only preferred underlying subsets associated with I and O.

A measure specific model developed by Joe Zhu et al. (2000) [56] for CRS pattern can be seen in the formulation as follows:

Input-oriented:

$$\min \theta - \varepsilon \left(\sum_{r=1}^{s} s_{r^+} + \sum_{r=1}^{m} s_{i^-}\right)$$

subject to
$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = \theta x_{io} \qquad i \in I$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = x_{io} \qquad i \notin I$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = y_{ro} \qquad r = 1,\ldots,s;$$

$$\lambda_j \geq 0 \qquad \mathrm{j} = 1,\ldots,\mathrm{n}$$

add convexity constraint

$$\text{VRS} \qquad \sum_{j=1}^{n} \lambda_j = 1$$

Projection for reaching efficient frontier is formulated as:

$$\hat{x}_{io} = \theta^* x_{io} - s_i^{-*} \qquad i \in I$$

$$\hat{x}_{io} = x_{io} - s_i^{-*} \qquad i \notin I$$

$$\hat{y}_{io} = y_{ro} + s_r^{+*} \qquad \mathrm{r} = 1,\ldots,\mathrm{s}$$

where $(\hat{x}_o, \hat{y}_o)$ also serves as the coordinates of the points on the efficient frontier used to evaluate DMU observed.

A measure specific model developed by Joe Zhu et al. (2000)[56] for CRS pattern can be seen as formulation below:

Output oriented:

$$\max \phi - \varepsilon \left(\sum_{r=1}^{m} s_{i^-} + \sum_{r=1}^{s} s_{r^+}\right)$$

subject to
$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = x_{io} \qquad i = 1,2,\ldots,m:$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = \phi r_{ro} \qquad r \in O$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_{r^+} = y_{ro} \qquad r \notin O$$

$$\lambda_j \geq 0 \qquad \mathrm{j} = 1,\ldots,\mathrm{n}$$

add convexity constraint

$$\text{VRS} \qquad \sum_{j=1}^{n} \lambda_j = 1$$

Projection for reaching efficient frontier is formulated as:

$\hat{x}_{io} = x_{io} - s_i^{-*}$ $\quad i = 1,2,...,m$

$\hat{y}_{ro} = \phi y_{ro} + s_r^{+*}$ $\quad r \in O$

$\hat{y}_{ro} = y_{ro} + s_r^{+*}$ $\quad r \notin O$

where $(\hat{x}_o, \hat{y}_o)$ also serves as the coordinates of the points on the efficient frontier used to evaluate DMU observed.

3.5.3 Returns to Scale

The constant returns to scale assumption that has been studied in the previous sections is only appropriate when all DMUs are operating at an optimal scale. Imperfect competition, constraints on finance are some of the obstacles for DMUs in reaching optimal scales (Tim Coelli,1996)[46].

An extension of CRS DEA model was made by Banker, Bardhan, and Cooper et al. (1994)[37] under VRS concept. VRS calculations of technical efficiency (TE) would devoid scale efficiency (SE) effects.

A linear programming adopts CRS to VRS by adding a convexity constraint as follows:

$\min_{\theta,\lambda} \theta$

subject $\quad -y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$N1\lambda = 1$

$\lambda \geq 0$

where $N1$ is $Nx1$ vector of ones (1).

Theorem :

i. The CRS efficiency score is equal to the VRS efficiency score if and only if there is an optimal solution. If CRS efficiency score is not equal to VRS efficiency score then;

ii. If DMU $_o$ exhibits IRC(increasing returns to scale), then $\sum_{j=1}^{n} \lambda_j^* \leq 1$ for all alternative optimals.

iii. If DMU $_o$ exhibits DRS(decreasing returns to scale) then $\sum_{j=1}^{n} \lambda_j^* > 1$ for all alternative optimal.

If we replace convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ with $\sum_{j=1}^{n} \lambda_j^* \leq 1$ then a non- increasing returns to scale (NIRS) pattern can be seen.

If we replace convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ with $\sum_{j=1}^{n} \lambda_j^* \geq 1$ then a non -decreasing returns to scale (NDRS) pattern can be seen.

Both situations are depicted in figures below:

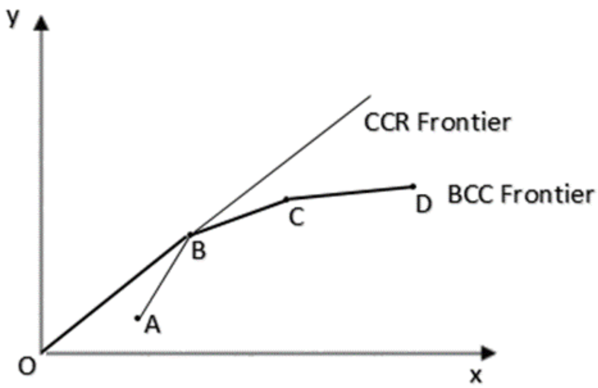


Figure 3.6: Non-increasing Returns to Scale

In figure 3.4 NIRS consists of DMU's B, C, D, and origin.

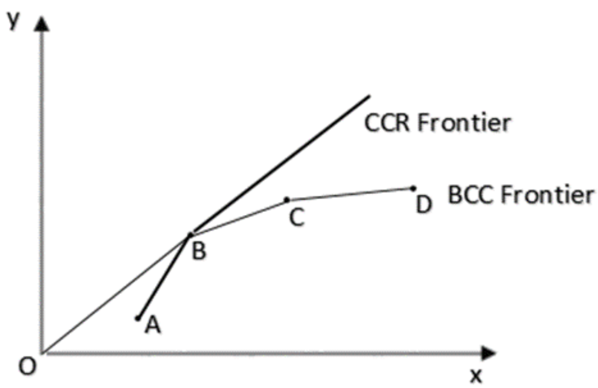


Figure 3.7: Non-decreasing Returns to Scale

In figure 3.5 NDRS consists of DMU's A, B and the section starting from B.

3.5.4 Additive Model

In a BCC model or a CCR model, a distinction between input and output orientations is required. However, an additive model combines both orientations. This model simultaneously maximizes outputs and minimizes inputs. A goal vector approach was made by Thrall et al. (1990) [39]as follows:

$$\max_{\lambda,s^-,s^+} = \sum_{i=1}^{m} g_i^- s_i^- + \sum_{r=1}^{s} g_r^+ s_r^+$$

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} + s_{i^-} = x_{io}$ $\quad i = 1,2,...,m$:

$$\sum_{j=1}^{n} \lambda_j y_{rj} + s_{r^+} = y_{ro} \qquad r = 1,...,s$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j, s_i^-, s_r^+ \geq 0$$

Slack measures are attained as goal weights that are ensured not to affect the optimal solution choices.

A DMU is evaluated as efficient if and only if all slacks are zero. For converting a dual (multiplier) model we first replace the projections as written below:

$$\hat{x}_{io} = x_{io} - s_i^{-*} \qquad i = 1,...,m$$

$$\hat{y}_{ro} = y_{ro} + s_r^{+*} \qquad r = 1,...,s$$

s_i^{-*} and s_r^{+*} are the slacks of the primal model. Converting to a dual (multiplier) model we reach a linear program as follows:

$$\min_{v,u,u_o} = \sum_{i=1}^{m} v_i x_{io} - \sum_{r=1}^{s} u_r y_{ro}$$

subject to $\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} + u_o \geq 0$ $\quad j = 1,...,n$

$v_i \geq g_i^-, u_r \geq g_r^+ : u_o$ free

where the variable u_o is used to evaluate returns to scale.

Inefficient DMUs can be improved by additive model projections as stated in models above. The figure 3.8 below shows how the additive model combines both input and output orientations simultaneously.

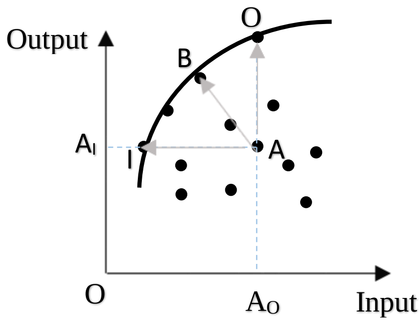


Figure 3.8: Projection of an Inefficient Unit by Additive Model

O: projection with the output oriented-model

I: projection with the input- oriented model

B: projection with the base-oriented model

Translation invariance property was employed in handling lost or negative data as well as profits or positive data. Given any problem, a DEA model is said to be translation invariant if translating the original input and/or output data value results in a new problem. This new problem has the same optimal solution for the envelopment form as the old one. Efficiency evaluations are coordinate independent on the unit of measurement of each input and output. Additive model is translation invariant in opposition to input and output oriented models that are only output and input translation invariant respectively. This condition is valid when the convexity assumption is kept.

The translation in the BCC model and the Additive model can be illustrated as below:

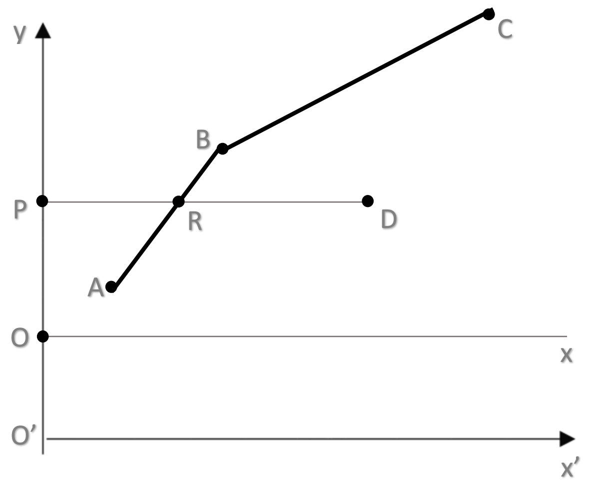


Figure 3.9 : Translation in the BCC Model

In Figure 3.9. above the BCC efficiency is PR/PD. Eventhough the origin is shifted from O to O' this ratio stays still thus translation invariant with respect to outputs. Similar reasoning can be made for an output-oriented model with respect to inputs vice versa.

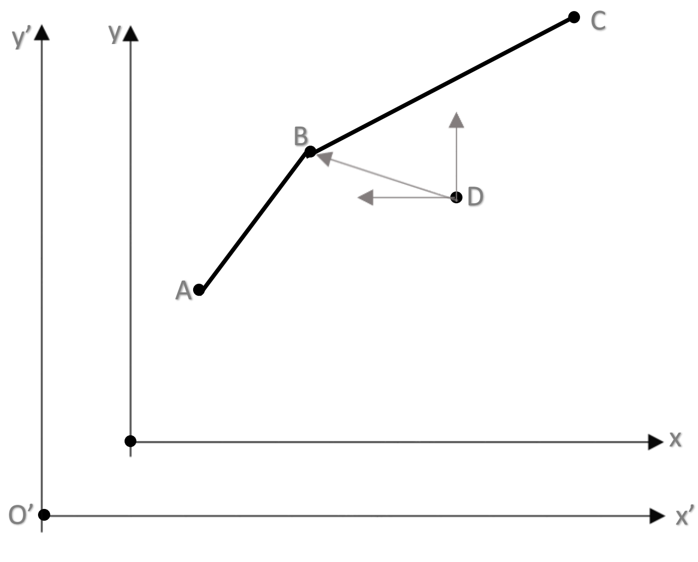


Figure 3.10: Translation in the Additive Model

In Figure 3.10 above the efficiency ratio is independent of the origin of coordinates therefore translation invariant in both inputs and outputs.

Comparison of DEA Models

Table 3.1. is a brief comparison for the DEA models used in the measurements. This comparison was adapted from W.Cooper's study in 2007[54]. Orientation section tells us if the model concern is input or output orientation targeting input reductions and output augmentations respectively. In the Add.(Additive) and SBM(Slack-Based Model) sections, there are no input or output orientations. The "S.P." Notation of Data section stands for the Semi-Positive where at least one of the data is positive. "Free" term is used for negative, positive and zero values. Θ*, Φ* are the efficiency scores for input oriented models and output oriented models respectively. In Returns to Scale section "CRS" denotes Constant Returns to Scale and "VRS" denotes for the Variable Returns to Scale. For the Additive and Slack-Based models this situation depends on the convexity constraint.

Table 3.1: Comparison of DEA the Models

Model	**CCR**	**BCC**	**ADD**	**SBM**	**Measure Specific**	**Returns to Scale**
Orientation	Input, Output	Input, Output	None	None	Input, Output	Input, Output
Data	S.P. Free	S.P. Free	Free Free	S.P. Free	S.P. Free	S.P. Free
Θ*,Φ*	[0,1]	[0,1]	None	[0,1]	[0,1]	[0,1]
Units Invariance	Yes	Yes	No	Yes	Yes	Yes
Returns to Scale	CRS	VRS	CRS VRS	CRS VRS	CRS VRS	CRS VRS

3.6 Advantages and Disadvantages of the DEA

DEA has fostered to debate revealing hidden points. Those points are not explained by classic approaches like regression analysis and stochastic frontier analysis. The advantages and disadvantages of DEA are categorized as follows:

ADVANTAGES

1. DEA can handle complex processes which include multiple inputs, multiple outputs and DMUs. These inputs and outputs can be not controlled by the DMU, in other words, they are exogeneous. DEA is unit invariant thus, inputs and outputs may vary in units of measurement.
2. Regarding to the results of efficiency measures, management can implement further improvements and savings. Management support and expertise can be transferred to those units relatively inefficient.
3. Dual structure is used; therefore, the analyst can simply adjust the DEA method according to his/ her purpose.
4. Optimal results are conducted, rather than the averages. DEA identifies best practice units as benchmarks. DEA deals with empirical efficiency results based on observed decision-making units. Therefore, no theoretical predictions are used. A priori assumption is not required for relating inputs to outputs. In other words, building a functional form is not needed as a precondition.
5. DEA is applicable from the entire organization to the smallest sub-units and departments in an identical way. Therefore, this method creates a uniform ranking and comparison framework for various DMUs.

DISADVANTAGES

1. By using the DEA no absolute efficiency is reached. Moreover, a relative efficiency is conducted among peer groups. There is no room to test the best performnce.
2. Only a few factors have significant power to affect the total efficiency scores.
3. DEA evaluates optimal ways; whereas no random mistakes are assumed.
4. High correlations among variables may mislead the analyst.
5. The results heavily depend on the selection criteria of input and output variables and leave open room for manupilations.

Questions answered by DEA are as follows including Fried, Lovell and Schmidt's statements (1994)[24]: 1.How do I select appropriate role models for the performance improvements?, 2.Which production facilities are the most efficient ones among the DMUs?, 3.What are the amounts of input reduction/output augmentation to reach efficient frontier?, 4.What is an optimum scale for operations?, 5.What are the “benefits of doubt” for each unit being evaluated, trying to make it look as efficient as possible in comparison with another unit? [41]

3.7 DEA Studies in Brewing Industries

Literature Review

The strengths of DEA have inspired many scholars use this method in various studies. The applications of DEA are used mainly in the banking industry. Applying DEA on brewing industries is getting more common because this method is advantegous in analyzing multiple decision-making units and multiple input/output combinations. In this section we make a brief literature review on two groups of studies. The first group is DEA studies in brewing industry and the second group is DEA studies in other industries or studies in brewing (with no DEA approach). This research was inspired and built on by combining these two group of studies.

Ralf Färe, S.Grosskopf, Barry J.Seldon and Victor J.Tremblay et al.(2003) use techniques from the efficiency measurement literaure, specifically DEA. The performance of six U.S. beer firms were evaluated regarding translating their advertising messages into sales. Anheuser-Busch, the biggest in scale, was also the most efficient in advertising and choice of the media mix. This paper created a technique using DEA to estimate overall cost efficiency in advertising and optimal media mix. The mixture of media messages included television, radio and print. The evaluations were made at corporate level rather than the industry level. The study addresses two issues such as: determining each firm’s overall level of advertising efficiency and correlation between this efficiency and its overall success.

Regarding the second group of studies, a research was made by J.Tremblay and N.Iwasaki et al.(2009)[33] to evaluate the effects of regulations on efficiencies. U.S. tobacco industry is imperfectly competitive and intensely advertised. The industry is far stipulated by drastic regulations, bans and restrictions made by the government. This study finds out the answer if the bans and regulations have predatory or coordinative effects over the firms. The inseparability assumption of marketing and production functions is used. In the industries with frequent introductions of new products, production and marketing departments should work collaboratively. They separated the background of the industry into regimes shaped by the regulations. The allocative and technical efficiencies are compared within these regimes.

Allocative efficiencies are positively effected by regulations. In hostile industries where competitors steal from each others' customer base using predatory advertising the government intervention may result in coordinative ways.

Many studies mostly in banking industires, used two staged models introduced in Chapter 4. Dauw-Song Zhu, Al Y.S.Chen, Yi-Kang Chen and Wei Hsin Cheng[16] used a two-staged module on 14 Taiwanese banks. The outputs of the first stage treat as inputs to the second stage in other words as intermediatery variables. In this study, CCR and BBC models were used to analyze, the overall efficiency, pure technical efficiency, and scale efficiency scores of banks. Related literature using two staged models to measure DEA efficiencies are listed in Table 3.2 as follows.

In another study, Kekvliet et al. (1998) [27] estimated an industry production function by expanding samples from 1950 to 1995 for the U.S. brewing industry. A ray-homothetic functional form was used with the decomposition of factors of production as input variables. These variables consist of labor (L),materials (M) and, capital(K) inputs. The study conducted results for the relationship between regimes and marginal products. The marginal products of inputs grew in the later periods, which was explained by the presence of technological changes in the brewing industry.

The first introduction of time-dependent use of DEA known as "Window Analysis" was made by G.Klopp et al. (1985)[22]. He developed techniques for the U.S. Army Recruiting Command, which recruits for the entire United States. By dividing U.S. into 5 regimes and 56 "Recruiting Batallions" various forms of DEA were applied. However conventional time series analysis of efficiency scores and statistical regression analysis were not satisfactory. The requirement in the form of trend analysis led him create Window Analysis.

Table 3.2: Summary of Related Literature Based on the Two-staged DEA Models

Authors	Samples	Input Variables	Intermediary Variables	Output Variables
Seiford and Zhu(1999)	Top 55 US commercial banks	• Assets • Employees • Stockholders' equity	• Revenues • Profits	• EPS • Market value • Total return to investors
Luo(2003)	245 US large banks	• Assets • Employees • Stockholders' equity	• Revenues • Profits	• EPS • Market value • Stock price
Ho and Zhu(2004)	41Taiwan commercial banks	• Assets • Branches and employees • Capital stock	• Deposits • Sales	• Net income • Interest income • Non-interest income
Lo and Lu(2006)	14 Taiwan FHCs	• Assets • Employees	• Revenues • Profits	• EPS • Market values
Howang and Kao(2006)	24 Taiwan's non-life insurance	• Stockholders' equity • Business and administrative expenses • Commission and acquisition expenses	• Direct pensions wrote • Reinsura nce premiums received	• Stock price • Net underwriting income • Investment income

Economies of scope concept were brought for the use of DEA by Baumol et al. (1982)[50]. Baumol defined economies of scope in terms of a firm that reaches to a lower cost level by producing two different products together rather than separately. The degree of economies of scope was conducted by a formula using production costs of the diversified firm and respective costs of specialized firms. A similar comparison of the two case can be applied to this research. These scenarios are categorized as: production of multiple products by one diversified firm or production of each of these products by different specialized firms.

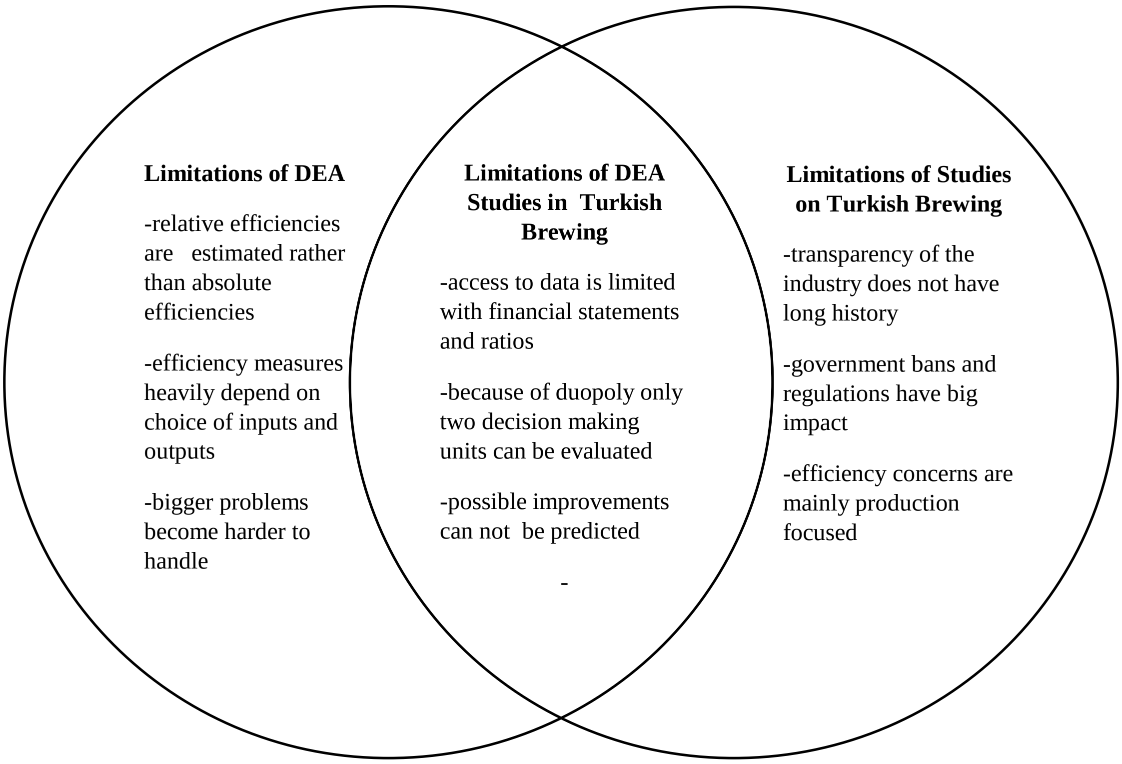
Färe, Grossopf and Lowell et al.(1994) [38] introduced a model to conduct capacity utilization of an organization under the constant returns to scale assumption. These utilizations can be derived by either measure of technical capability or a measure of price based capacity. In their model capacity utilization deals with situations where some inputs are fixed and can not be altered flexibly while some can be. This study divided inputs into fixed and variable sub-categories and conducted efficiency scores for each category.

Despite countless of studies on DEA and beer industries, Turkish brewing industry had limited research on both topics. These studies did not pick DEA methodology, yet used strategical approaches. A.Hamdi Demirel and Fred Miller et al. (1983)[21] examined Turkish beer market under firms' competitive strategies. Their work separated Turkish beer industry into regimes that shaped by government regulations and bans. Success of Efes was studied at the main interest as the market leader. Several lessons were taken for marketing consumer goods like beer in developing countries. Another study was made by Cemhan Ozguven as thesis of his graduate course et al.(2004)[9]. He examined demand and pricing policies in Turkish beer market and whether these policies were efficient or not.

3.8 Limitations of the Research

During this research we encountered some obstacles due to the characteristics of DEA, brewing industry in a general perspective and Turkish brewing industry in a narrower perspective. The limitations of current approaches are addressed as follows:

Figure 3.11: Limitations of the Research



Chapter 4

Models Used in DEA Efficiency Measurements

In this chapter, we introduce the models used in DEA efficiency measurements of Turkish brewing industry. The models are either designed by researcher or adapted from earlier studies of various scholars. Each model carries a specific objective for measuring DEA efficiency scores of the DMUs observed. Eventhough we execute the two staged profitability-marketability and the productivity models in efficiency measurements,it may be useful to introduce further models for the future studies.

4.1 Two Staged Profitability- Marketability Model

We apply a specific two-staged model which includes profitability and marketability functions. The model is adapted from earlier studies mainly made in banking industries. This model was used for a performance measurement of Fortune 500 companies at a corporate level. The output variables from the profitability stage serve as input variables to the marketability stage, in other words, they treat as intermediary. The profitability stage targets to view, abilities of companies to generate revenues and profits.

Total assets (excluding financial investments and investment properties), stockholders' equity and total number of all employees, serve as input variables in stage 1. Revenue and profits from the operations serve as outputs in stage 1 and as inputs in stage 2 of the iterative process. The second stage is called "marketability". In this stage, we target to identify companies' stock market performances using their revenues and profits. At the marketability stage revenues and profits from the operations serve as input variables; earnings per share(EPS), average stock price, return on invested capital (ROIC) and net income serve as outputs.

We construct a two staged profitability-marketability model as follows:

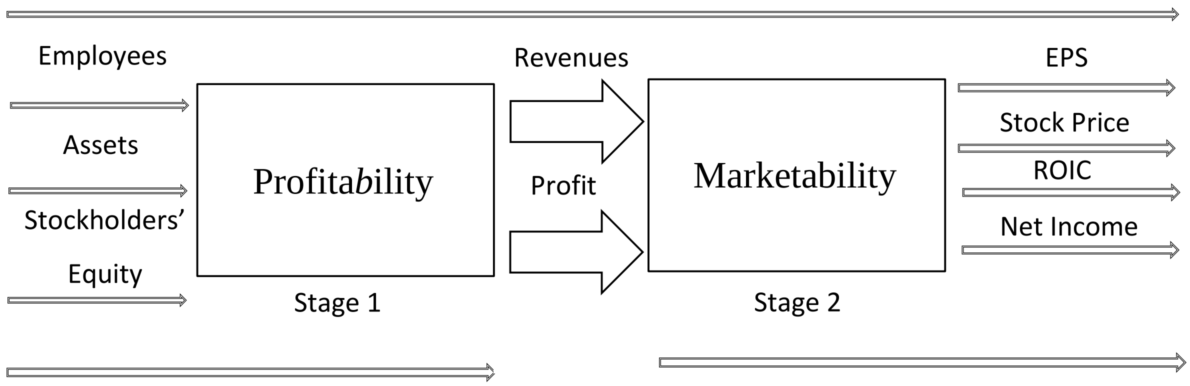


Figure 4.1:Two Staged Profitability-Marketability Model

4.2 Productivity Model

In industries like consumer goods, for products like beer, both production and marketing functions are inseparable from sales. Mass beer producers like Anadolu Efes and Turk Tuborg, frequently introduce new products. Therefore, production and marketing functions should not treat separately. Moreover, under inseparability assumption close coordination is required between marketing and production divisions. Customers should frequently be informed about new products. With the help of this coordination, greater demand uncertainties and unexpected increases in inventories can be eliminated.

Under inseparability assumption of marketing and production technologies,we construct the productivity model illustrated as follows:

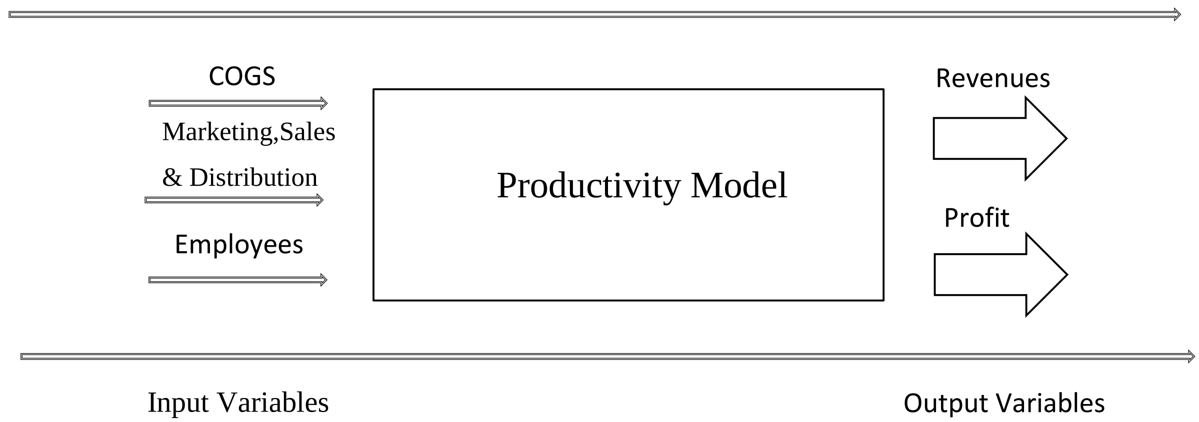


Figure 4.2: Productivity Model

The lack of private cost information alternates us using public data from corporate financial statements. Cost of goods sold (COGS), the number of employees and marketing, selling & distribution expenses treat as input variables; profit from the operations and revenues treat as output variables at this stage.

With this model we aim to evaluate how efficient the coordination is, in using production and marketing technologies collaboratively.

4.3 Suggested Models for Further Studies

In this section we introduce additional models applicable for further studies in DEA efficiency measurements as below:

Production Function Model

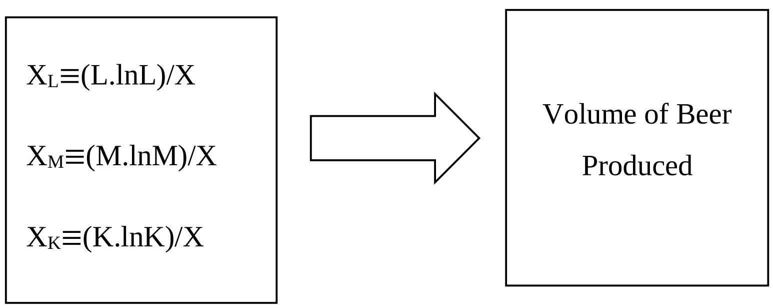
We use this model which focuses on factors of production to calculate DEA efficiency scores. On the contrary to productivity model,we exclude coordination effect of marketing function (separability assumption) and adapt the work of Kervliet et al. (1998)[27] in prepration of the input variables. This model sets labor(L), materials(M) and capital (K) as inputs which are estimated by ordinary least squares. Factors of production cost function can be generated as below:

$$C(y, w_K, w_L, w_M) = \min\{w_K x_K : x_K \; can\ produce\ \mathrm{y}\} + \min\{w_L x_L : x_L \; can\ produce\ \mathrm{y}\} + \min\{w_M x_M : x_M \; can\ produce\ \mathrm{y}\}$$

(4.1)

where y is output, x_K is a vector of capital (K) inputs, w_K is a vector of capital (K) input prices; x_L is a vector of labor (L) inputs, w_L is a vector of labor (L) input prices; x_M is a vector of materials (M) inputs, w_M is a vector of materials (M) input prices.

We construct the production function model as below:



where X≡ (L+M+K)

Figure 4.3: Production Function Model

Production function includes mainly three inputs as stated above labor, capital, and materials under assumption of no changes in technologies.

Labor (L): Labor inputs include all production and non-production employees. Hospitality and retail sectors are stimulated positively with jobs created by the brewing industry. However, in this research, we only use direct employment subject to labor input variables. In general, the brewing industry has high productivity of employees [49]. The brewing sector's value-added arises from the production and sale of beer 45%, which is much higher than its share in total employment from beer (4.5%). Recently, labor is replaced by capital because of the decline in overall employment due to labor-saving technology changes.

Capital(K): Inputs of capital include assets and exclude investment activities (financial investments and investment properties) of financial sheets. Brewing equipment depreciates slowly, fixed, and sunk costs are high in brewing. According to the financial statements almost no R&D expenditures are made by beer producers. Technical advances from outside the industry are used for benefits (i.e.: fast scanning lines, effective foaming).

Materials(M): Beer is made from four ingredients: water, hops, yeast and grains. Cereal grains include malted barley, corn, rice, wheat. Usage of materials' inputs may vary according to the trends and customers' preferences. The market leader, Efes captured its leading position by identifying customers' complaints about Tekel beer. It was the flagship brand of a government monopoly entity under the same name. Eventhough customers liked Tekel's taste; they wanted more consistency, higher alcohol content, and thicker foam. As a response, Efes brewed a slightly higher alcohol level (4.2 percent to Tekel's 3.8 percent) with more foam (see Chapter 1).

Marketing Function Model

Eventhough marketing has no significant effect on overall demand in saturated beer markets; a capturing effect can be seen among the two competitors. Efes may capture from Tuborg's customer portfolio and Tuborg from Efes' customer portfolio. An inverse demand function is used to evaluate marketing estimates as input variables as follows:

$$P_{t,EFES} = \beta_0 + \beta_1 q_{t,EFES} + \beta_2 q_{t,Others} + \beta_3 A_{t,EFES} + \beta_4 A_{t,Others} + \beta_5 Inc + \beta_6 Dem_t + e_{t,EFES}$$

where $P_{t,EFES}$ is the average price of Efes' flagship brands in period t, $q_{t,EFES}$ is Efes' total output of beer production, $q_{t,Others}$ is combined output of other brewers including Tuborg, $A_{t,EFES}$ is Efes' expenditures for advertising and promotions, $A_{t,Others}$ are combined expenditures for advertising and promotions of other companies, Inc is disposable income, Dem_t is demographic variable and $e_{t,EFES}$ is an error term.Same model is applied on Tuborg as follows:

$$P_{t,TUBORG} = \beta_0 + \beta_1 q_{t,TUBORG} + \beta_2 q_{t,Others} + \beta_3 A_{t,TUBORG} + \beta_4 A_{t,Others} + \beta_5 Inc + \beta_6 Dem_t + e_{t,TUBORG}$$

where $P_{t,TUBORG}$ is the average price of Tuborg's flagship brands in period t, $q_{t,TUBORG}$ is Tuborg's total output of beer production, $q_{t,Others}$ is combined output of other brewers including Efes, $A_{t,TUBORG}$ is

Tuborg's expenditures for advertising and promotions $A_{t,Others}$ are combined expenditures for advertising and promotions of other companies, Inc is disposable income, Dem_t is demographic variable and $e_{t,TUBORG}$ is an error term.

The parameters for the advertising variables (β_3 in both demand functions) and "Marketing, sales, and distribution" item from the financial statements treat as inputs, revenues and profit treat as outputs to the marketing function model. We evaluate the efficiency of the observed DMU's marketing and advertising activities in competition with rivals and the entire market.

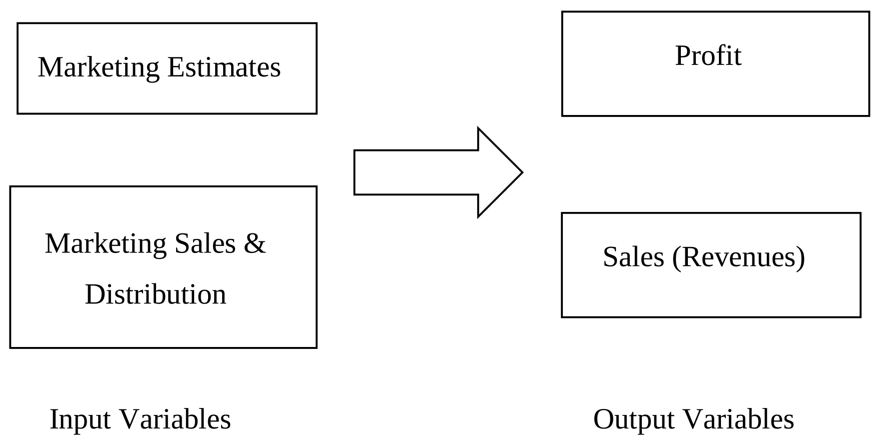


Figure 4.4: Marketing Function Model

Economies of Scope vs. Scale Efficiency

Economies of scope between two products (y_1, y_2) were defined by Baumol et al. (1982)[50]. If in specialized firms, the cost of producing both products jointly together is less than the cost of producing them separately a formulation will emerge as follows:

$$C(y_1, y_2) < C_1(y_1, 0) + C_2(0, y_2) \tag{4.2}$$

where $C(y_1, y_2)$ is the cost of joint production by the diversified firms like Efes and Tuborg, and $C_1(y_1, 0)$ $C_2(0, y_2)$ are the costs of producing y_1 and y_2 by two specialized firms.

The degree of economies of scope (DES) for firm j can be formulated as follow:

$$DES_j = \frac{C_1(y_1,0) + C_2(0,y_2) - C(y_1,y_2)}{C(y_1,y_2)} \tag{4.3}$$

DES_j >0 is the situation where firm j exhibits economies of scope, DES_j <0 exhibits diseconomies of scope and DES_j =0 is the situation where costs are additive.

In this model, economies of scope evaluation for both companies are evaluated under a comparative approach. Four types of firms are subject to our measurements such as: beer(only) producers, canning and bottling firms, malt producers and diversified firms are represented by Efes and Tuborg. The following scheme shows on input and output flows for our model:

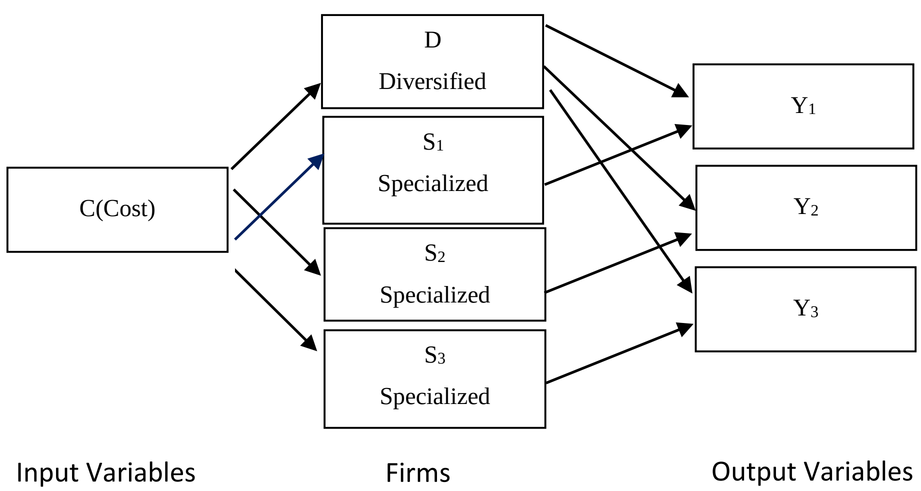


Figure 4.5: Economies of Scope Model

where cost is represented by COGS (Cost of Goods on Sales) of financial statements for the observed firms and outputs y_1,y_2,y_3 represent volume produced and sales generated. The initial D represents diversified firms like Anadolu Efes and Turk Tuborg that are jointly producing beer, malt and have bottling & canning lines and facilities. Initials S_1, S_2, and S_3 respectively represent specialized firms which produce only beer or malt or operate in bottling and canning.

Technical Capacity Utilization

Some of the input resources are fixed that are irreplaceable while some are variable that are flexibly replaceable.With the set of observed DMUs given as:

$\{(x_i^F, x_i^V, y_j)\}$ $(j = 1,\ldots,n)$ the efficiency evaluation using output oriented non-radial model is described as follows [47]:

$[SBM_o - \text{Restricted}]$

$$\phi^* = \max_{\lambda, s^+} \left(1 + \frac{1}{s} = \sum_{r=1}^{s} \frac{s_r^+}{y_{ro}} \right)$$

subject to

$$x_{io}^F \geq x_{i1}^F \lambda_1 + \ldots + x_{in}^F \lambda_n (1 = 1,\ldots, f)$$

$$x_{io}^V \geq x_{i1}^V \lambda_1 + \ldots + x_{in}^V \lambda_n (1 = 1,\ldots, v) \tag{4.4}$$

$$y_{ro} = y_{r1} \lambda_1 + \ldots + y_{rn} \lambda_n - s_r^+ (r = 1,\ldots, s)$$

$$1 = \lambda_1 + \ldots + \lambda_n, \lambda_j \geq 0 (\forall j), s_r^+ \geq 0 (\forall r).$$

we now relax the model (4.4) by deleting constraints of variable input values and the model is yielded as follows:

$\left[SBM_o - \text{Relaxed}\right]$

$$\phi_F{*} = \max_{\lambda, s^+}\left(1 + \frac{1}{s} = \sum_{r=1}^{s}\frac{s_r^+}{y_{ro}}\right)$$

subject to

$$x_{io}^F \geq x_{i1}^F\lambda_1 + \ldots + x_{in}^F\lambda_n\left(1 = 1, \ldots, f\right) \tag{4.5}$$

$$y_{ro} = y_{r1}\lambda_1 + \ldots + y_{rn}\lambda_n - s_r^+\left(r = 1, \ldots, s\right)$$

$$1 = \lambda_1 + \ldots + \lambda_n, \lambda_j \geq 0(\forall j), s_r^+ \geq 0\left(\forall r\right).$$

A capacity utilization measure is defined by using optimal solutions as follows:

$$\kappa_o^* = \frac{\phi{*}}{\phi_F{*}}\left(\leq 1\right) \tag{4.6}$$

where $\phi{*}$ is efficiency score including fixed and variable inputs, and $\phi_F{*}$ is efficiency score relaxed by deleting variable inputs. This ratio was introduced by Färe, Grosskopf, and Lowell et al. 1994[38] as Plant Capacity Utilization measure of the DMU observed. In our calculations, we collect fixed and variable expense inputs from financial statements of Efes and Tuborg. These variables can be categorized as follows:

Variable expenses(inputs): COGS (Cost of Goods Sold), commissions paid to salespeople on their sales, franchise fees based on total sales for the period, transportation costs in delivering products to the customers via shipping agencies and fees that a retailer pays when a customer uses a credit card.

Fixed expenses (inputs): Gas and electricity cost, employees' salaries and benefits, real estate property taxes, annual audit fee, general liability and directors insurance premium. Under DEA approach and with the use of variables above we construct a model for technical capacity utilization as follows:

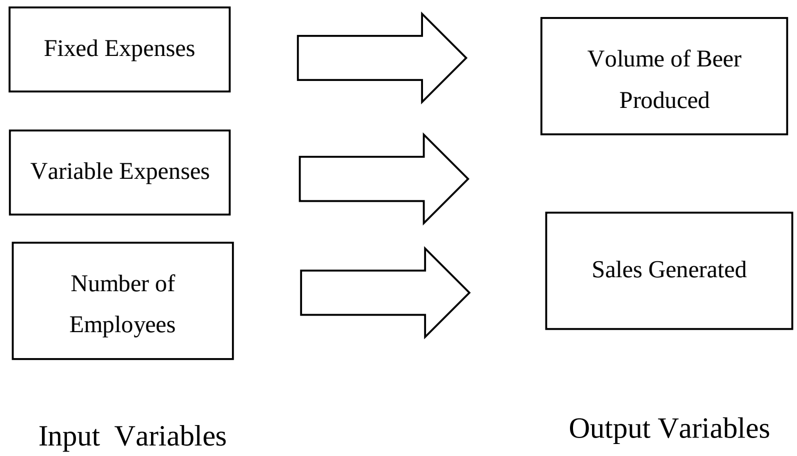


Figure 4.6: Technical Capacity Utilization Model

In this chapter, we introduce the models used in DEA evaluations for the Turkish brewing industry. These models are designed in accordance with their objectives. In Chapter 5, we explain data sources and methodology for the collection process of data.

Chapter 5

Data and Issues

This chapter is an explanation of the collection and preparation process of data sources and the issues that a researcher has to overcome during this process. In Chapter 5, we introduce: 1.The criteria for deciding the number of DMUs and input-output variables, 2.Collection and organization process of financial variables, 3.Methods of adjusting data ready for the use of these models, 4.Sources of data (financial statements and ratios) and, 5.The reasoning for selection of financial statements and ratios as the main data source,

5.1 Preparing the Data

Selection and preparation of data is critical in DEA methodology. There are over 30 models in DEA literature. However, only certain data can be used in execution of the models, because they meet the requirements. The study of Joseph Sarkis et al.(2002) "Preparing Your Data for DEA"[25] guided us to refine and filter input and output variables in this research. We use same source to decide the appropriate number of DMUs. To construct a managerial reasoning for data selection, a researcher has to be familiar with the industry he/she is studying. The importance of selection is stated by Necmi Avkiran et al. (2002) as "Typically, the choice and the number of inputs and outputs, and the DMUs determine how good of a discrimination exists between efficient and inefficient units." There is a dilemma with the size of data set. The larger the data, the more successful it is to distinguish efficient units shaping the frontier. However, homogeneity decreases as the size increases because of independent exogenous factors[23]. Another complication would be the complexity of the computational requirements.

For the selection of appropriate number of DMUs some rules of thumb were applied by different scholars as follows:

Table 5.1: Rules of Thumbs on the Number of Input and Outputs to Select DMUs

Scholar	**Number of Inputs and Outputs**	**Number of DMUs**
Boussofiane(1991)	I+O	2x(I+O)
Golany and Roll(1989)	I+O	2x(I+O)
Bowlin(1998)	I+O	3x(I+O)
Dyson (2001)	I+O	2xIxO

Source: Joseph Sarkis,(2002) "Productivity Analysis in the Service Sector with Data Envelopment Analysis"[22]

In the next step, the analyst should reduce the data set by eliminating highly correlated input and output variables. Eventhough this process is a time saver, an acceptable level of correlation should be taken into account. However identifying the level of acceptable correlation is not an easy task for the analyst.

Preparing data in same or similar magnitudes may remove imbalance situations. Dividing data by the mean is a suitable way to normalize it.

An analyst has to carry out the "positivity" requirement of DEA in data preparation. Basic DEA models can not complete analysis with negative numbers. All numbers have to be non-negative or strictly positive. We can avoid this obstacle by adding sufficiently large positive constants to input and output variables. Another solution advised by Bowlin et al. (1998)[52] is making negative values a smaller number in magnitude. However in terms of "undesirable outputs" the larger values are less preferable[50]. In our research, we use only desirable outputs. An analyst should be careful in assigning smaller values to input variables and larger values to output variables. On the contrary, Bowlin et al.(1998)[52] suggests substituting negative values with very small positive values. His reasoning is to emphasize outputs on the best performing DMUs, which weight highest. DMUs with small output values like negative values would not be expected to contribute higher efficiency scores.

In some cases, there is missing data. In our research, we use a managerial perspective to get “best estimates” which may be judged for its subjectiveness. We illustrate the steps used in data preparation in Figure 5.1. as below:

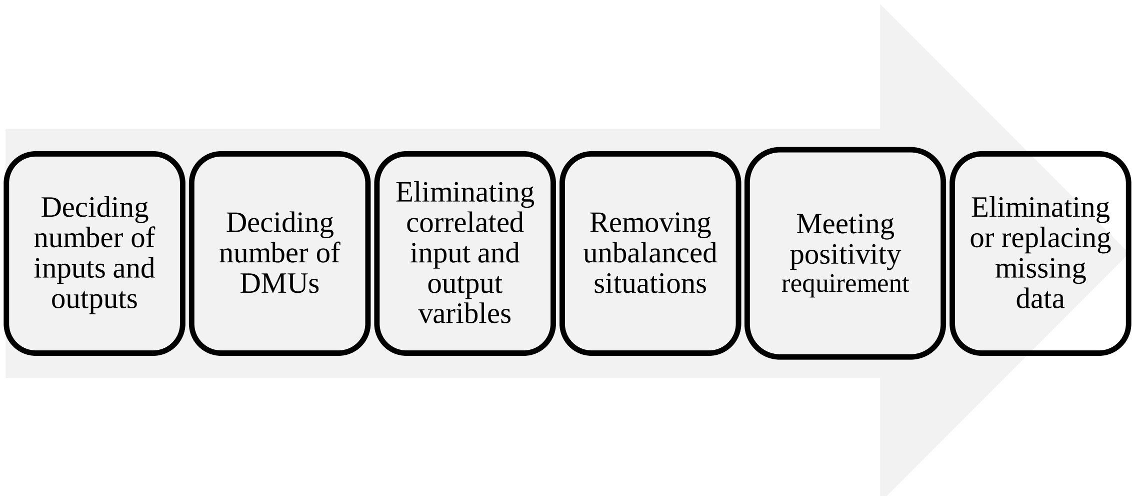


Figure 5.1: Steps in Data Preparation

5.2 Sources of the Data

Financial Statements

We use financial statements and financial ratios as the main data source. Data is extracted from financial reports of companies, from database publications, websites, and stock markets. All sources of the data are reliable and accessible to the public. On the contrary using discreet data sources would have resulted in questionable findings for this research. The reasoning for selection of financial statements and ratios as the main data source are classified as follows:

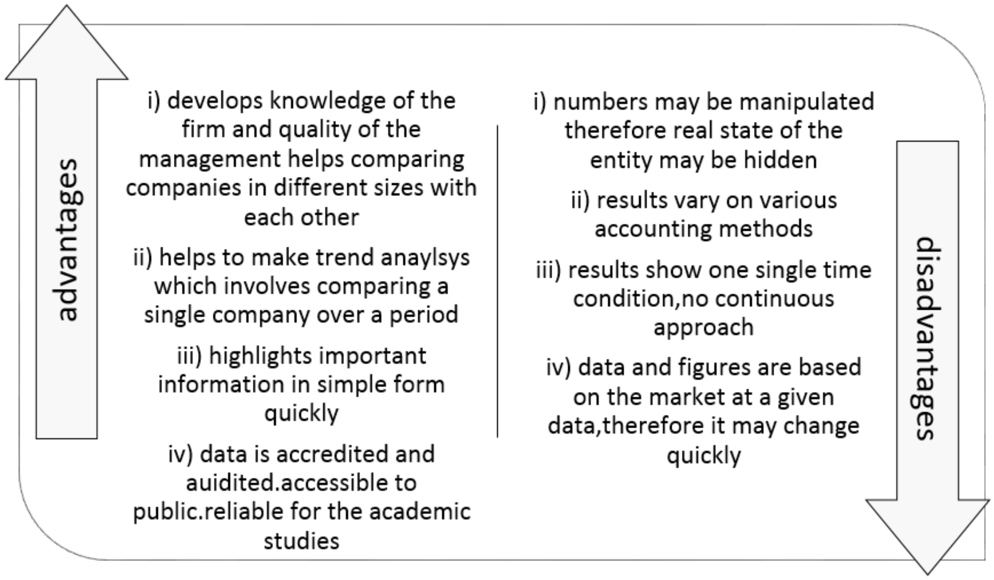


Figure 5.2: Reasons of Selecting Financial Statements as the Main Data Source

In this section we give a brief introduction to the financial statements concept. A company's annual report contains four basic financial statements:

1. The balance sheet shows the financial position–assets, liabilities, and stockholders equity – of the firm on a particular date.
2. The income or earnings statement presents the results of the operations-revenues, expenses, net profits or loss, and net profit or loss per- share for the accounting period.
3. The statement of shareholders' equity reconciles the beginning and ending balances of all accounts that appear in the shareholder's equity section.
4. The statement of cash flows provides information about the cash inflows and outflows from operating, financing, and investing activities during an accounting period.

The balance sheet shows the financial condition or position of a company on a particular date. It is a summary of what the firm owns (assets) and what the firm owes to outsiders (liabilities) and stakeholders (stockholders' equity). The components of the balance sheet are illustrated in Table C.1 (see Appendix).

According to balance sheet equation:

Assets=Liabilities+Stockholders' Equity

The income statement is a primary information source for evaluating a company's performance. Various sources of incomes and expenses are differentiated in format. The steps taken from generated revenue to the net income is shown as follows (for further details see Appendix).

1. The income statement begins with a presentation of sales revenue. By deducting sales returns and allowances and discounts, we get net sales.
2. Companies use net sales as some sales revenue. By deducting cost of goods sold from net sales we get gross profit.
3. Operating expenses is the next component of the income statement for a merchandising company. They are expenses included in the process of earning sales revenue.
4. Other income and expense in the next step consist of various revenues and gains; expenses and losses unrelated to the main line of the company.
5. Financing activities, which result in interest expense, represent distinctly different types of costs to business. After deducting the interest expense from other income and expenses we get net income.

The cash flow statement provides information about cash inflows and cash outflows during an accounting period. On the statement ,cash flows are segregated by operating activities, investing activities, and financing activities. The components of the cash flow statement are shown in Table C.2 (see Appendix).

Financial Ratios

Ratio analysis expresses, the relationship among selected items of financial statements data. A financial ratio expresses a mathematical proportion in percentile form. The categories of financial ratios and most common types belonging to these categories are explained as follows:

Liquidity ratios, measure the short-term ability of the company to pay its maturing obligations and meet unexpected needs for cash. Most common types of liquidity ratios can be seen in Table C.5 (see Appendix).

Profitability ratios, measure the income or operating success of a company for a given period. Most common types of profitability ratios can be seen in Table C.6 (see Appendix).

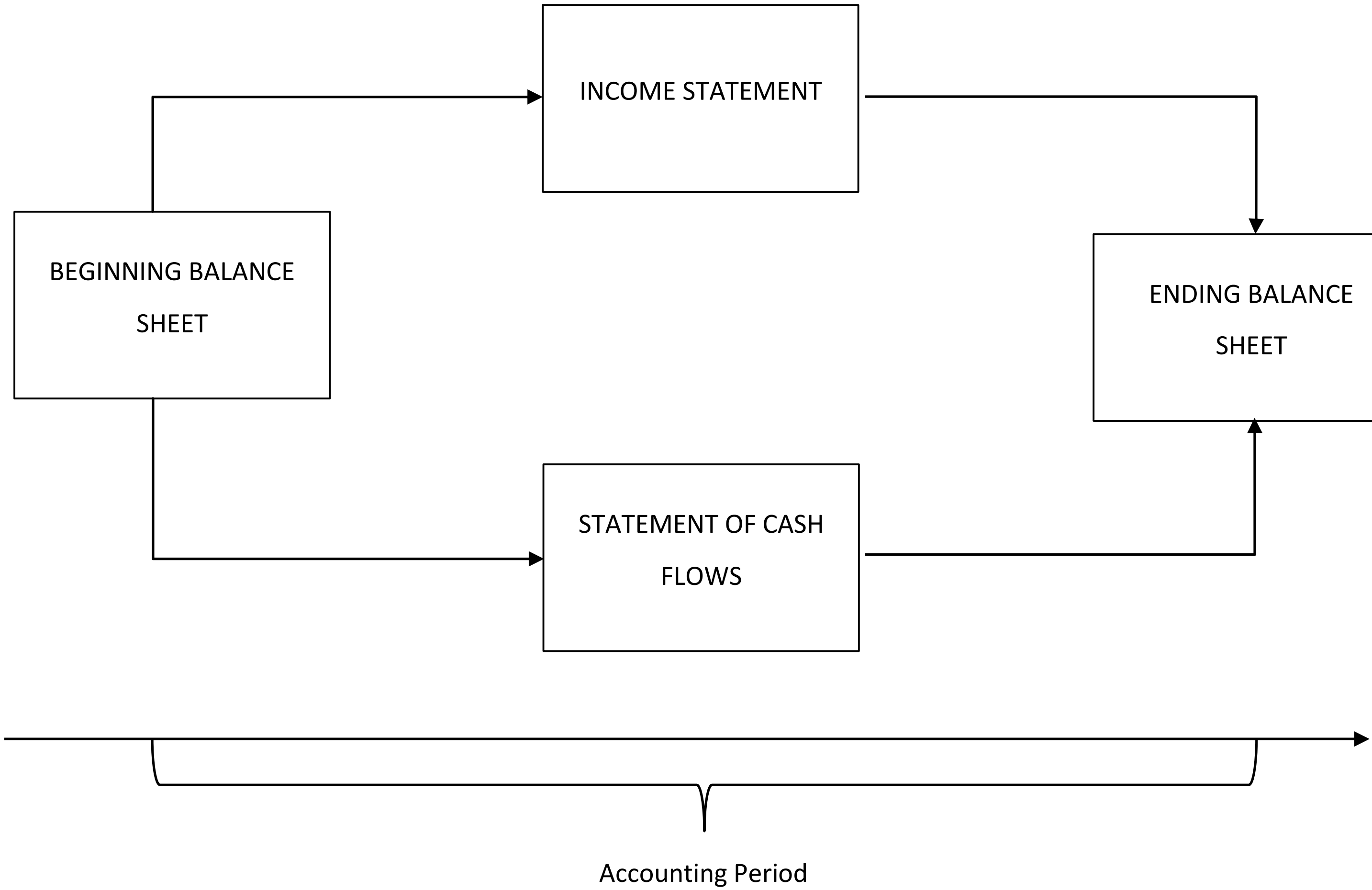
Solvency ratios, measure the ability of a company to survive over a long period. Most common types of profitability ratios can be seen in Table C.7 (see Appendix).

Cash flow adequacy is the primary measure of cash sufficiency. Most common types of profitability ratios can be seen in Table C.8 (see Appendix).

Market strength ratios, measure how confident the investors are about an entity. Most common types of profitability ratios can be seen in Table C.9(see Appendix).

In Figure 5.3 as follows, we show all types of financial statements and their relationships with each other in an accounting period (i.e. one year). A balance sheet shows the organization's financial position at one point in time. The income statement and cash flow statements report activities over a period. Therefore, these two statements in the middle of the figure link the beginning balance sheet to the ending balance sheet. They explain how an entity's financial position changes from a point of time to another.

Figure 5.3: The Relationship Between Financial Statement



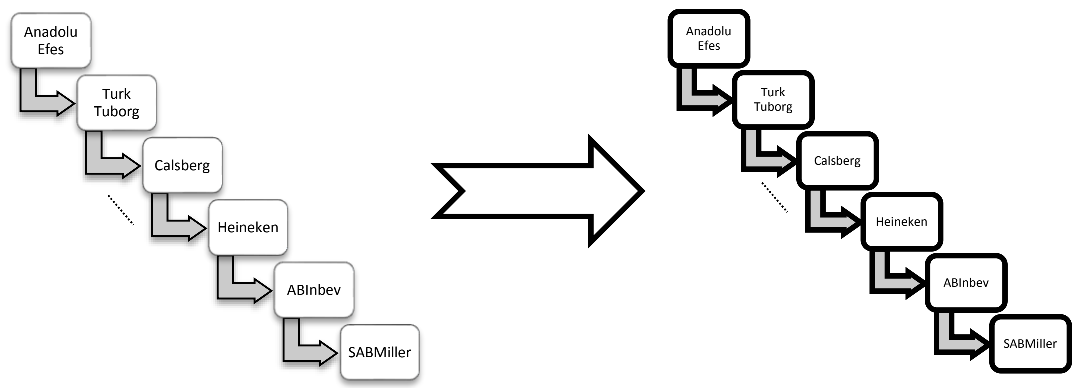
5.3 Collection and Organization Process of Financial Variables

In our research most relevant information was collected from the Balance Sheet, Income Statement, Cash Flow Statement and Financial Ratios spreadsheets. All companies are within the same or similar industries. Therefore, they are expected to label their items identically in their financial statements. However, there are some differences between their data, or at least some of their data has to be adjusted for the use of DEA measurements. We use the methods explained at the beginning of this chapter for such circumstances. The adjusted data is first converted into templates and then plugged in the software program for the measurements.

The steps below define the process we follow in our data decision, collection, adjusting and making it ready for the use of the software:

Step 1: Creation of Template Financial Statements

As preliminary, we reorganize and adjust the data by converting them into statement templates. Steps of this process are: 1.Adjusting negative data or losses to the positivity constraint of DEA, 2.Assigning suitable data for missing or lacking data, 3.Unifying data into same units and formats. Same input or output variables should be in same units (i.e.: dollar amount, percentages or numbers), 4.Currencies vary according to the countries. Therefore, we need to convert all of the financial variables into the same currencies and, 5.Companies are subject to different inflation rates and depreciation methods. These differences are minimized (if possible unified) with adjusting by appropriate deflation or depreciation methods (i.e. deflating data by using PPI (Producer Price Index)).



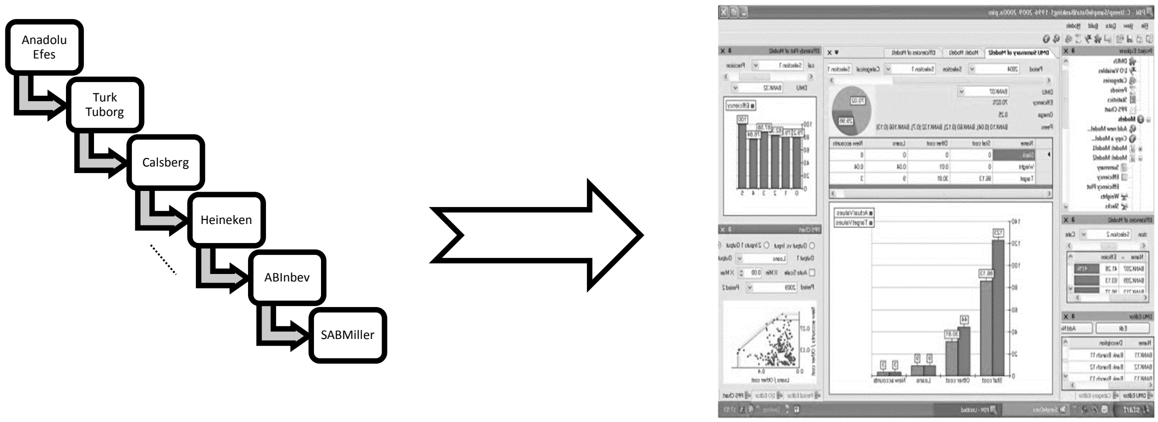
Each company's financial statements and other data information are collected from the official websites and other databank sources.

Collected data is reorganized and adjusted, ready to use for DEA measurements. They are prepared in template statement format.

Figure 5.4: Creation of Template Financial Statement

Step 2.Entering Data into Software

In the next step, we run the software for each user-specific DEA model. The financial statement templates are adjusted data for the use of the software. We use PIM-DEA as the software in our DEA efficiency evaluations. In the final stage we get the results conducted by using this software as follows:



We pick the variables suitable for each model. These variables are the adjusted data from financial statements templates.

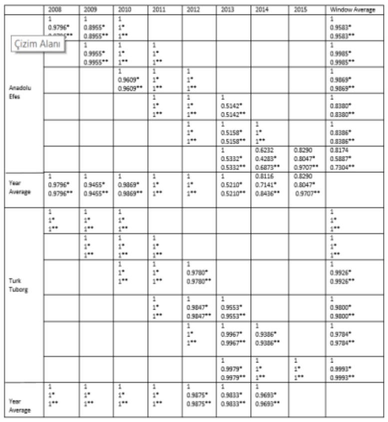
We execute adjusted data on PIM-DEA which is a DEA software. According to the results we identify if the observed DMUs are efficient or inefficient.

Figure 5.5: Conducting Results with the Software

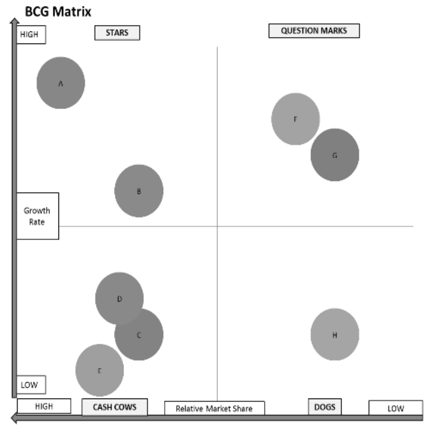
Step 3.Evaluating the Results

According to the results we conduct by PIM-DEA we evaluate if the DMUs are efficient or inefficient. The software uses a scoring metric between 0 and 1 for the input oriented models and above 1 for the output oriented models. We test our models by using different orientations and constraints to compare the results. By using DEA score metrics, we locate the DMUs on graphs like efficient frontier or BCG matrices.This procedure helps us to verify the position of the observed DMU among others.

In addition to PIM-DEA, we use Stata, (a data analysis and statistical software), either to get some estimates or variables used in the models or test the results conducted by PIM- DEA software. We illustrate this process as follows:



	2008	2009	2010	2011	2012	2013	2014	2015	Window Average
Anadolu Efes	1 0.9796* [illegible]	1 0.8955* 0.8955**	1 1* 1**						1 0.9583* 0.9583**
		1 0.9955* 0.9955**	1 1* 1**	1 1* 1**					1 0.9985* 0.9985**
			1 0.9609* 0.9609**	1 1* 1**	1 1* 1**				1 0.9869* 0.9869**
				1 1* 1**	1 1* 1**	1 0.5142* 0.5142**			1 0.8380* 0.8380**
					1 1* 1**	1 0.5158* 0.5158**	1 1* 1**		1 0.8386* 0.8386**
						1 0.5332* 0.5332**	0.6232 0.4283* 0.6873**	0.8290 0.8047* 0.9707**	0.8174 0.5887* 0.7304**
Year Average	1 0.9796* 0.9796**	1 0.9455* 0.9455**	1 0.9869* 0.9869**	1 1* 1**	1 1* 1**	1 0.5210* 0.5210**	0.8116 0.7141* 0.8436**	0.8290 0.8047* 0.9707**	
Turk Tuborg	1 1* 1**	1 1* 1**	1 1* 1**						1 1* 1**
		1 1* 1**	1 1* 1**	1 1* 1**					1 1* 1**
			1 1* 1**	1 1* 1**	1 0.9780* 0.9780**				1 0.9926* 0.9926**
				1 1* 1**	1 0.9847* 0.9847**	1 0.9553* 0.9553**			1 0.9800* 0.9800**
					1 1* 1**	1 0.9967* 0.9967**	1 0.9386* 0.9386**		1 0.9784* 0.9784**
						1 0.9979* 0.9979**	1 1* 1**	1 1* 1**	1 0.9993* 0.9993**
Year Average	1 1* 1**	1 1* 1**	1 1* 1**	1 1* 1**	1 0.9875* 0.9875**	1 0.9833* 0.9833**	1 0.9693* 0.9693**		



We collect the efficiency scores conducted by the PIM-DEA. We locate all DMUS on graphs like effieent frontier or matrices like BCG Matrix.

We reach to a clear and visual understanding from where an observed DMU is located. We can compare its distance to the best efficient frontier or reference sets. We define required improvements for the inefficient parts(i.e. input reductions or output augmentations according to the results).

Figure 5.6: Plotting the Results

In this Chapter, we define the entire process from selecting DMUs and variables to evaluating DEA results. Eventhough we study on brewing industry; there may be differences due to the characteristics of other industries. These differences may depend on laws, regulations, accounting policies, inflation rates, depreciation on various parameters like methods, constraints. We adjust data at most to avoid these differences in reaching fair results. In the following chapters, we introduce the empirical work done for DEA efficiency measurements of the Turkish brewers both in national and international prospects.

Chapter 6

DEA Window Analysis Approach in Turkish Brewing Industry

In this chapter, we evaluate productive efficiencies of the Turkish brewing industry using a sub-approach of DEA, called "Window Analysis". The organization of this chapter includes theoretical foundations and empirical applications of Window Analysis on Turkish brewing industry as follows:

6.1 Mathematical Foundation

The fractional linear programming model, also known as "CCR ratio model" can be transformed into a linear programming model as follows (see also Chapter 3):

$$\text{maximize } \theta_o = \sum_{r=1}^{s} u_r y_{ro}$$

$$\textit{subject to} \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1,\dots,n \tag{6.1}$$

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$u_r, v_i \geq 0$$

The formulation above is called the "multiplier model", but it lacks time as a component. If a particular point in time is put into account, the above formulation or a cross-sectional analysis would be sufficient. However, a further approach is needed for time span evaluations. A time series analysis is needed to evaluate DMUs over multiple periods. One way of using the DEA method in time series mode is DEA Window Analysis. This model was described by Charles et al.(1984) [7] and later G.Klopp (1985)[22] developed this technique for his job in the U.S. Army.

This time-dependent DEA model approach treats a DMU in each period as a different DMU and uses panel data to compare its performance. The performance of the observed DMU is compared with its performance in other periods. Moreover, observed DMU's performance is compared with other DMUs at the same period. Thus for **n** number of DMUs and **N** periods we need a total of **nxN** DMUs for simultaneous assessment. The changes in efficiencies over time may be due to seasonal factors or operational policies.

The efficiency of **N** periods can be monitored by DEA as follows:

- Considering each DMU in each time as a different unit and evaluating total **nxN** units
- Track changes with the application of window analysis. A window length **p** can be chosen, and **nXp** units are subject to the evaluations.

The weaknesses of window analysis are identified as: 1.The absence of attention to non-zero slacks that were stated by Cooper, Lawrence, and Tone et al.(2007)[54] and, 2.The beginning and ending periods of time spans are not as included in measurements as others.

However, window analysis gives a researcher the ability to increase number of DMUs for evaluation and brings more discriminatory power. A model was formulated by D.B.Sun et al. (1988)[14] as follows:

n = number of DMUs

k = number or periods (6.2)

p = length of the window (p $\leq k$)

w: number or windows

	Formula	
number of windows:	w=k-p+1	(6.3)
number of DMUs in each window	np/2	(6.4)
number of different DMUs	now	(6.5)

An alternative formulation derived from above symbols by Charnes and Cooper et al. (1991)[13] is as follows:

Total number of different DMUs: $now = n(k-p+1)p$ (6.6)

After differentiating the function above on **p** and equating it to zero we get:

$$p = \frac{k+1}{2} \tag{6.7}$$

6.2 DEA Window Analysis in Turkish Brewing Industry

In this chapter, the efficiency trends with time incorporation are applied on the duopoly companies of Turkish brewing industry, between 2003 and 2015. This study is made under Window Analysis approach developed by Klopp et al.(1985)[22].

Deciding what output and input variables are suitable for the brewing industry is a complicated task. Companies use same staff or facilities for different operations within the entire organization. In this section, we use the first three models introduced in Chapter 4 for DEA efficiency measurements under Window Analysis approach. They are the two staged profitability- marketability and productivity models applied on Anadolu Efes and Turk Tuborg for the period 2003-2015.

Table 6.1 is a classification of input and output variables for the three models we execute in DEA efficiency calculations. The output variables from the profitability stage treat as input variables to the marketability stage of the iterative process.

Table 6.1: Input and Output Variables for the Models

Model	Inputs	Outputs
Profitability	• Assets- I_{11} • Shareholders Equity- I_{12} • Number of Employees-I_{13}	• Profit-O_{11} • Revenue-O_{12}
Marketability	• Profit-I_{21} • Revenue-I_{22}	• EPS- O_{21} • ROIC-O_{22} • Net Income-O_{23} • Stock Price-O_{24}
Productivity	• COGS-I_{31} • Marketing, Sales & Dist-I_{32} • Number of Employees-I_{33}	• Profit –O_{31} • Revenue- O_{32}

We assume having **n** number of DMUs with observations of **k** periods. We assume **p** is the length of the window that provides **p** < **k**. The length of the window was found by using Charnes and Cooper's formulation. It is stated in the previous section as follows:

$$p = \frac{k+1}{2} \qquad \text{when n is odd and} \tag{6.8}$$

$$p = \frac{k+1}{2} \pm \frac{1}{2} \qquad \text{when n is eve}$$

for a detailed view see Charnes and Cooper (1991)[13].

In this chapter, we take window length as three years for duopoly industry. The time interval is taken short due to limited data access. Therefore, we assume three years would be a suitable window length for the comparisons.

For the preliminary data analysis histograms,whisker-plot charts and scatter matrices are conducted by using Stata software. For each variable, we create pooled data sets collected from financial statement items of Anadolu Efes and Turk Tuborg for the period 2003 - 2015.

In the tables follows we provide descriptive statistics of output and input variables for the two staged profitability-marketability model and the productivity models.

Table 6.2: Descriptive Statistics of Input and Output Variables for Anadolu Efes and Tuborg

The Profitability Stage

Statistical Measure	Mean	Std. Dev.	Min	Max
Assets * - I_{11}	4426279	6700936	188069	21970874
Equity * – I_{12}	2474141	4027565	-1058	13461926
Nr of Employees - I_{13}	7291.077	7732.116	198	19852
Revenue * - O_{11},I_{21}	2363656	3090324	152504	10205146
Profit * - O_{12},I_{22}	303783	335886.4	-57997	928877

Variables with the “ *” mark are in thousands TRL

“ Assets” variables are collected by deducting “Financial Investments” and “Investment Properties” from “Total Assets” item of the Balance Sheets. As “Profit” item we prefer using “Operating Profit” from the Income Statements.

Table 6.3: Descriptive Statistics of Input and Output Variables for Anadolu Efes and Turk Tuborg

The Marketability Stage

Statistical Measure	Mean	Std. Dev.	Min	Max
Revenue * - O_{11},I_{21}	2363656	3090324	152504	10205146
Profit * - O_{12},I_{22}	303783	335886.4	-57997	928877
EPS - O_{21}(in TRL)	0.4085	1.149862	-1.37	4.41
Stock Price - O_{22} (USD)	2.2605	1.102043	0.27	5.43
ROIC - O_{23} (in%)	4.66444	29.20263	-86.28	43.61
Net Income * – O_{24}	629807.69	660483.4	-512000	320900

Variables with the “ *” mark are in thousands TRL

In the above table Earnings per Share (EPS) is in Turkish Lira and Return on Invested Capital(ROIC) is in percentages. The stock prices are in USD. All the data above are conducted from consolidated financial statements of companies, Financial Times Magazine and www.morningstar.com website for company quotes and financial data.

Table 6.4: Descriptive Statistics of Input and Output Variables for Anadolu Efes and Turk Tuborg

The Productivity Model

Statistical Measure	Mean	Std. Dev.	Min	Max
COGS * - I_{31}	1300500	1777648	79265	6018448
Nr of Employees- I_{32}	7291.077	7732.116	198	19852
Marketing,Sales and Distribution & *- I_{33}	629887.3	772809.7	54086	2495486
Revenue *- O_{31}	2363656	3090324	152504	10205146
Profit *-O_{32}	303783	335886.4	-57997	928877

Variables with the " *" mark are in thousands TRL

The productivity model has three input variables COGS, the number of employees and marketing, sales and distribution, (representing advertising and promotional expenses) and two output variables revenue and profit from operations.

The figures below illustrate distribution of each variable within given ranges. The left side of the graphs are histograms, and the right side are whisker- box plots.

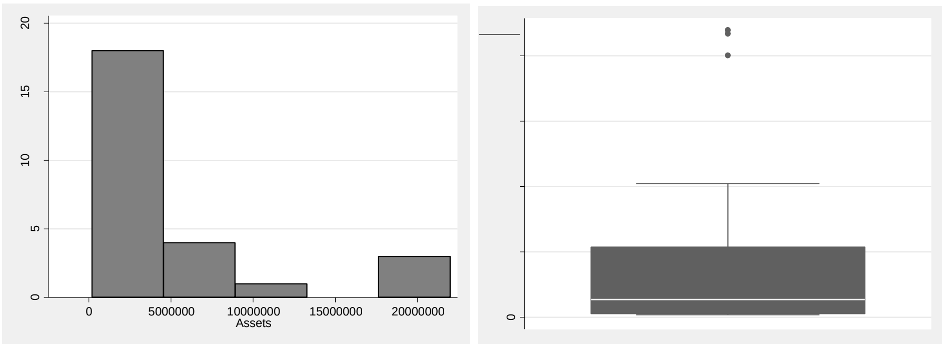


Figure 6.1: Histogram and Box Plot of Assets

Regarding DEA input, Assets tends to be positively skewed where the mean is 4,426,279 (in thousands TRL). Anadolu Efes is the market leader with asset size 25 times larger than Turk Tuborg. Assets are mainly spread up to an interquartile –range of 5,000,000(thousands TRL).

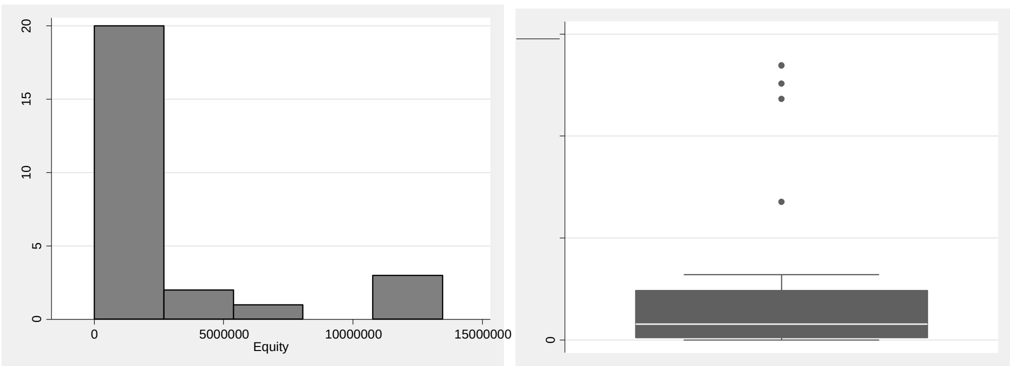


Figure 6.2: Histogram and Box Plot of Equity

Regarding DEA input, Equity shows a positively skewed pattern, very similar to Assets. The mean is 2,474,141(in thousands TRL). Anadolu Efes has over 30 times larger equity size than Turk Tuborg.

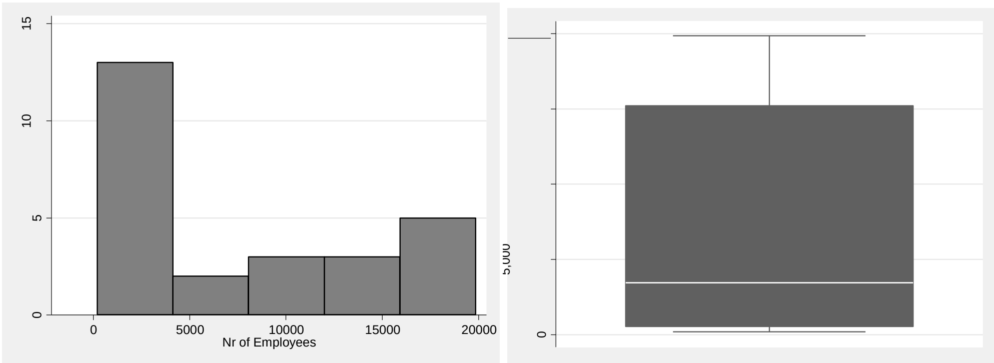


Figure 6.3: Histogram and Box Plot of Number of Employees

The histogram for the number of employees shows a big difference between the two companies due to their scales. Turk Tuborg has employees within a range 300 and 750, and Anadolu Efes' within a range 6000 and 19000. The histogram does not show any distinct behavior where values are spread throughout the given range. However, the whisker-box plot has a very significant behavior regarding number of employees.

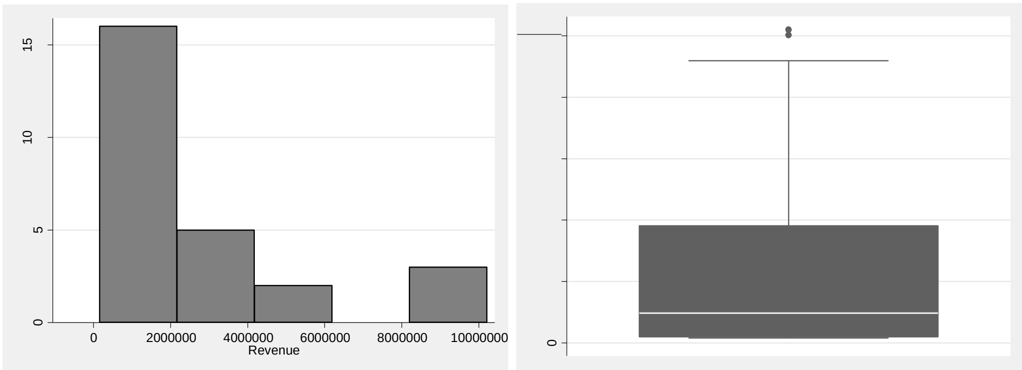


Figure 6.4: Histogram and Box Plot of Revenues

Regarding DEA variable Revenues both histogram and whisker-box plots do not show distinct behaviors. Left side of histogram belongs to distribution of Anadolu Efes, which is slightly positively skewed.

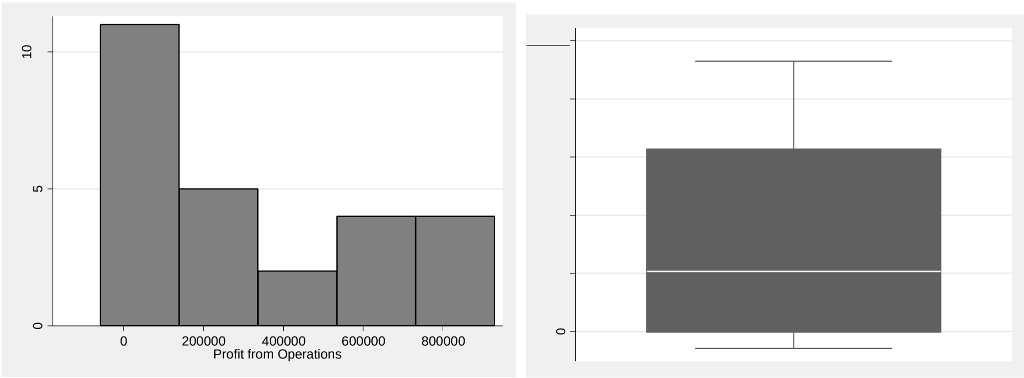


Figure 6.5: Histogram and Box Plot of Profit from Operations

Profit from Operations does not show any distinct behavior, where all values are spread throughout the given range. The whisker-box-plot above has an apparent range for the Profit variables.

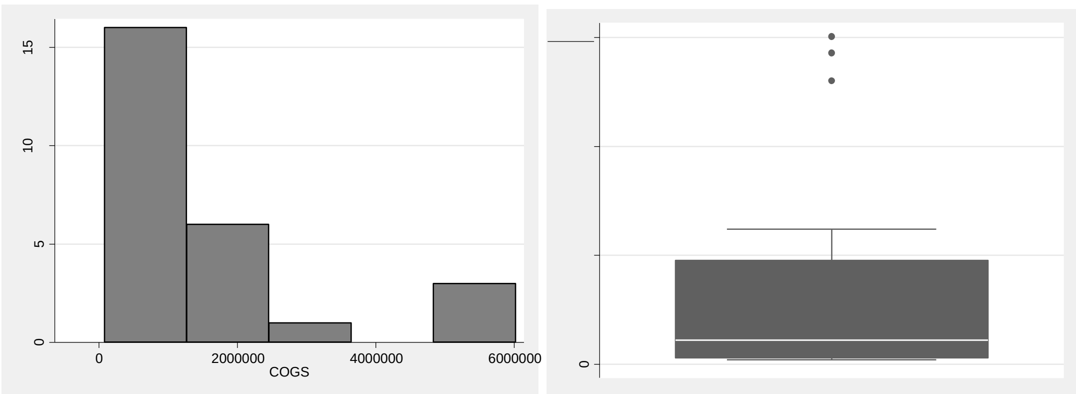


Figure 6.6: Histogram and Box Plot of COGS

Regarding DEA input, COGS does not show a distinct behavior. The left side belongs to the distribution of Anadolu Efes variables , which is slightly positively skewed. The histogram of COGS has almost same distribution pattern as Revenues, considering those two variables are highly related. However, the interquartile range of the whisker-box plot is narrower than revenues below 2,000,000 (in thousands TRL) level.

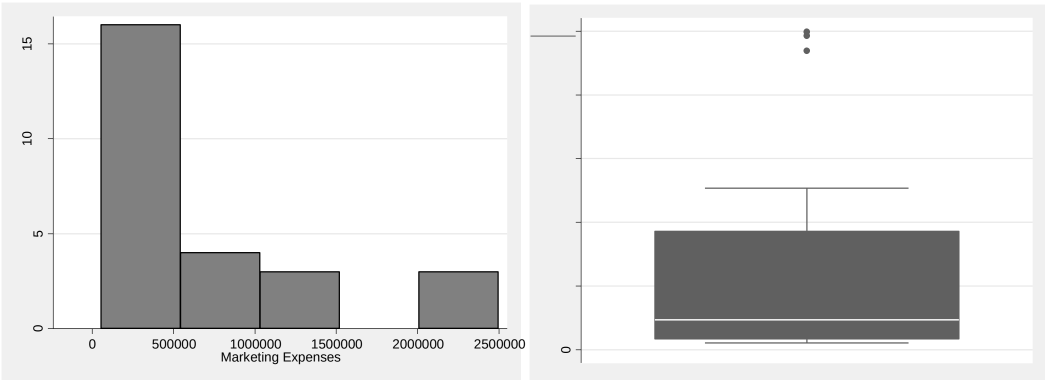


Figure 6.7: Histogram and Box Plot of Marketing, Sales & Distribution

Regarding DEA input variable, Marketing Sales and Distribution does not show a distinct behavior. The left side belongs to the distribution of Anadolu Efes, which is slightly positively skewed. The histograms and whisker-box plots of COGS and Marketing, Sales & Distribution, treat similar patterns.

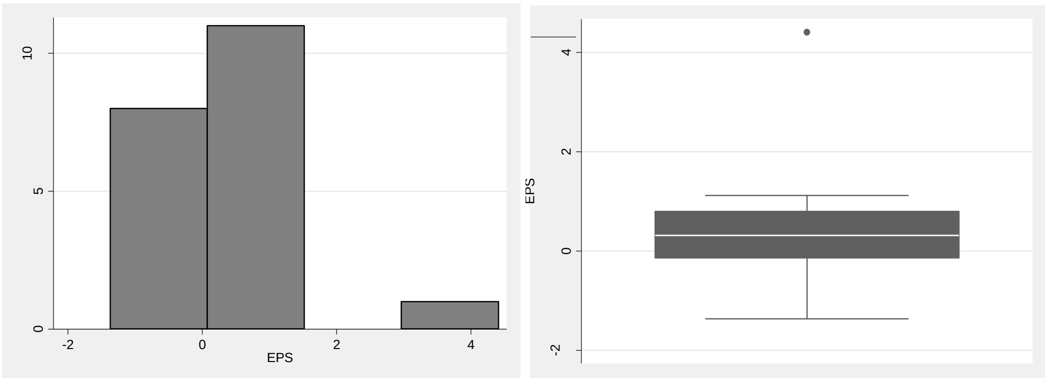


Figure 6.8: Histogram and Box Plot of EPS

From the histogram of EPS, as seen in Figure 6.8 the data does not vary throughout a wide range of values. The majority of EPS varies in between -1.5 and +1.5 TRL. We do not see distinct behaviors in both of the graphs above.

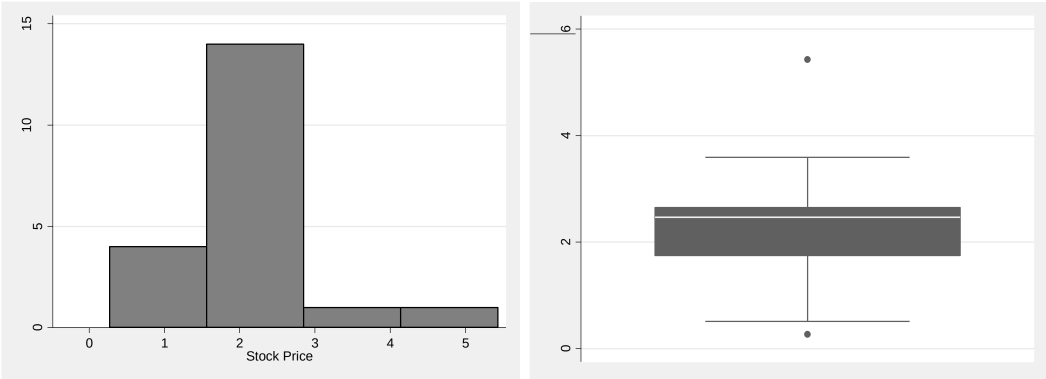


Figure 6.9: Histogram and Box Plot of Stock Prices

From the histogram of Stock Prices, as seen in Figure 6.11 the data is spread mainly in between 1.5 and 3.0 USD share price levels. The histogram has an exponential distribution. The interquartile range of whisker-box plot is very narrow with a median over 2.0 USD.

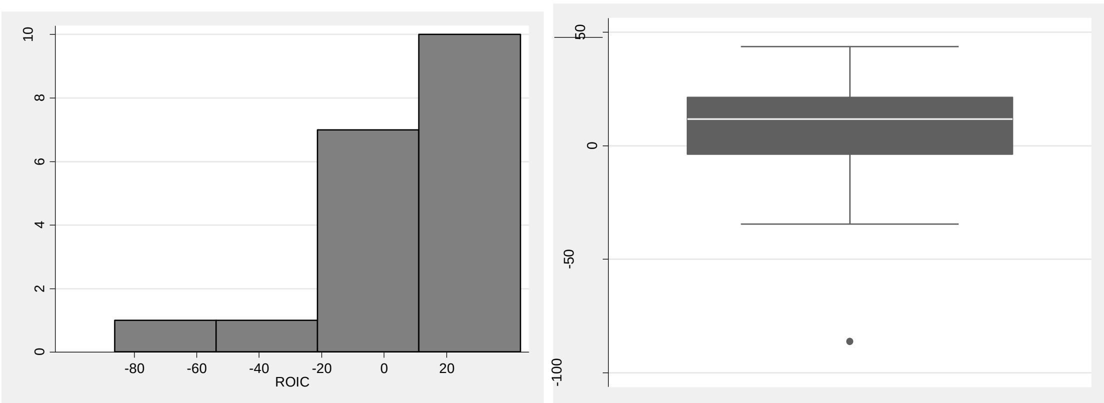


Figure 6.10: Histogram and Box Plot of ROIC

Regarding DEA output, ROIC has a negatively skewed distribution of values. The majority of the values vary in between -20% and 40%. The interquartile range of whisker-box plot spreads in between 0 and -20% values.

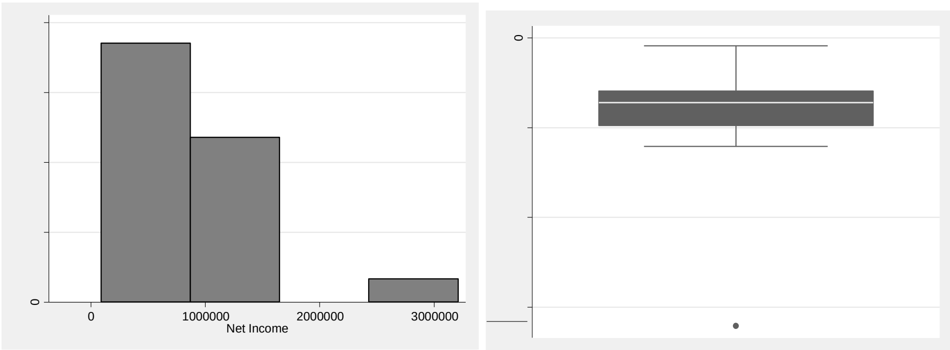


Figure 6.11: Histogram and Box Plot of Net Income

Regarding DEA input, Net Income has a histogram that is slightly distinct and positively skewed. The values are spread throughout a range up to 1,5000,000,000 TRL.The whisker-box plot has a narrow interquartile range.

By using histograms for each variable various trends and patterns are identified. Despite the fact that we only have two companies as DMUs we get a better visual insight from the way data sets behave. The two companies have big scale and scope differences. DEA deals with the proportions between inputs and outputs rather than their magnitudes. However, significant differences in magnitudes may prevent us to reach distinct behaviors for the histograms and box plots above.

In this section, we describe each model (the two staged profitability-marketability and the productivity) by using scatterplot matrix and correlation matrix.

The following figure is the scatterplot matrix for the profitability stage. Best fit lines produced by the Stata software are not linear but forced to pass through the origin.

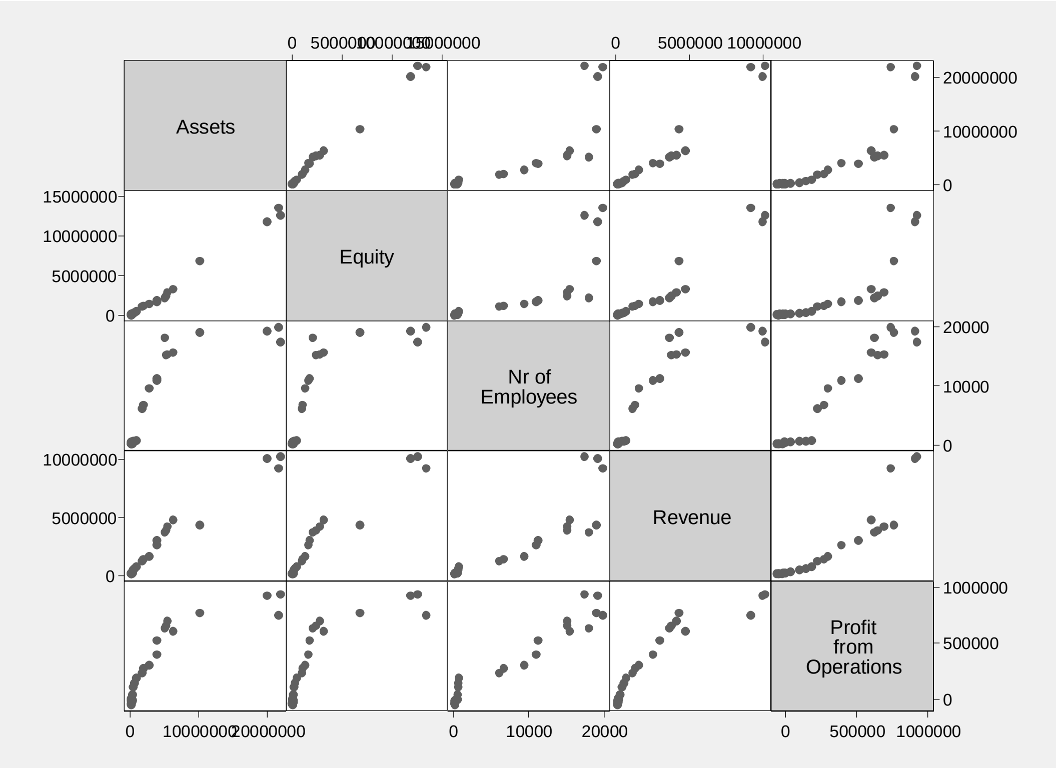


Figure 6.12: Scatterplots of DEA Variables for the Profitability Stage

From the Figure 6.13 as follows, we examine the coefficient of correlation with the highest absolute magnitude (except 1) is between Assets and Equity, which is 0.9961. There is a well-known balance in accounting because every business transaction affects at least two accounts of a company. In general, the correlations between variables at this stage are significantly high.

DEA is not affected by collinearity even if two or more variables are highly correlated; the results will not change drastically with small changes to the model or data[28].

	Assets	Equity	Employees	Revenues	Profit
Assets	1.0000				
Equity	0.9961	1.0000			
Employees	0.8098	0.7815	1.0000		
Revenues	0.9803	0.9624	0.8760	1.0000	
Profit	0.8483	0.8195	0.9718	0.9153	1.0000

Figure 6.13: Coefficients of Correlation for Variables in the Profitability Stage

The following figure is the scatterplot matrix for the Marketability stage. Best fit lines produced by the Stata software are not linear and not forced to pass through the origin.

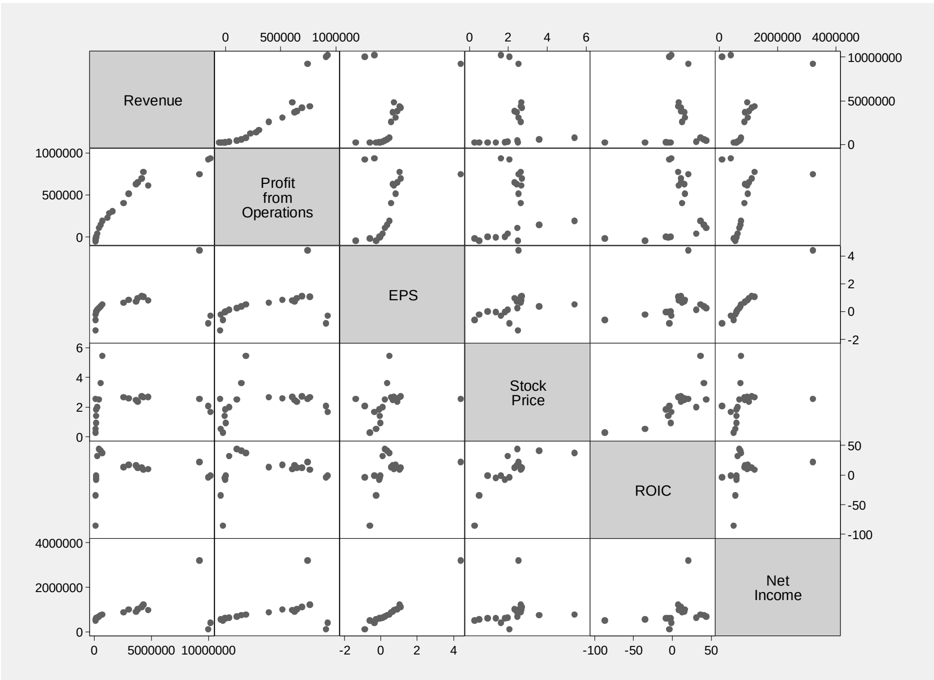


Figure 6.14: Scatterplots of DEA Variables for the Marketability Stage

From the Figure 6.15 as follows the coefficient of correlation with the highest absolute magnitude (not 1) is between Net Income and Earnings per Share(EPS) which is 0.9894. Both Net Income and EPS indicate the earnings generated by the company. Therefore, a high correlation is expected. The correlations between other variables are significantly low.

	Revenues	Profit	EPS	ROIC	Stock Price	Net Income
Revenues	1.0000					
Profit	0.9118	1.0000				
EPS	0.3335	0.3584	1.0000			
ROIC	0.0798	0.2512	0.3289	1.0000		
Stock Price	0.0832	0.2066	0.3773	0.7511	1.0000	
Net Income	0.3265	0.3130	0.9894	0.2255	0.2604	1.0000

Figure 6.15: Coefficients of Correlation for Variables in the Marketability Stage

The following illustration is the scatterplot matrix for the Productivity model. Best fit lines produced by the Stata software are not linear but forced to pass through the origin.

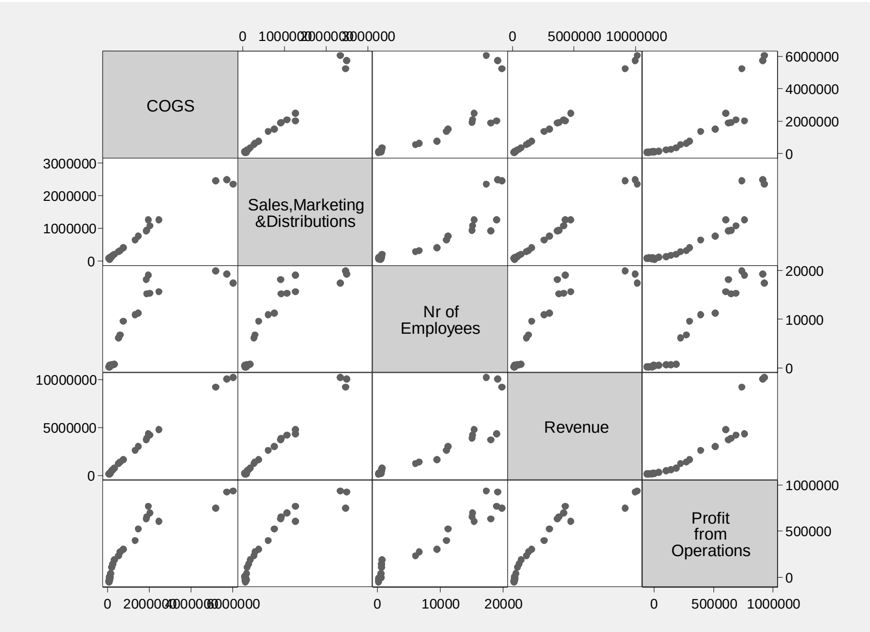


Figure 6.16: Scatterplots of DEA Variables for the Productivity Model

From the Figure 6.17 below the coefficients of correlation between all variables are significantly very high. According to the inseparability assumption of production and marketing technologies, both departments should be working collaboratively in industries like brewing.

	COGS	Marketing Expenses	Employees	Revenues	Profit
COGS	1.0000				
Marketing Expenses	0.9901	1.0000			
Employees	0.8390	0.8847	1.0000		
Revenues	0.9969	0.9962	0.8760	1.0000	
Profit	0.8844	0.9137	0.9718	0.9156	1.0000

Figure 6.17: Coefficients of Correlation for Variables in the Productivity Model

In this section, we exhibit DEA efficiency scores conducted in Turkish brewing industry. We conduct results in terms of BCC, CCR and, Scale efficiencies. BCC efficiency scores include the assumption of VRS (Variable Returns to Scale) relationship in between input and output variables. Therefore, they are more suitable to real industry conditions. We conduct technical efficiency scores through BCC model. CCR efficiency scores include the assumption of CRS (Constant Returns to Scale) relationship in between input and output variables. We aggregate the overall efficiency scores for each unit. The overall efficiency scores include both pure technical efficiency and scale efficiency. This model is not preferable for the measurements ,because it assumes optimal industry conditions under CRS. Scale efficiency scores are conducted by dividing overall efficiency from CCR model to the technical efficiency from the BCC model. It measures how optimal an observed DMU is operating.

The following tables show DEA efficiency scores in Turkish brewing industry. For each year, there are three types of efficiency scores. BCC efficiency scores fulfill requirements rather than CCR,because this assumption includes VRS and relaxes optimal market condition. In DEA approach, each observation for a brewer in a different year is treated as a separate DMU, and measured against each other on an intertemporal basis. Considering the period between 2003 and 2015 we assume there may be numerous exogenous factors affecting the industry, (i.e.changes in technologies). To eliminate such situations we employ DEA Window Analysis with three years window lengths.

The two-staged model was adapted from the research of Seiford and Zhu et al.(1999)[40]. We calculate the companies' ability to generate revenues and profits using their assets and equities. This model consists of three input variables (assets, employees, and shareholders' equity) and two output variables (revenues and profits). Both companies have low levels of the volatility of efficiencies. Their average DEA efficiency scores are over 95 percent. Turk Tuborg operates on the efficient frontier with a full efficiency which is equal to 1. From the results of profitability stage we assume both companies are highly effective in generating revenues and profits using assets, equities, and their workforce.

Table 6.5: Profitability Model DEA Efficiencies of Anadolu Efes and Turk Tuborg for the Years 2008-2015 Using a Three-Year Window

Profitability Stage	2015	2014	2013	2012	2011	2010	2009	2008	Window Average
	1	1	0,8631						0,9544
	0,5858	0,5772	0,4978						0,5536
	0,5858	0,5772	0,5768						0,5799
		1	0,8867	1					0,9622
		0,6163	0,5469	0,4171					0,5268
		0,6163	0,6167	0,4171					0,5500
			1	1	1				1
			0,6325	0,4171	0,7409				0,5968
			0,6325	0,4171	0,7409				0,5968
Anadolu				1	1	1			1
Efes				0,4342	0,7667	0,7784			0,6598
				0,4342	0,7667	0,7784			0,6598
					1	1	1		1
					0,8298	0,8317	0,8198		0,8271
					0,8298	0,8317	0,8198		0,8271
						1	1	1	1
						0,8242	0,8071	0,8345	0,8219
						0,8242	0,8071	0,8345	0,8219
Year Average	0,7239	0,7312	0,6948	0,6152	0,8528	0,8743	0,8756	0,8897	
	1	1	1						1
	1	1	1						1
	1	1	1						1
		1	1	1					1
		1	1	1					1
		1	1	1					1
			1	1	1				1
			1	1	0,9923				0,9974
Turk			1	1	0,9923				0,9974
Tuborg				1	1	1			1
				1	0,9923	0,8981			0,9635
				1	0,9923	0,8981			0,9635
					1	1	1		1
					1	0,9713	1		0,9904
					1	0,9713	1		0,9904
						0,9767	1	1	0,9922
						0,9611	1	1	0,9870
						0,984	1	1	0,9947
Year Average	1	1	1	1	0,9966	0,9623	1	1	

First-row scores represent BCC efficiency scores out of 1(full efficiency score).

Second-row scores represent CCR efficiency scores out of 1(full efficiency score).

Third-row scores represent Scale efficiency scores out of 1(full efficiency score).

Table 6.6: Profitability Model DEA Efficiencies of Anadolu Efes and Turk Tuborg for the Years 2003-2009 Using a Three-Year Window

Profitability Stage	2009	2008	2007	2006	2005	2004	2003	Window Average
	1	1	1					1
	0,7726	0,7908	0,8408					0,8014
	0,7726	0,7908	0,8408					0,8014
		1	1	0,9205				0,9735
		0,8581	0,9325	0,7848				0,8585
		0,8581	0,9325	0,8526				0,8811
			1	0,9255	0,9011			0,9422
Anadolu			1	0,8451	0,8892			0,9114
Efes			1	0,9132	0,9868			0,9667
				1	0,9213	1		0,9738
				0,9206	0,8312	1		0,9173
				0,9206	0,9021	1		0,9409
					1	1	0,9496	0,9832
					0,9294	1	0,9478	0,9590
					0,9294	1	0,9981	0,9758
Year Average	0,8484	0,8830	0,9496	0,8981	0,9212	1	0,9652	
	1	1	1					1
	1	1	1					1
	1	1	1					1
		1	1	1				1
		1	1	1				1
		1	1	1				1
Turk			1	1	0,9624			0,9875
Tuborg			1	1	0,9594			0,9865
			1	1	0,9968			0,9989
				1	1	1		1
				1	1	1		1
				1	1	1		1
					1	1	1	1
					1	0.9924	1	1
					1	0.9924	1	1
Year Average	1	1	1	1	0,9910	1	1	

First-row scores represent BCC efficiency scores out of 1(full efficiency score).

Second-row scores represent CCR efficiency scores out of 1(full efficiency score).

Third-row scores represent Scale efficiency scores out of 1(full efficiency score).

In stage-2, marketability of companies is measured by performances at the stock market, regarding two input variables (revenues and profits) and four output variables (EPS, net income, ROI and stock price) which is consistent with the existing literature. Revenues and operating profit employ as intermediate factors that are outputs from the stage-1 and inputs to the stage-2 of the iterative process. Regarding the results shown in Table 6.7 and Table 6.8 as follows both companies employ high levels of efficiency scores. Anadolu Efes and Turk Tuborg has 0.7131 and 0.7562 minimum efficiency scores respectively. Turk Tuborg operates on the efficient frontier like the profitability stage of this model. We conclude that the two companies' competence in providing sufficient benefits to its shareholders is adequate.

Table 6.7: Marketability Model DEA Efficiencies of Anadolu Efes for the Years 2006-2015 Using a Three-Year Window

Marketability Stage	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	Window Average
	0,9065	1	1								0,9688
	0,8259	1	0,7131								0,8463
	0,9111	1	0,7131								0,8747
		1	1	0,9608							0,9869
		1	0,7116	0,7861							0,8326
		1	0,7116	0,8181							0,8432
			1	1	1						1
			0,7157	0,8275	0,9159						0,8197
			0,7157	0,8275	0,9159						0,8197
Anadolu				0,9618	1	1					0,9873
Efes				0,8360	0,9253	0,9201					0,8938
				0,8692	0,9253	0,9201					0,9049
					1	1	1				1
					0,9597	0,9501	0,9657				0,9585
					0,9597	0,9501	0,9657				0,9585
						1	1	1			1
						0,9494	0,9655	1			0,9716
						0,9494	0,9655	1			0,9716
							1	1	1		1
							0,9662	1	1		0,9887
							0,9662	1	1		0,9887
								1	1	1	1
								1	0,9286	1	0,9762
								1	0,9286	1	0,9762
Year Average	0,8812	1	0,8090	0,8763	0,9558	0,9599	0,9772	1	0,9762	1	

First-row scores represent BCC efficiency scores out of 1(full efficiency score).

Second-row scores represent CCR efficiency scores out of 1(full efficiency score).

Third-row scores represent Scale efficiency scores out of 1(full efficiency score

Table 6.8: Marketability Model DEA Efficiencies of Turk Tuborg for the Years 2006-2015 Using a Three-year Window

Marketability Stage	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	Window Average
	1	1	1								1
	1	1	1								1
	1	1	1								1
		1	1	1							1
		1	1	1							1
		1	1	1							1
			1	1	1						1
			1	1	1						1
			1	1	1						1
Turk				1	1	1					1
Tuborg				1	1	1					1
				1	1	1					1
					1	1	1				1
					1	1	1				1
					1	1	1				1
						1	1	1			1
						1	1	0,8446			0,9482
						1	1	0,8446			0,9482
							1	1	1		1
							1	0,7562	1		0,9187
							1	0,7562	1		0,9187
								0,8795	1	1	0,9598
								0,7917	1	1	0,9306
								0,9002	1	1	0,9667
Year Average	1	1	1	1	1	1	1	0,8637	1	1	0,9863

First-row scores represent BCC efficiency scores out of 1(full efficiency score).

Second-row scores represent CCR efficiency scores out of 1(full efficiency score).

Third-row scores represent Scale efficiency scores out of 1(full efficiency score).

The last model is a measure of the productivity using inseparability assumption of production and marketing technologies. The cost of sales (COGS), marketing, sales and distributions from income statement (as the marketing and promotion expenses) and number of employees treat as input variables; revenues and profit from operations treat as output variables. According to the results in Table 6.9 and Table 6.10 as follows both companies treat almost full efficiency scores. We conclude that efficiency concerns on production process (i.e. reducing water and energy consumption, adopting the technology of state from other industries) provided companies to reaching high-efficiency production process.

Table 6.9: Productivity Model DEA Efficiencies of Anadolu Efes and Turk Tuborg for the Years 2008-2015 Using a Three-year Window

Profitability Model	2009	2008	2007	2006	2005	2004	2003	Window Average
	1	0,9917	1					0,9972
	1	0,9850	1					0,9950
	1	0,9932	1					0,9977
		1	1	1				1
		0,9989	1	1				0,9996
		0,9989	1	1				0,9996
			1	1	1			1
Anadolu			1	1	1			1
Efes			1	1	1			1
				1	1	1		1
				1	0,968	1		0,9893
				1	0,968	1		0,9893
					1	1	1	1
					0,968	1	0,9946	0,9875
					0,968	1	0,9946	0,9875
Year Average								
	1	1	1					1
	1	1	1					1
	1	1	1					1
		1	1	1				1
		1	1	1				1
		1	1	1				1
Turk			1	1	0,9564			0,9855
Tuborg			1	1	0,9563			0,9854
			1	1	1			1
				1	0,9567	1		0,9856
				1	0,9544	1		0,9848
				1	0,9976	1		0,9992
					1	0,9813	1	0,9938
					0,9284	0,9434	1	0,9573
					0,9284	0,9616	1	0,9633
Year Average	1	0,9978	1	1	0,9750	0,9905	0,9982	

First-row scores represent BCC efficiency scores out of 1(full efficiency score).

Second-row scores represent CCR efficiency scores out of 1(full efficiency score).

Third-row scores represent Scale efficiency scores out of 1(full efficiency score).

Table 6.10: Productivity Model DEA Efficiencies of Anadolu Efes and Turk Tuborg for the Years 2003-2009 Using a Three-year Window

Profitability Model	2009	2008	2007	2006	2005	2004	2003	Window Average
	1	0,9917	1					0,9972
	1	0,9850	1					0,9950
	1	0,9932	1					0,9977
		1	1	1				1
		0,9989	1	1				0,9996
		0,9989	1	1				0,9996
			1	1	1			1
Anadolu			1	1	1			1
Efes			1	1	1			1
				1	1	1		1
				1	0,968	1		0,9893
				1	0,968	1		0,9893
					1	1	1	1
					0,968	1	0,9946	0,9875
					0,968	1	0,9946	0,9875
Year Average								
	1	1	1					1
	1	1	1					1
	1	1	1					1
		1	1	1				1
		1	1	1				1
		1	1	1				1
Turk			1	1	0,9564			0,9855
Tuborg			1	1	0,9563			0,9854
			1	1	1			1
				1	0,9567	1		0,9856
				1	0,9544	1		0,9848
				1	0,9976	1		0,9992
					1	0,9813	1	0,9938
					0,9284	0,9434	1	0,9573
					0,9284	0,9616	1	0,9633
Year Average	1	0,9978	1	1	0,9750	0,9905	0,9982	

First-row scores represent BCC efficiency scores out of 1(full efficiency score).

Second-row scores represent CCR efficiency scores out of 1(full efficiency score).

Third-row scores represent Scale efficiency scores out of 1(full efficiency score).

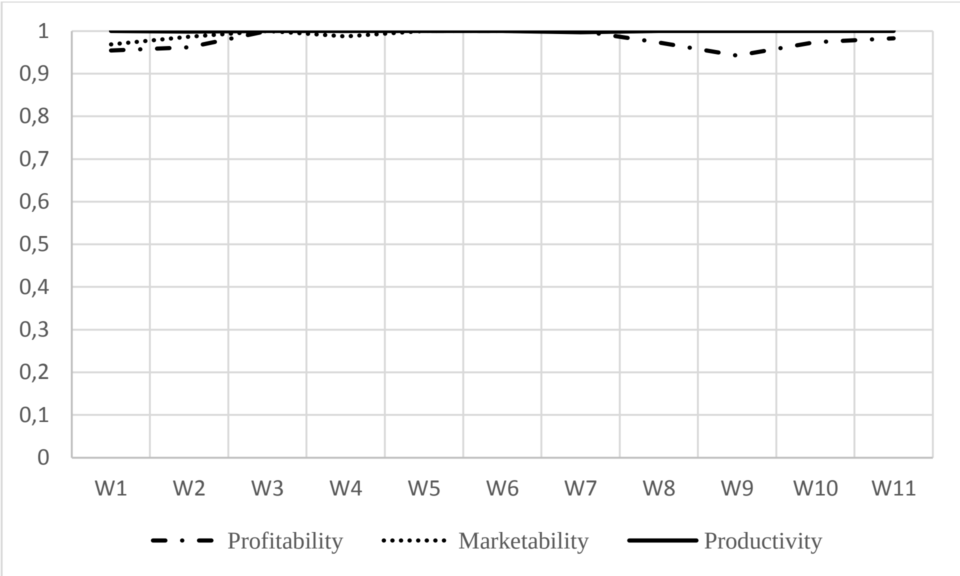


Figure 6.18: DEA Efficiency Score Trends for Anadolu Efes

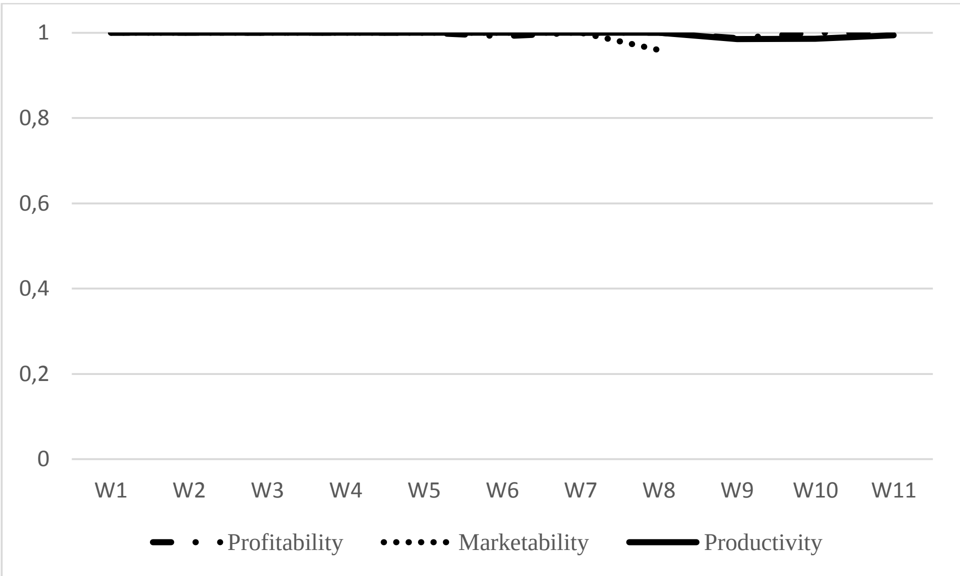


Figure 6.19: DEA Efficiency Score Trends for Turk Tuborg

As we see in Figure 6.18 and Figure 6.19 above both companies employ almost full efficiency scores for the three models. In DEA calculations, we treat each firm for each year as a separate decision-making unit (i.e., Anadolu Efes 2015 as.DMU_1, Anadolu Efes 2014 as DMU_2). Therefore, for the two companies for 13 years, we have 26 DMUs in total.

In this study by using DEA methodology operating, profitability and marketing efficiencies are aggregated. We suggest further research because factors like risk, change in technologies and discreet company data are not involved in this study.

The efficiency scores for both BCC and CCR are presented to provide a comparison. There are not large differences between these models. BCC model implies technical efficiency however such a DMU may not have the scale efficiency in some circumstances.

We reveal the relationship between the efficiency scores and market sizes of the brewing companies. For this purpose, we use a dummy variable regression analysis. We use only one dummy variable to facilitate a comparison between the two brewers . Companies with assets over 1 billion TRL are taken as large brewers and with assets below 1 billion TRL as small brewers. We could not find any literature about a classification of brewers regarding their asset sizes.

Using dummy variables we have the following equation:

$$Y_i = \beta_i + \beta_2 D_{2i} + \beta_3 D_{3i} + \varepsilon \tag{6.1}$$

where Y_i refers to efficiency score

D_{2i} refers to dummy variable taking the value one if the company is a large brewer

D_{3i} refers to dummy variable taking the value one if the company is a small brewer

ε ~ N(0,1) a random noise such as E(ε)=0

The results of the dummy variable regression analysis would be as follows:

$$Y_i = 0.9981545 + -0.0173182\ D_{2i} + 0.0173182\ \beta_3 D_{3i} + \varepsilon$$

t-stat	216.76	-2.66	2.66
p-stat	0.000	0.015	0.015

The results indicate that there is not a significant correlation between the asset size and the efficiency scores because the coefficients are very low. The negative signs of the coefficients show us the relationships are reversely correlated. The bigger asset size the harder to achieve DEA efficiencies. We explain this situation with the hardships brought by economies of scale, economies of scope and decentralization effects. The high levels of t-stat show the greater evidence against the null hypothesis that there is no significant difference.

In this chapter, we examine high levels of DEA efficiency scores for both companies in Turkish brewing industry. Companies have no concerns on predatory advertising strategies and capturing each others' market shares. The frequent government bans and regulations carry out coordinative effects as stated by Tremblay and Iwasaki(et al. 2009)[33]. However, we should not forget that DEA is a comparative method thus relative efficiency scores are conducted. A relatively full efficient company does not mean absolutely fully efficient in all respects. In the next chapter, we evaluate Turkish brewers against their European counterparts to have more clear insights.

Chapter 7
A Comparative Approach to European Brewing Industry

This chapter is a comparative approach to Turkish brewing companies with their European counterparts under the DEA assumption. In section (7.1) we make a brief introduction to European brewing industry. In section(7.2) we use the two-staged profitability-marketability and productivity models to execute productive efficiency scores of 10 brewing companies including Anadolu Efes and Turk Tuborg.

7.1 The Structure of the European Brewing Industry

The European Union is rich with around 4500 breweries. More than 2.5 million people are employed in the brewing industry. With over 400 million hectoliters, it is the second largest beer producer region of the world, which hosts headquarters of the world's largest brewing companies.

European beer industry treats a diverse structure varying from small and middle size entrepreneurs to “big four” Europe based world leading brewers: ABInbev, Carlsberg, Heineken and SAB Miller. In addition,the rise of microbrewery companies, brings innovation potential to beer industry.

As stated in Chapter 4, beer is made up of four main ingredients as: water, yeast, hops and cereals. With a 92 percent level of usage, water is the main ingredient. Therefore, protection of ground water and efficiency improvements for sustainability are critical in beer production. Besides efficiency concerns of water usage, other factors like the quality of barley, and other harvests and price volatility of agricultural products significantly have impact on the industry. The brewing industry is highly dependent on the agriculture sector. 2008 economic crisis and decline in consumption before 2011 led important changes for brewing companies. Some of the structural recovery steps for aftermath of 2008 ecconomic downturn were:

1.Investments outside the EU region by the national and international groups and, 2.Growth of microbreweries which brought diversity.

As we see in Figure 7.1. Western Europe and Eastern Europe were behind of other regions in terms of annual growth rates due to government intervention and recession effects.

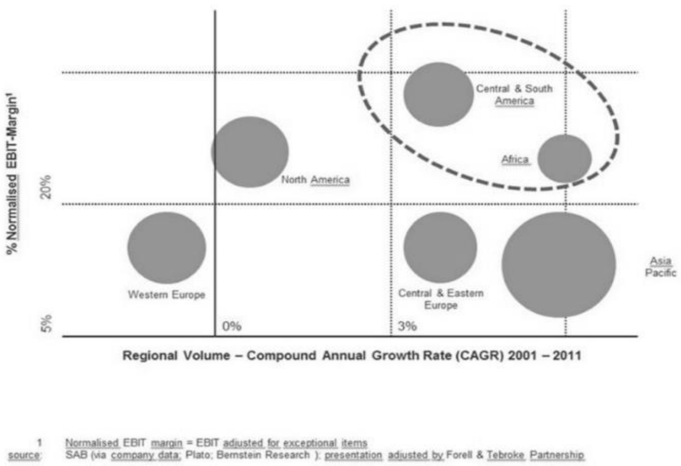


Figure 7.1: Compound Annual Growth Rate of Regions

Recently, European beer industry has been facing some obstacles such as : 1.Insufficient recovery, 2.Declining employment and 3.Challenging tasks.

After a decline period, over the years 2011 and 2012 European beer market showed a recovery albeit a slow one. Comparing to the six percent mean inflation, a positive progress was made within the industry which still did not create a recovery. The increase in production of two percent and consumption by one percent, an increase in exports of four percent and a trade surplus of three percent were not enough for the sufficient recovery (see Appendix). Consumption in Europe has been steadily decreasing over the last ten years. Cheap and discounted products are getting more popular while drinking at home becomes more preferable.

According to the Brewers of Europe's Report of 2013[45], off-trade segment was gaining market share over 2011 and 2012, at the expense of the on-trade segment in which beer is usually priced higher. The reduction in purchasing power had a negative impact on the on-trade beer consumption. Over 63 percent of beer production is sold in supermarkets and other retail outlets(the off-trade), the remaining 37 percent is purchased in places like bars, pubs, restaurants called the "on-trade".

The government revenues from beer are increasing due to high excise duties and taxes on employment. Therefore, there is a declining trend in the employment of four percent over the period 2010 and 2012. Comparing to 11 percent decline after 2008 crisis, this value can be counted as a recovery. The biggest decrease in employment was in hospitality sector which is the main source of job opportunities in the industry. This vicious cycle causes decline in jobs is depicted in Figure 7.2 below:

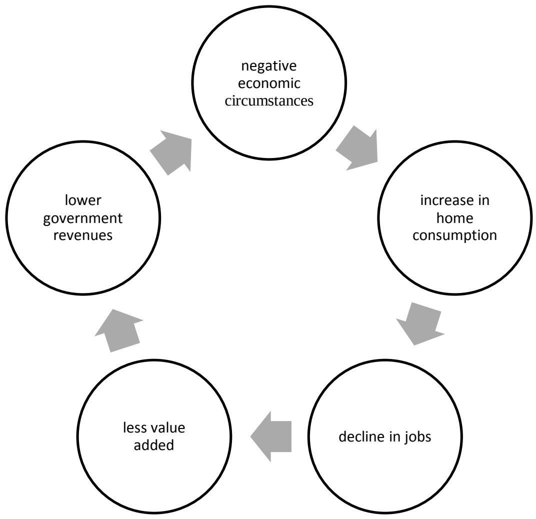


Figure 7.2 : Vicious Cycle of Negative Economic Circumstances

Beer is also subject to standard VAT (Value Added Tax) rate. Therefore, increases in VAT have a direct impact on the pricing. Despite the standard VAT rate European brewers benefit from prospering hospitality sector.

Figure 7.2 illustrates the vicious cycle and negative effects of 2008 economic downturn, regarding to decline in employment, value added, and government revenues. All values treat as declining trends from 2008 to 2010 then a recovery has been made. However, a steady decrease existed in employment mainly from the hospitality sector rather than main brewing activities (see Figure B.1 and Figure B.2 ,Appendix).

In the last period, beer companies focused on developing new products and gaining further access in the hospitality sector. Furthermore, they focused on optimizing process and expanding to export regions. With rapid growth of microbreweries, the industry became highly competitive than before. However, this situation may be turned into a positive cycle as seen in Figure 7.3 below. This positive cycle is a part of the structural recovery after 2008 downturn.

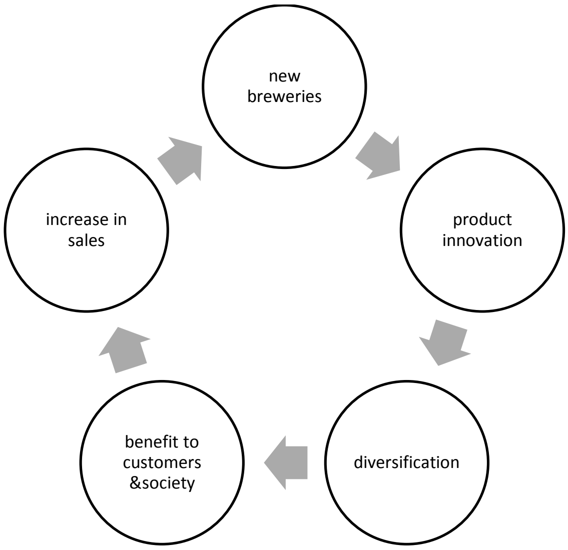


Figure 7.3: Effects of Positive Economic Circumstances

Brewing sector provides a wide range of job opportunities for the agricultural sector, hospitality sector and retail sector. The industry employs more than 2 million people in the European continent, including direct employment of more than 130,000 people. Over 75 percent of this workforce is employed in the hospitality sector. However, the employment level fell 9 percent between 2008 and 2010 due to the reduced consumption. The sector focused on some improvements like reducing water usage (4.5%), energy usage (3.8% per hectolitre) and reducing CO_2 emission (7.1%)in between 2008 and 2010. Increasing water quality is one of the examples for the sustainability efforts. In addition to the main production line, secondary products from brewing process like pharmaceuticals, health foods, agricultural products have been taken seriously in the account to help maintaining productive efficiency and sustainability.

For further success of the industry, we refer a report written by Forrell et al. (2009)[20]. Forrell suggested three tasks as: 1.The trend towards value, 2.Focus on differentiation and , 3.Building your own strategy.

Recently,a volume-centric approach has been replaced by value management in many industries. Red Bull is a good example having factors for success like conviction, speed,sustainability, and persistence. In an industry where fierce competition takes place, only product differentiation and efficiency improvements can be supportive for success. In the Turkish market, Turk Tuborg replaced Anadolu Efes' residual demand at the expense of reaching to price –oriented customers, as an example of differentiation. Despite saturation to customer demands, there is still room for the new entrants those who own their particular strategies. Creating a niche or premium product line, focusing only on export channels or diversification in products are some examples of these strategies.

Governments receive a significant amount of revenues by excise, VAT and income taxes from brewing companies. Besides these continuously increasing taxes, social contributions paid by workers and their employers of brewing companies and related sectors are additional revenues to government economies. Increasing taxes directly affect the brewing industry and indirectly hospitality sector negatively. However, there is no correlation between the excise duty rates and excise duty revenues (see Figure B.4, Appendix). The composition of government revenues collected from beer industry is seen in Figure B.5 (see Appendix). Main entries of revenue for the government are: income taxes and social security contributions from the other sectors like hospitality.

Turkey, comparing to other countries with similar GDP per capita in Europe, is considered to be at very low levels of beer consumption per capital (See Figure B.6, Appendix). However, Turkey employs a more significant contribution to European economy by production volume. Anadolu Efes takes seventh place in European brewing industry, which is comparatively successful considering the tough competition including the "big four" brewers.

7.2 DEA Efficiency Measurements of the European Brewing Industry

Descriptive Statistics

In this study, Turkish brewing companies, Anadolu Efes, and Turk Tuborg are examined within a peer group of European companies. Ten companies are subject to DEA efficiency evaluations, including the big four: ABInbev, Carlsberg, Heineken and SAB Miller.

Peer group includes mainly brewing companies as well as producers of other alcoholic beverages, wine, and soft drinks. These companies and their country origins are alphabetically: Anadolu Efes Biracilik ve Malt Sanayi AS(Turkey), Anheuser-Busch Inbev SA ADR(Belgium), Carlsberg A/S ADR(Denmark), C&C Group PLC ADR(Ireland), Grupa Zywiec SA(Poland), Heineken NV ADR(Netherlands), Remy Cointreau(France), Royal Unibrew A/S(Denmark), SAB Miller PLC ADR(Great Britain), Turk Tuborg Bira ve Malt Sanayi AS(Turkey).

The output and input variables are used to perform a correlation analysis as seen in Table 7.1 below. In the profitability stage, the highest correlation is 0.9658 and found in between assets and shareholders equity. The lowest correlation is 0.2647 and found in between operating profit and consumption per capita.

Table 7.1: Coefficients of Correlation for Variables in the Profitability Stage

	Assets	Equity	Consumption p.Capita	Revenues	Profit
Assets	1.0000				
Equity	0.9856	1.0000			
Consumption p.Capita	0.2807	0.2757	1.0000		
Revenues	0.9295	0.9406	0.3208	1.0000	
Profit	0.9614	0.9495	0.2647	0.8960	1.0000

In the marketability stage, as seen in Table 7.2 below the highest correlation is 0.9447 and found in between operating profit and market capitalization. However, we can not conclude these two variables are indicators for each other. The lowest correlation is -0.1973 and found in between ROA and revenue. This finding may raise the question if some of the companies are not utilizing their capitals properly to generate revenues and profits.

Table 7.2: Coefficients of Correlation for Variables in the Marketability Stage

	Revenues	Profit	EPS	Market Cap.	ROA
Revenues	1.0000				
Profit	0.9217	1.0000			
EPS	0.6037	0.6261	1.0000		
Market Cap.	0.9299	0.9447	0.5518	1.0000	
ROA	-0.1973	-0.0754	-0.0566	-0.0985	1.0000

We apply the two-staged profitability-marketability (see Table 7.3 below) model with some adaptations. In the profitability stage Assets, Shareholders Equity and consumption per capita for the country of origin, serve as input variables. Operating Profit and Revenue serve as intermediary variables (outputs for profitability stage and inputs to the marketability stage of the iterative process). Earnings per Share(EPS), Market Capitalization, Return on Assets (ROA) and serve as output variables for marketability stage.

Table 7.3: Data Source for Input and Output Variables

Profitability	• Assets- I_{11} • Shareholders Equity- I_{12} • Consumption per Capita-I_{13}	• Operating Profit-O_{11} • Revenue-O_{12}
Marketability	• Profit-I_{21} • Revenue-I_{22}	• EPS-O_{21} • Market Cap.-O_{22} • ROA-O_{23}

All of the data is converted into U.S. dollars by using the exchange rate of 31st December each year, which is the date for the end of the accounting period. All values with (*) mark are in million USD besides Consumption per Capita, EPS and, ROA. The values for consumption per capital is in hectoliters, EPS is in USD and ROA is in percentile notion.

In the following Table 7.4 and Table 7.5, we see the descriptive statistics for the input and output variables of the profitability and marketability stages.

Table 7.4: Descriptive Statistics for Input and Output Variables of the Profitability Stage

Statistical Measure	Mean	Std. Dev.	Min	Max
Assets - I_{11}	22198.46	34803.66	73	142550
Equity – I_{12}	8247.906	11813.03	3	50365
Consumption per Capita - I_{13}	56.1433	26.698	12	96
Revenue - O_{11},I_{21}	9282.102	11840.07	48	47603
Operating Profit - O_{12},I_{22}	2054.145	3724.962	-129	20443

Table 7.5: Descriptive Statistics for Input and Output Variables of the Marketability Stage

Statistical Measure	Mean	Std. Dev.	Min	Max
Revenue - O_{11},I_{21}	9282.102	11840.07	48	47603
Operating Profit -O_{12},I_{22}	2054.145	3724.962	-129	20443
EPS - O_{21}	1.9951	2.5307	-2.7967	9
Market Cap. - O_{22}	36534.26	54271.2	210	201030
ROA- O_{23} (in%)	7.5560	7.0048	-5.93	30.37

Data in Table 7.4 and 7.5 is collected from same sources with Chapter 6 for the period 2003-2015.

The following Figure 7.4 is the scatterplot matrix for Profitability stage. Best fit lines produced by Stata software are not linear but mostly forced to pass through the origin. The following Figure 7.5 is scatterplot matrix for marketability stage. Best fit lines produced by Stata software are not linear and not forced to pass through the origin.

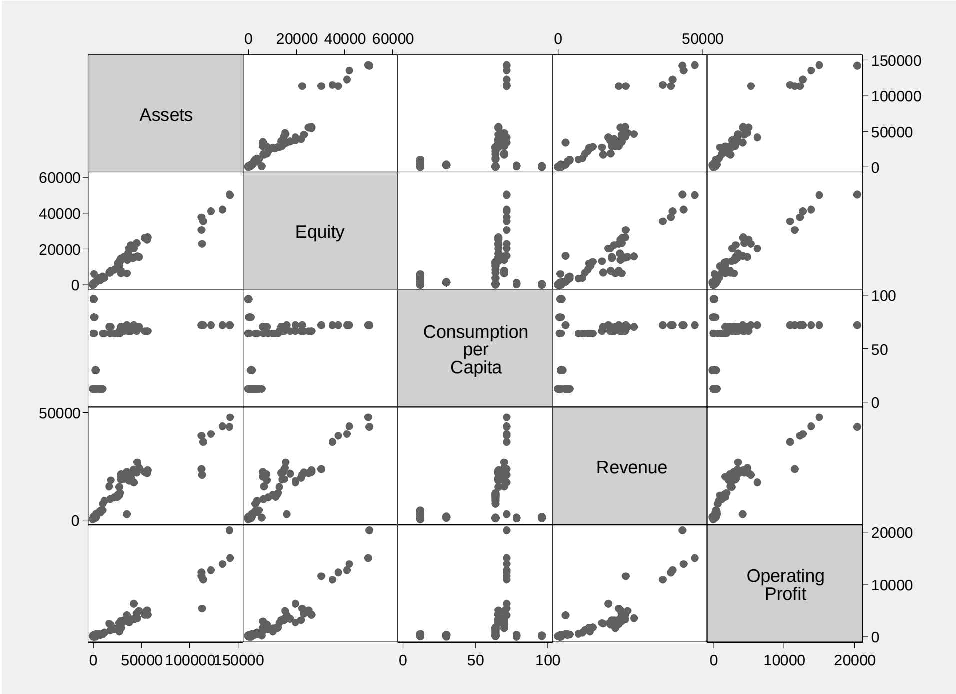


Figure 7.4: Scatterplot Matrix for the Profitability Stage

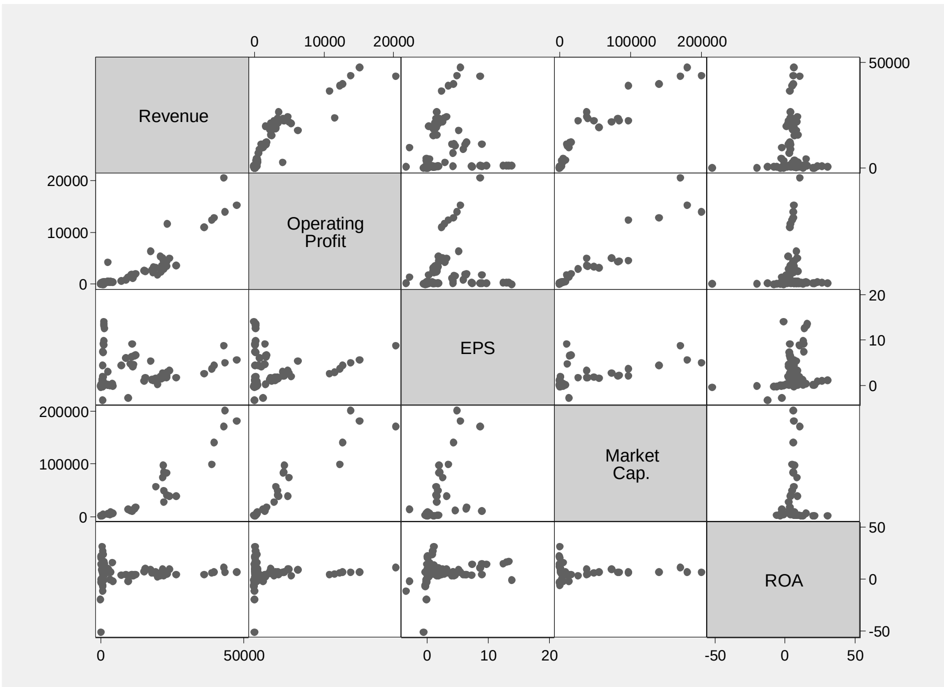


Figure 7.5: Scatterplot Matrix for the Marketability Stage

DEA Results and Conclusions

In Table 7.6 and Table 7.7 below, the first-row average efficiency scores represent Technical Efficiency scores out of 1 (one) where the companies operate on the efficient frontier. Second-row scores with (*) mark represent Cost Efficiency scores and third-row scores with (**) mark represent Allocative Efficiency scores.

From a manager's point of view, controlling and deciding input reduction is easier than output augmentation. Beer is a product consumed freshly, and sunk costs play crucial roles in inventory management. Therefore input orientation should be priority for the management. When we examine the first-row scores, we conclude that companies perform at very high levels of technical efficiencies. Turk Tuborg of Turkey operates on the efficient frontier in both stages while Anadolu Efes operates on the frontier in Probability stage and employs a 0.86 efficiency score in Marketability stage. From these scores, we conclude that brewing companies are successful in using the right amount of resources. However , we do not reach to same conclusion for the allocative efficiencies where using the right proportions of resources is measured.

From the results , we identify that brewing companies perform better in profitability stage than marketability stage, for ten(10) European brewers. According to these scores, we conclude that corporations are showing good performances to generate profits and revenue. They possess competent business management and operation skills. However, their performances in providing superior financial benefits to their shareholders are comparatively inadequate according to the marketing stage DEA efficiency scores. Some of the companies like ABInbew, SAB Miller , and Turk Tuborg perform very successfully in both stages. These brewers have overall good performances regarding integrated infrastructure, human resource management, asset utilization, and cost control to generate a maximum return to their shareholders.

Table 7.6: DEA Efficiency Scores for the Profitability Stage

DMU	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average Scores
Anadolu	1	1	1	1	1	1	1	1	1	1
Efes	0.9407*	0.8565*	0.9575*	0.2131*	0.2365*	0.7345*	1*	0.7968*	0.7330*	0.7187*
	0.9407**	0.8565**	0.9575**	0.2131**	0.2365**	0.7345**	1**	0.7968**	0.7330**	0.7187**
Turk Tuborg	1	1	1	1	1	1	1	1	1	1
	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
	1**	1**	1**	1**	1**	1**	1**	1**	1**	1**
Carlsberg	1	1	0.6041	0.7534	0.7295	0.8385	0.7727	0.8409	0.9369	0.8306
	1*	1*	0.5273*	0.7018*	0.6067*	0.7499*	0.7087*	0.8099*	0.9664*	0.7961*
	1**	1**	0.8728**	0.9315**	0.8316**	0.8944**	0.9171**	0.9632**	0.9694**	0.9311**
Heineken	0.6435	1	1	1	1	1	1	1	1	0.9603
	0.5415*	0.6637*	1*	1*	1*	1*	1*	1*	1*	0.9116*
	0.8416**	0.6637**	1**	1**	1**	1**	1**	1**	1**	0.9450**
Remy Cointraeu	0.4652	0.6117	0.4924	0.6775	0.4622	0.8418	0.8707	0.7367	0.5205	0.6309
	0.2552*	0.2721*	0.2152*	0.2136*	0.1704*	0.4440*	0.5738*	0.4369*	0.7626*	0.3715*
	0.5487**	0.4448**	0.4370**	0.3152**	0.3688**	0.5274**	0.6590**	0.5930**	0.6825**	0.5084**
C&C Group	1	1	0.5307	0.6369	1	0.9294	0.6162	1	0.6100	0.8136
	1*	1*	0.4601*	0.4497*	1*	0.6212*	0.4968*	1*	0.4543*	0.7202*
	1**	1**	0.8601**	0.7061**	1**	0.6684**	0.8062**	1**	0.6098**	0.8500**
SAB Miller	1	1	1	0.9645	1	1	0.8784	0.9056	0.9543	0.9669
	1*	1*	1*	0.8568*	0.9785*	0.9063*	0.8056*	0.7988*	0.9543*	0.9242*
	1**	1**	1**	0.8883**	0.9785**	0.9063**	0.9171**	0.8820**	1**	0.9582**
ABInbev	1	1	1	1	1	1	1	1	1	1
	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
	1**	1**	1**	1**	1**	1**	1**	1**	1**	1**
Royal Unibrew	1	0.7245	0.8140	0.8334	0.7033	1	0.7425	1	1	0.8686
	0.9056*	0.2110*	0.7202*	0.7697*	0.7165*	0.8406*	0.6004*	0.7366*	1*	0.7222*
	0.9056	0.1671**	0.8847**	0.9235**	1**	0.8406**	0.8086**	0.7366*	1**	0.8074**
Grupa Zywiec	1	1	1	1	1	1	1	1	1	1
	1*	1*	1*	1*	0.9472*	1*	1*	1*	1*	0.9941*
	1**	1**	1**	1**	0.8472**	1**	1**	1**	1**	0.9830**

TE:Tecnical efficiency score

*CE:Cost efficiency score

**AE:Allocative efficiency sc

Table 7.7 : DEA Efficiency Scores for the Marketability Stage

DMU	2010	2011	2012	2013	2014	Average Scores
Anadolu	0.8533	0.9672	0.9916	0.4914	1	0.8607
Efes	0.8345*	0.7696*	0.6680*	0.3925*	0.3777*	0.6084*
	0.9779**	0.7957**	0.6737**	0.7986**	0.3777**	0.7247**
Turk Tuborg	1	1	1	1	1	1
	1*	0.3135*	1*	1*	1*	0.8627*
	1**	0.3135**	1**	1**	1**	0.8627**
Carlsberg	0.4956	0.4123	0.6853	0.6766	0.4393	0.5418
	0.4628*	0.3210*	0.3712*	0.4176*	0.2666*	0.3678*
	0.9339**	0.7785**	0.5418**	0.6172**	0.6069**	0.5742**
Heineken	0.5109	1	0.6913	0.8314	0.8262	0.7719
	0.4318*	0.4348*	0.4675*	0.4467*	0.3896*	0.4340*
	0.8452**	0.4348**	0.6763**	0.5373**	0.4716**	0.5930**
Remy Cointraeu	1	1	1	1	1	1
	1*	1*	1*	0.9178*	0.8311*	0.9497*
	1**	1**	1**	0.9178**	0.8311**	0.9497**
C&C Group	1	1	0.9390	1	0.6688	0.9215
	1*	1*	0.8747*	1*	0.3869*	0.8523*
	1**	1**	0.9316**	1**	0.5785**	0.9020**
SAB Miller	1	1	0.9731	1	1	0.9946
	1*	1*	0.9626*	1*	1*	0.9925*
	1**	1**	0.9892**	1**	1**	0.9978**
ABInbev	1	1	1	1	1	1
	1*	1*	1*	1*	1*	1*
	1**	1**	1**	1**	1**	1**
Royal Unibrew	1	1	0.9329	0.8850	0.7838	0.9203
	0.8019*	1*	0.6755*	0.7350*	0.7610*	0.7946*
	0.8019**	1**	0.7242**	0.8306**	0.9710*	0.8655**
Grupa Zywiec	1	1	1	1	1	1
	1*	1*	1*	1*	1*	1*
	1**	1**	1**	1**	1**	1**

TE:Tecnical efficiency score

*CE:Cost efficiency score

**AE:Allocative efficiency score

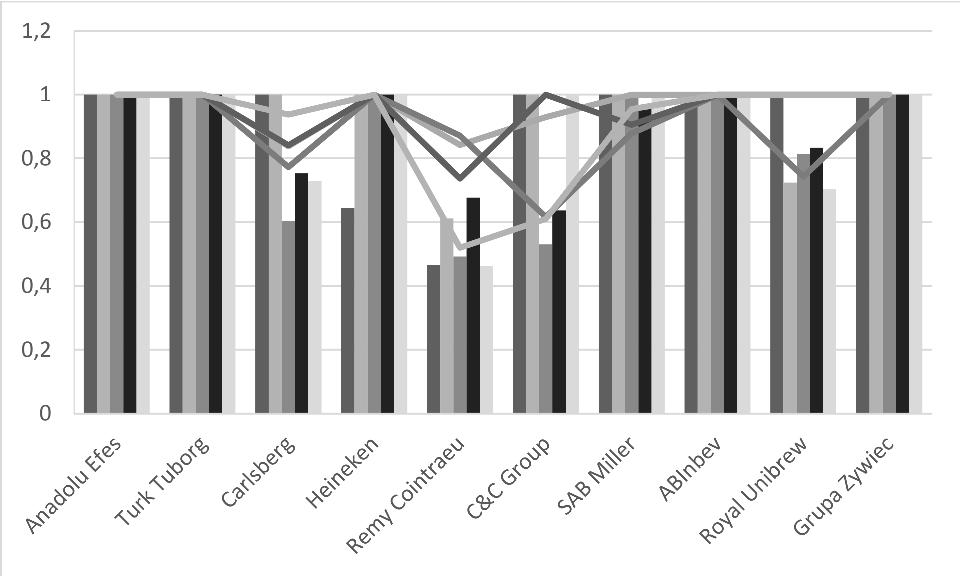


Figure 7.6: Trends for the Profitability Stage DEA Scores

(2007-2015)

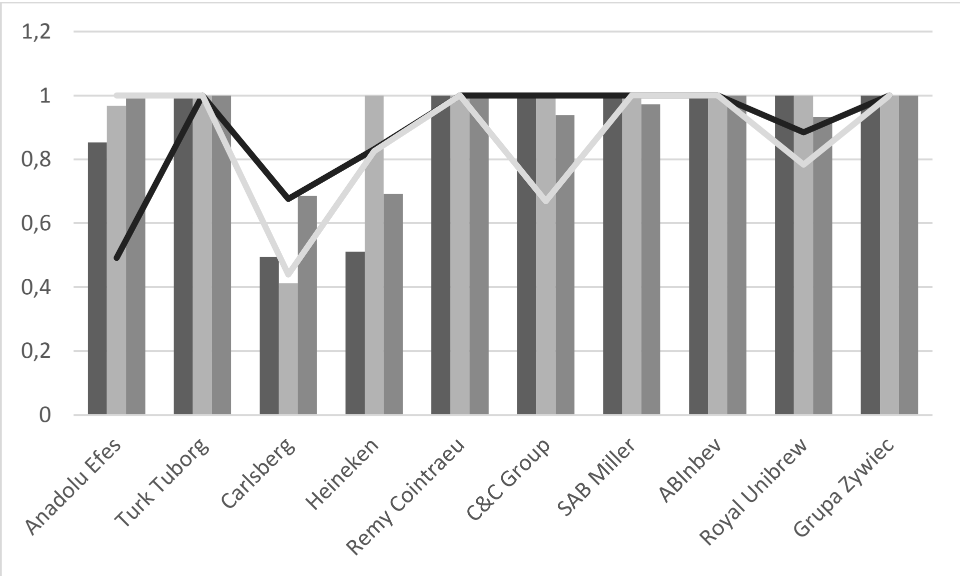


Figure 7.7: Trends for the Marketabiliy Stage DEA Scores

(2010-2014)

According to the Figure 7.6 and Figure 7.7 above the majority of the brewing companies show trends of high DEA efficiency scores in both stages. ABInbev, Grupa Zywiec, and Turk Tuborg operate on the efficient frontiers in both stages. From these scores, we do not conclude a significant correlation between the market sizes and efficiency scores. Anadolu Efes operates on the efficient frontier at the profitability stage and has over 0.80 efficiency scores at the marketability stage. In our calculations, we apply VRS input-oriented model. Therefore, we suggest with 20 percent input reduction, Anadolu Efes can increase its productive efficiency level at the marketability stage.

We adapt a specific analysis called the BCG Matrix (Boston Consulting Group) to our research for a better visual understanding the performance of the observed companies. The BCG matrix named for its creator targets to identify high-growth prospects by categorizing the company's products according to growth rate and market share.

The average scores using TE, CE, and AE helps us to plot positions of each company on a two-axis and four quadrants matrix. The four quadrants are as: “stars”, “cows”, “sleepers”, and “dogs”. The “stars” are located to demonstrate efficiency scores of 1 in each dimension and “dogs” represent the lowest scores in both categories. Figure 7.8 shows distribution of the ten brewing companies on a profitability-marketability BCG matrix. The explanation of four quadrants are as follows:

- **Stars:** The brewing companies belonging to this group have high scores of efficiency in both profitability and marketing stages. Companies found in this quadrant can serve as perfect benchmarking sets to others because they have high technical efficiency scores and some of them also operate on the efficient frontier Anadolu Efes and Turk Tuborg are both located in this quadrant.
- **Cows:** These brewing companies have higher levels of profitability but lower levels of marketability. The firms can be stated as high-profit makers but suffering lower performances in the stock markets. Only Carlsberg is found in this quadrant, with a moderate increase in profit and EPS the company can slide to the “cows” area.
- **Sleepers:** Brewing companies with high marketability but lower profitability efficiencies perform at this level. Only Remy Cointreau performs at this quadrant. The company should pay more attention on profit making progress by using their Assets and Equity.

- **Dogs:** Companies with lower market attractiveness and lower profits are found in this quadrant. No observed brewer operates in this area. In other words,no brewer operates at an inferior profitability and marketability efficiency level.

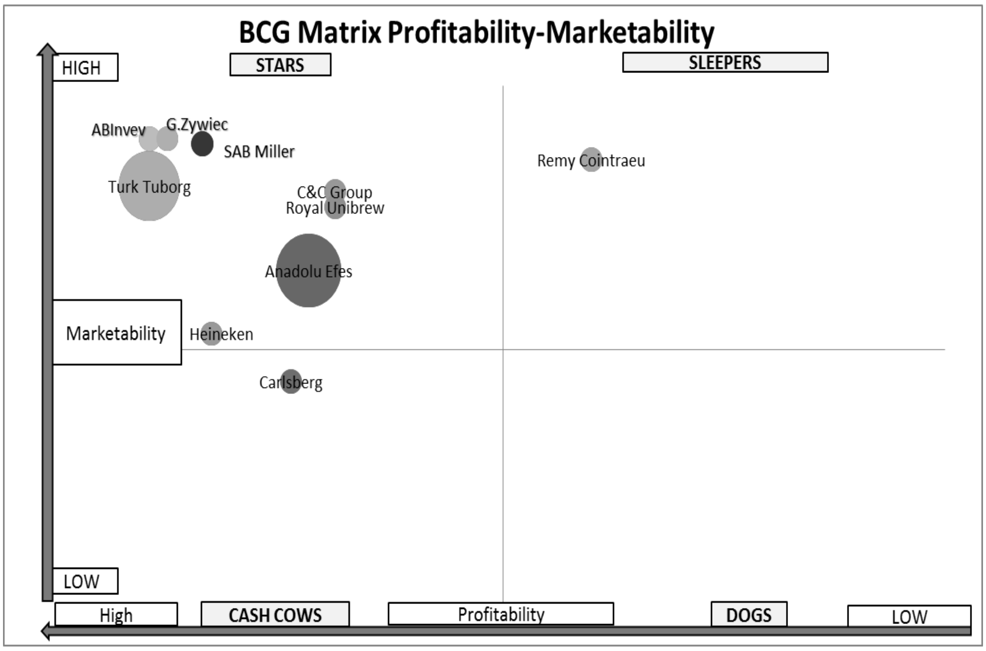


Figure 7.8: BCG Matrix for the Two- Staged Model

In this chapter we evaluate productive efficiencies of Turkish brewers relative to their European counterparts. Turk Tuborg still operates on the efficient frontiers in both stages under a peer analysis including 10 European brewers. Anadolu Efes has 1.00 and 0,86 DEA efficiency scores in profitability and marketability stages respectively, which may be classified as very high levels. With measuring productive efficiency scores of Turkish brewers both in local and international environment ,we offset some of the limitations of DEA.

Conclusions

Summary and Contributions

In this research, we study DEA efficiency evaluations of duopoly companies in Turkish brewing industry. We evaluate, Anadolu Efes and Turk Tuborg localy against each other and against their European counterparts on an international prospect. We use financial statements and financial ratios of each company and execute these variables on user-specific DEA models.

In this research, we use two types of data such as: 1.Financial variables of balance sheets, income statements and cash flow statements from each company's annual reports and, 2.Other type of variables like financial ratios.

Initially, we search studies made on brewing industries and "Data Envelopment Analysis". By using related literature, we adopt user-specific DEA models designed for this research. In the next step, we collect data that meets requirements of the DEA models. Next.we check correlations of input and output variables with each other. Finally, we execute adjusted data on DEA efficiency methodology and conduct scores of decision-making units.

From the results, we conclude that the positions (leader-follower) in the duopoly market and market sizes of these companies have no significant correlations on efficiency scores. Considering economies of scale, it may be favourably arguable that the bigger scale, the more efficiency in the production process. Previous studies stated that companies require six to seven facilities to reach minimum efficient scales (MES) in the brewing industry. Anadolu Efes is the only company that reached MES among Turkish brewers. However, Turk Tuborg shows more efficient results under DEA methodology. Turk Tuborg has around one-fourth (1/4) market share and one twenty-fifth(1/25) assets of Anadolu Efes. This contradictory situation can be explained by centralizational organization structure Turk Tuborg's focus on a premium product line from residual demands of Anadolu Efes.Turk Tuborg is categorized as a macro (mass) brewer for the production and sales volume. However, it treats like a micro brewery for its focus on the product line and brand aware customer portfolio. This characteristic helps Turk Tuborg operate on the efficient frontier.

Anadolu Efes, in addition to being Turkey's largest brewery, has most of its money earned through sales of sparkling beverages rather than beer. Operating income and revenue for the company has been growing for the last five years. When the company decided to include Coca-Cola Turkey in its consolidated financial statements, EPS and net income increased, resulting higher DEA efficiency scores. Anadolu Efes' business is stable and well-diversified. Receiving 15 percent of revenue from beer and the rest from soft drinks protects the company against uncertainties due to religious risks in the country. Separating non-alcoholic beverages from total revenues and evaluating beer only DEA efficiencies remains a task for further studies.

In Turkish brewing industry we examine both companies have different strategies. Anadolu Efes concentrates on capturing the market size and maintaining the economies of scale. This company reduces risks of Islamic abolition and conservative government by expanding overseas and preserving 80 percent of its production line to soft drinks. On the other hand Turk Tuborg concentrates on residual demands of Anadolu Efes with its loyal customer portfolio. From DEA scores we conclude Turk Tuborg sets a centralized organization structure with one big factory in Izmir to achieve efficient operations.We can classify Anadolu Efes as the market leader whereas Turk Tuborg as the efficieny leader. There is no profit maximization competition among duopoly companies. The government regulations and bans bring coordinative effects over the market which is consistent with similar conditions of U.S. tobacco industry[33]. Due to Islamic abolition the total customer demand is saturated at 17-18 percent of total population.

This research has several contributions as follows:

1) A DEA approach was applied to the Turkish brewing industry as a novel methodology.

2) User-specific models reflect different objectives on the DEA efficiency evaluations. Any user can execute productive efficiencies on any industry by using a similar approach.

3) We are able to reveal hidden facts and results by DEA, rather than regression analysis or other well-known methods.

4) DEA scores give management a different perspective to indicate inefficient units. With the transfer of expertise and management support these inefficient units can be improved.

5) The methodology applied in our research can be easily adapted to DEA efficiency measurements on other fields. The selection of input and output variables for each model would be at the discretion of the researcher's purposes. For example depending on the industry, either a capital intensive or labor intensive structure may affect the results more than other. For example, the cash flow statement and trade data may provide more valuable information on a model for

the banking industry. Further examples may be given to explain industry based scenarios and their effects on DEA efficiency measurements.

Finally, this thesis has practical contributions to applications of social and economic behaviours. For researchers, the same methodology can be applied to other industries in DEA efficiency evaluations. For creditors by using DEA, inefficient units can be revealed, and required improvements can be done. For investors, this model (see Figure C.1) can be used to identify efficient and inefficient companies, helping one to invest more in efficient companies. The Figure C.1 as follows illustrates the modelling of our methodology that is applicable to other industries, with minor changes depending on the researcher's objectives.

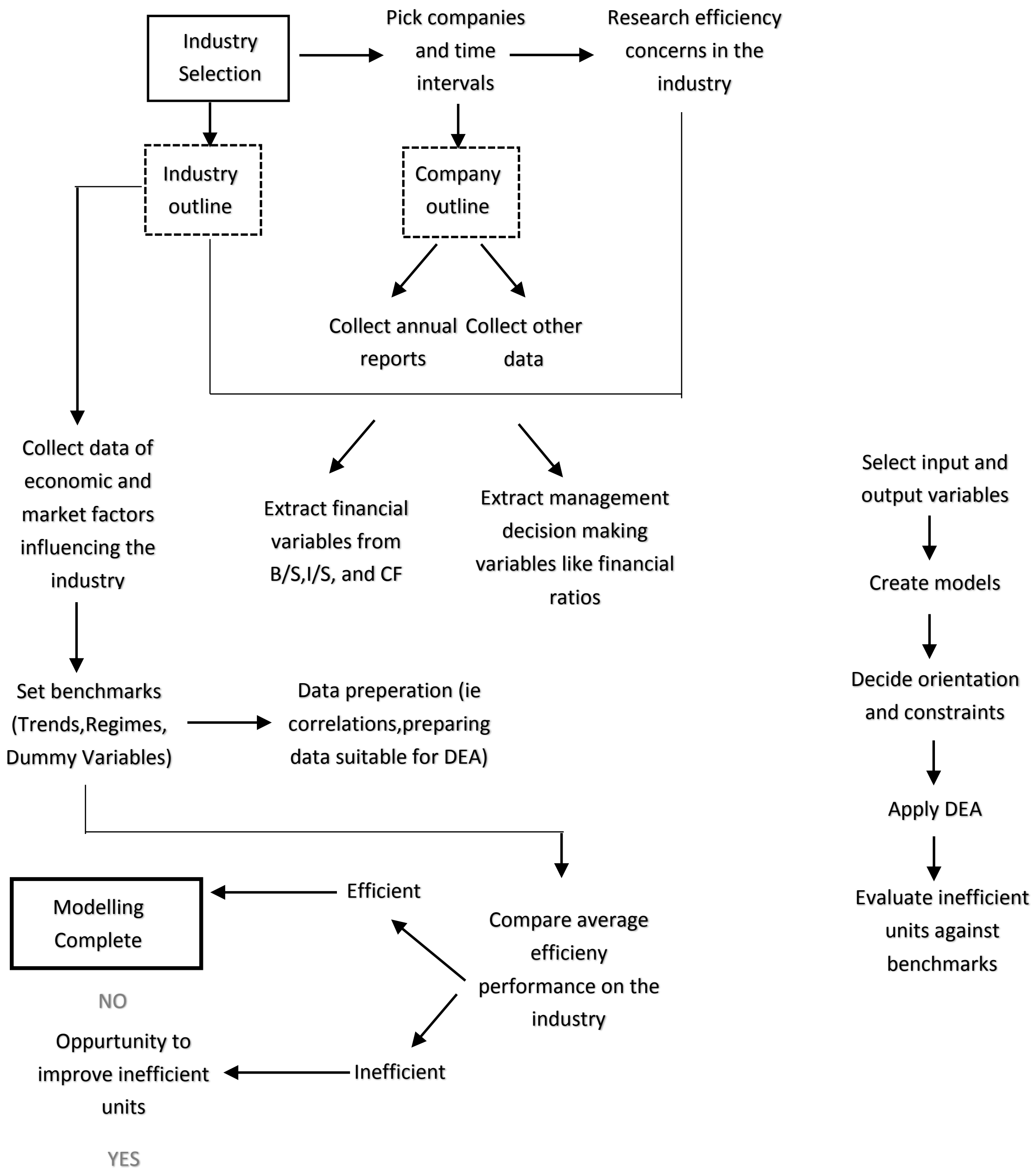


Figure C.1: Modelling Methodology Applicable to Other Industries

Finally, we foresee that several recommendations can be made for future studies as follows:

i. Studying the impact of external factors on the Turkish brewing industry.
ii. Effects of laws, regulations and bans on efficiencies. A study was made by V.J.Tremblay and N.iwasaki et al. (2009)[33] on the U.S.tobacco industry to indicate these effects. They divided the history of the U.S. tobacco industry into regimes shaped by government interventions and compared efficiencies on these regimes. We suggest a complementary study to be done which includes a clear comparison of efficiency scores before and after the bans and regulations.
iii. Studying quarterly and monthly data to examine the seasonality effect. Because sale amount of beer varies by seasons.
iv. A comparison of the results conducted by DEA results and regression analysis.
v. The impact of market shares on efficiency evaluations. This study can be made using historical data from the start of the industry to today.
vi. Analyzing companies by further decomposing into segments. For example, Anadolu Efes has the exclusive rights to the sales and distribution of Coca-Cola. Both segments financial reports are prepared on consolidated base with no distinction. Further analysis can be made by a segmentational approach (i.e. beer only segment, malt the only segment, bottling and canning the only segment).
vii. Adding information which is excluded from financial statements such as:

   -Advertising and promotion costs separately. Because these expenses are published together under Sales, Distribution and Advertising item of the Income Statement.

   -The number of employees by departments.

   -Fixed and variable costs.

   -Decomposition of raw material costs.

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APPENDIX

A Supplementary Tables and Figures for the Turkish Brewing Industry

Table A.1: Characteristics of Turkish Brewing Industry

	2008	**2009**	**2010**	**2011**	**2012**	**Δ2008-2012**
Total production (in hectoliters)	9,244,384	10,219,290	10,278,536	10,163,665	11,013,188	+19.1%
Brewing companies	7	7	7	7	7	0.0%
Breweries(including microbreweries)	11	11	11	11	11	0.0%
Microbreweries	5	5	5	5	5	0.0%

Source: Tobacco and Alcohol Market Regulatory Authority and the Beer and Malt Producers' Association of Turkey (2013) ,Datamonitor 2012 [15]

Table A.2: Beer Producing Companies in Turkey

Beer company	**Number of breweries**	**Number of brands**
Anadolu Efes	5	17
Turk Tuborg	1	8
Park Gida	1	1
Sural Holding	1	1
Elif Tourism	1	4
Istanbul Turizm	1	3
Feza Gida	1	3
Total	11	37

Source: Questionnaires BMUD 2013,Datamonitor 2012 [15]

Table A.3 : Beer Cider &FABs ,Turkey Production Volume by Category

(litres m),2007-2011

Category	2007	2008	2009	2010	2011	CAGR
Beer	901.7	925.0	937.6	951.1	965.5	1.4%
FABs	1.0	1.0	1.0	1.0	1.0	0.2%
Cider	0.2	0.2	0.2	0.2	0.2	0.1%
Total	902.9	926.3	938.8	952.3	966.8	1.4

Source: Datamonitor 2012 [15]

Table A.4: Beer, Cider and FABs Expenditure per Capita

(Turkish Lira),2007-2011

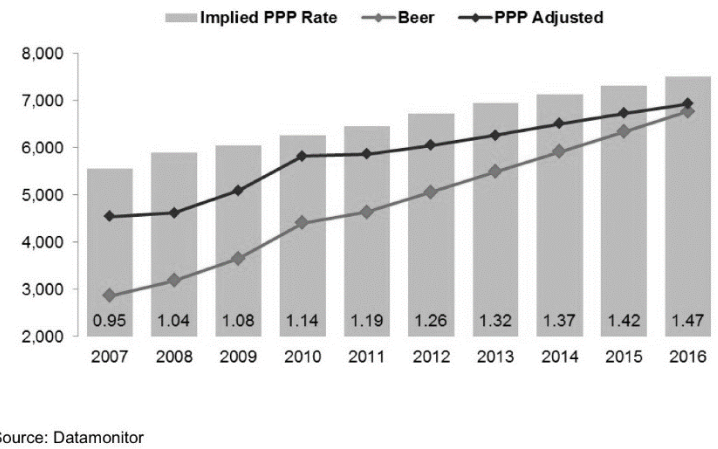
Category	2007	2008	2009	2010	2011	CAGR
Beer	57.7	63.4	71.6	85.4	88.7	9.0%
FABs	0.1	0.1	0.1	0.1	0.1	-0.03%
Cider	0.02	0.02	0.02	0.02	0.02	-005%
Total	57.8	63.5	71.7	85.5	88.8	9.0%

Source: Datamonitor 2012 [15]

Table A.5 : Beer,Cider an FABS Consumption per Capita(Turkish Lira),2007-2011

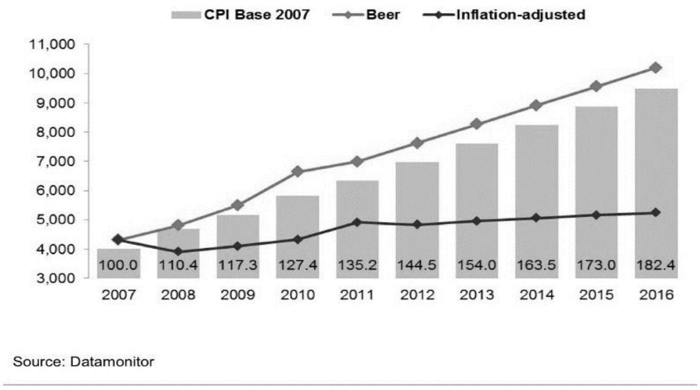
Category	2007	2008	2009	2010	2011	CAGR
Beer	12.1	12.2	12.2	12.2	12.3	0.3%
FABs	0.1	0.1	0.1	0.1	0.1	-0.9%
Cider	Below 0.01	Below 0.01	Below 0.01	Below 0.01	Below 0.01	-0.9%
Total	12.1	12.2	12.2	12.2	12.3	0.3%

Source: Datamonitor 2012 [15]



Source: Datamonitor 2012 [15]

Figure A.1: Beer, Purchasing Power Adjusted Market Value (US dollars in m (2007-2016)



Source: Datamonitor 2012 [15]

Figure A..2: Beer, Inflation Adjusted Market Value(US dollars m (2007-2016)

B Supplementary Tables and Figures for the European Brewing Industry

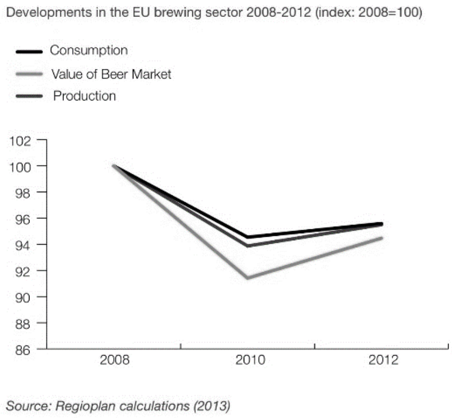


Figure B.1: Developments in the Impact of the EU Brewing Sector (2008-2012) [45]

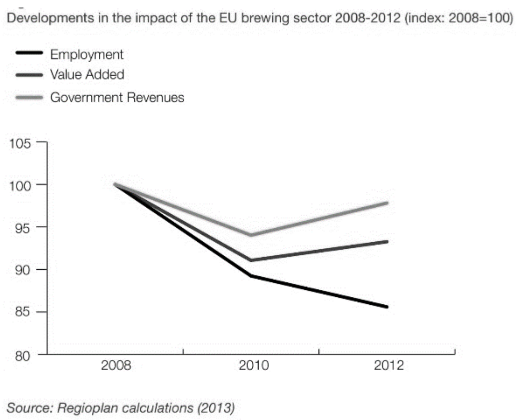


Figure B.2: Relationship Between Excise Duty Rate Changes and Development of the Revenues (2008-2012) [45]

Assumptions: capacity 0.4 ml,6.2 the h per year operation

Item	**Ratio /hl beer produced**	**Cost USD/hl beer produced**
malt	18 kg	5
hops (cones)	0.15 kg	0.5
yeast(thick)	0.61	0
fuel	150 MJ	0.7
electricity	12kWh	1.2
water	0.7m3	0.3
waste water treatment	0.55m3	1.1
space part	lumpsum	1.2
Miscellaneous	lumpsum	1.3
labour (120)	(USD 20000/year)	6
Total		17.3

Source: H.Marina et al...2004 “Efficiency and concentration in the Ukranian brewing industry.”

Figure B3: European Standard Plant Operation Costs [32]

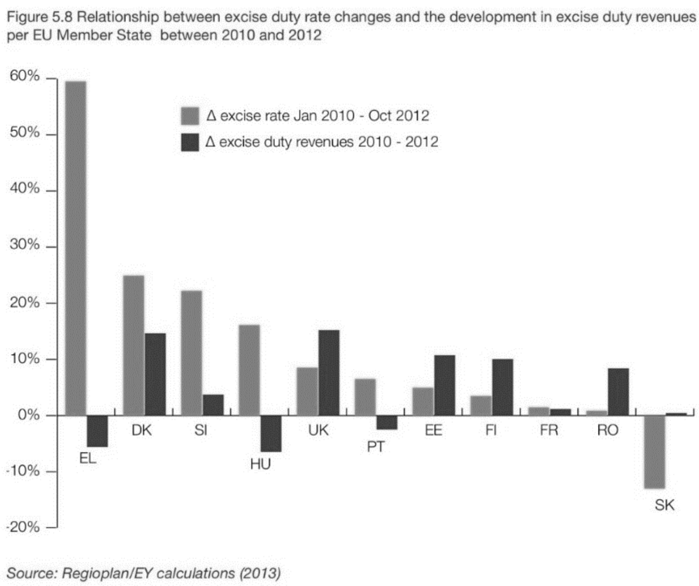


Figure B. 4: Developments in the European Union Brewing Sector (2010-2012) [45]

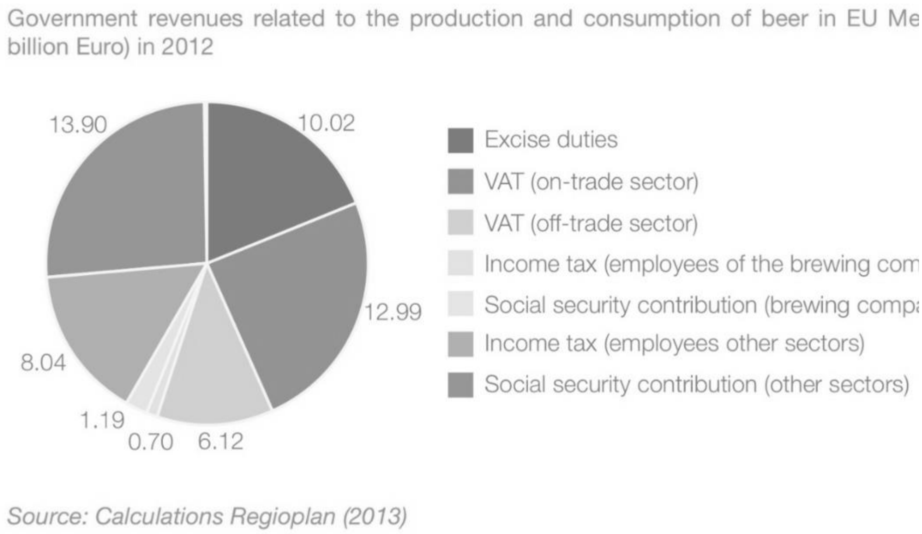
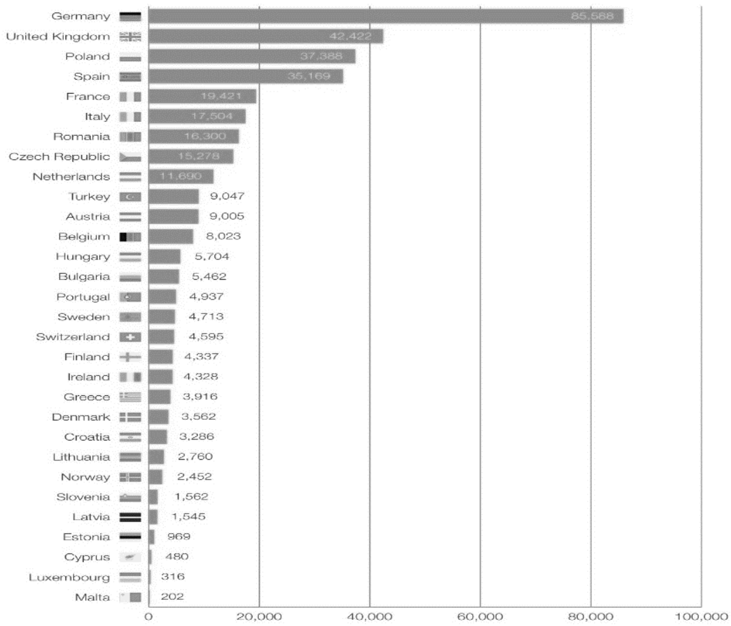
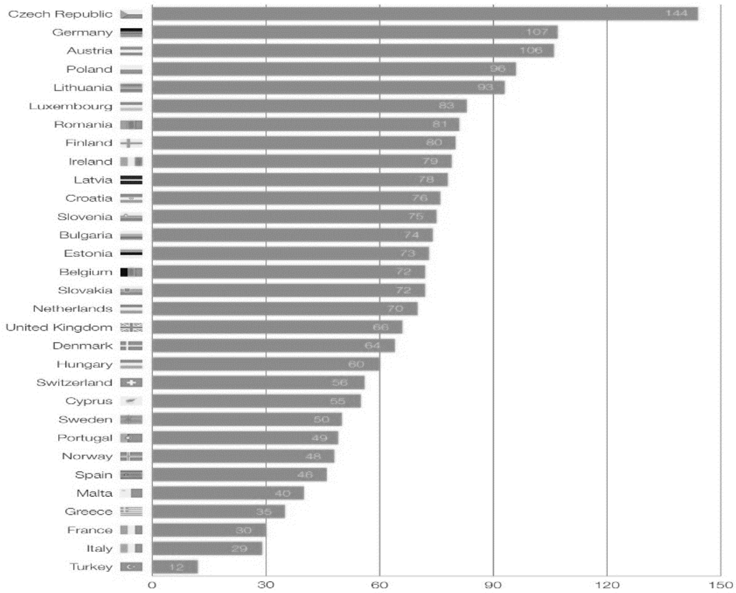


Figure B.5: Government Revenues Related to the Production and Consumption of Beer in EU(2012) [45]



Source: The Brewers of Europe 2012 [45]

Figure B.6: Beer Consumption in Europe in 1,000 Hectolitres



Source: The Brewers of Europe 2012 [45]

Figure B.7: Beer Consumption per Capita in Europe in Liters

C Supplementary Tables and Figures for the Financial Statement Analysis and Financial Ratios

Standards of Financial Statements

International Accounting Standard (IAS): The international accounting standards (IAS) is a set of standards stating how particular types of transactions and other events should be reflected in financial statements. These standards have been issued by International Accounting Standards Board(IASB) since 2011. Many countries like Turkey require the financial statements to be prepared in accordance with IAS.

International Financial Reporting Standards(IFRS): IFRS are designed as a common global language for business affairs so that the company accounts are understandable and comparable worldwide.

Both Anadolu Efes and Turk Tuborg prepare their annual consolidated financial statements under IAS and IFRS.

Balance Sheet

Table C.1: The Balance Sheet Components

Assets: Assets are valuable resources owned by an entity. Assets are classified into two types: current assets or non-current assets. They are shown on the balance sheet in decreasing order of liquidity.	
Current Assets	They are assets that a company expects to convert to cash or use up within one year. Common types are prepaid expenses, inventories, receivables, short-term investments and cash.
Non-current Assets	They are assets that are expected to be useful for longer than one year. Common types are: intangible assets, PPE (property, plant, and equipment), long-term investments and long-term notes receivable.
Liabilities: The claims of creditors and outside parties are called liabilities. There are two types of liabilities: current and non-current liabilities.	
Current Liabilities	They are obligations that a company has to pay within the coming year. Common Examples are accounts payable, wages payable, bank loans payable, interest payable and taxes payable.
Non-current Liabilities	They are obligations that a company expects to pay after one year. They include bonds payable, mortgages payable, long-term notes payable, lease and pension liabilities.
Shareholders' Equity: The ownership interests in the company are represented in the final section of the balance sheet called shareholders' equity. It is the residual interest in assets that remains after deducting liabilities.	

The Income Statement

The income statement begins with a presentation of sales revenue. By deducting sales returns and allowances and discounts, we get net sales. This can be designed as below:

Illustration C.1: Computation of net sales

Sales Revenues

Sales

Less:Sales returns and allowances

Sales discounts

Net sales

Companies use net sales as some sales revenue. The deducting cost of goods sold from net sales we get gross profit. This step can be designed as below:

Illustration C.2: Computation of gross profit

Net sales

Cost of goods sold

Gross profit

Operating expenses are the next component in the income statement of a merchandising company. They are expenses included in the process of earning sales revenue. The operating expenses are illustrated as below:

Illustration C.3.Operating expenses

Operating expenses

Salaries expense

Utilies expense

Advertising expense

Depreciation expense

Freight-out

Insurance expense

Total operating expenses

Other income and expense in the next step consist of various revenues and gains; expenses and losses unrelated to the main line of the company. Examples of other income and expenses are as follows:

Illustration C.4: Other income and expenses

Other Income

Interest revenue from notes receivable and marketable securities.

Dividend revenue from investment in ordinary sales.

Rent revenue from subleasing a portion of the store.

Gain from the sale of property, plant, and equipment.

Other Expense

Casualty losses from causes such as accidents.

Loss from the sale or abandonment of property, plant, and equipment.

Loss from strikes by employees and strikes.

Financing activities, which result in interest expense, represent distinctly different types of cost to business. After deducting the interest expense from other income and expenses we reach net income as illustrated below:

Illustration C.5: Net Income

Other income and expenses

Interest expense

Net Income

Cash Flow Statement

Table C.2: Components of Cash Flow Statement

<table>
<tr><th>Cash Inflows</th><th>Activities</th><th>Cash Outflows</th></tr>
<tr><td rowspan="2">From sale of goods and services to customers</td><td rowspan="6">OPERATING ACTIVITIES</td><td>To pay wages</td></tr>
<tr><td>To purchase inventory</td></tr>
<tr><td rowspan="2">From sale of marketable securities</td><td>To pay expenses</td></tr>
<tr><td>To pay interest</td></tr>
<tr><td rowspan="2">From receipt of interest or dividends on loans or investments</td><td>To pay taxes</td></tr>
<tr><td>To purchase marketable securities</td></tr>
</table>

Table C.3: Components of Cash Flow Statement

Cash Inflows	**Activities**	**Cash Outflows**
From sale of property, plant and equipment and other long-term assets	**INVESTING ACTIVITIES**	To purchase property, plant, and equipment and other long-term assets
From sale of short-term marketable securities and long-term investments		To purchase of short-term marketable securities and long-term investments

Table C.4: Components of Cash Flow Statement

Cash Inflows	**Activities**	**Cash Outflows**
From sale of preferred or common stock	**FINANCING ACTIVITIES**	To reacquire preferred or common stock
From insurance of debt		To repay debt
		To pay dividends

Financial Ratios

Table C.5 : Liquidity Ratios

Current ratio	$=\frac{\text{Current Assets}}{\text{Current Liabilities}}$	It measures an entity's short-term debt paying ability.
The Quick ratio	$=\frac{\text{Cash} + \text{Securities} + \text{Receivables}}{\text{Current Liabilities}}$	It measures an entity's short term debt paying ability.
Receivable turnover	$=\frac{\text{Net Sales}}{\text{Average Accounts Receivable}}$	It measures average number of days receivables are turned into cash during an accounting period.
Days' sales uncollected	$=\frac{\text{Days in Year}}{\text{Receivable Turnover}}$	It measures the average number of days an entity must wait to receive payment for credit sales or to collect accounts receivable.

Table C.6 : Profitability Ratios

Profit margin	$=\frac{\text{Net Income}}{\text{Net Sales}}$	It is the percentage of each sales amount that contributes to net income.
Asset turnover	$=\frac{\text{Net Sales}}{\text{Average Total Assets}}$	It measures how efficiently assets are used to produce sales.
Return on assets(ROA)	$=\frac{\text{Net Income}}{\text{Average Total Assets}}$	It measures how efficiently an entity uses its assets to produce income.
Return on equity(ROE)	$=\frac{\text{Net Income}}{\text{Average Shareholders' Equity}}$	It is the relationship the amount earned by a business to the owner's investment.

Table C.7 : Long Term Solvency Ratios

Debt to equity ratio	$=\frac{\text{Total Liabilities}}{\text{Shareholders}'\text{Equity}}$	It is the proportion of an entity's assets financed by creditors and the proportion financed by the owner.
Interest coverage ratio	$=\frac{\text{Income Before Income Taxes} + \text{Interest Expense}}{\text{Interest Expense}}$	It measures the degree of protection of an entity has from default on interest payments.

Table C.8 : Cash Flow Adequecy Ratios

Cash flow yield	$=\frac{\text{Net Cash Flows from Operating Activities}}{\text{Net Income}}$	It measures an entity's ability to generate operating cash flows in relation to net income.
Cash flow to sales	$=\frac{Net\ Cash\ Flow\ from\ Operating\ Activities}{Net\ Sales}$	It is the ratio of net cash flows from operating activities to sales.
Cash flow to assets	$=\frac{Net\ Cash\ Flows\ from\ Operating\ Activities}{Average\ Total\ Assets}$	It measures the ability of assets to generate operating cash flows.

Table C.9 :Market Stregth Ratios

Price/earnings ratio	$\frac{\text{Market Price per Share}}{\text{Earnings per Share}}$	It measures the investors confidence in an entity's future.
Dividends yield	$=\frac{\text{Dividend per Share}}{\text{Market Price per Share}}$	It measures a stock's current return to an investor or stockholder.