# QUARTERLY PERFORMANCE AND STABILITY PATTERNS OF THE TURKISH LARGEST COMMERCIAL BANKS IN 2003-2009 PERIOD: AN APPLICATION OF DATA ENVELOPMENT WINDOW ANALYSIS

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## Abstract
*After the 2001 financial crises, in a new macroeconomic environment with low inflation, Turkish banks increased loans in order to maintain profitability and made efforts to operate efficiently to support their sustainable growth. In this context, this study evaluates dynamic efficiencies and is monitoring stability patterns for Turkish banks, between the periods of December 2003 – March 2009 in a quarterly basis. A two-stage analysis is performed on the financial ratios of largest Turkish banks which control vast majority of the market by total assets. Firstly, in order to deal with the proper variables to measure financial performance, the objective importance weights of the pre-selected financial ratios are determined via Shannon's "entropy" measure. With these relative weights, a performance index of the sector during the analysis period is calculated and presented. After choosing the most important ratios as input and output variables, we evaluate the relative efficiency patterns of large Turkish banks via Data Envelopment Window Analysis over a period of 22 quarters with a window width of 4 (a year).*

***Keywords:*** *Efficiency; DEA; Turkey, Banking, Financial Performance*

***JEL codes:*** *G01, G21, C14*

## 1. Introduction

After the negative effects of the financial crisis in 2001, Turkish banking sector has been experiencing more competitive pressure due to financial globalization, and change in macroeconomic climate. In recent years, Turkish economy can generally be characterized by falling interest and inflation rates, decreasing public sector borrowing requirement, raising economic activity in the real sector, and capital inflow. These developments led to a rapid growth in the banking sector and raising foreign fund entry but, incurred lower profit margins.

Hence, faced with a more competitive environment, banks had to account for expenses and loan losses while increasing their loan supply to became more profitable.

Therefore, it became more crucial for all stakeholders of the banks to continuously analyze the overall performance of the sector and efficiencies of the similar banks relative to each other. A great number of researches are devoted to banking sector performance analysis. One approach is to analyze the ratios between the financial statement table items to explore performance. They show different financial dimensions of a bank such as profitability, liquidity, credit risk and the intermediation function. Accounting for different aspects provide a multi-dimensionally and overall picture of performance. But there are different aspects of performance which usually contradict each other, e.g., liquidity versus profit. In this context, Multicriteria Decision Making (MCDM) approach and its methods are powerful tools to evaluate global performance via an aggregation of these aspects (DIAKOULAKI et. al., 1995; THANASSOULIS et. al., 1996; ALESKEROV et. al., 2004, SECME et. al., 2009). One weakness in this approach is its requirement from the user to determine the significance of individual criteria in the analysis. Such significance reflects the relative importance of criteria represented by their respective weights. Based on this analysis units can be ranked from the worst to the best performer or can be discriminated as good or bad ones. The auditing agencies use such methods in order to give ratings to firms or countries In this context, the financial performance of banks is generally measured by the internationally accepted ratio-based “CAMEL” methodology (DERVIZ and PODPIERA, 2008; BROCKETT, et. al., 1997: 252-253). In this methodology the ratios related to Capital adequacy, Asset quality, Management, Earnings, and Liquidity as obtained from banks’ financial statements are considered to measure performance. The simplest way of monitoring the development of the sector in a compound measure is to aggregate the indicators within a weighted sum and observe its variation over time. Banking Regulation and Supervision Agency (BRSA) in Turkey is computing and presenting such a performance index since the end of 2003.

The second approach is the efficiency analysis in which inputs and outputs of a production function are defined and weights of them are derived by means of an optimizing calculation. Based on that, units can be classified into efficient and inefficient, i.e. distinguish the efficient banks from the inefficient ones. In these studies both parametric and non parametric methodologies were used. There are many banking efficiency studies in the global literature (e.g., see DRAKE et. al., 2009; BERGER and HUMPHREY, 1997, reviews). The Turkish banking sector was also studied using both parametric and non-parametric approaches. ZAIM (1995), YOLALAN (1996), JACKSON, FETHI and INAL (1998), ISIK and HASSAN (2002), MERCAN et. al. (2003), OZKAN-GUNAY and TEKTAS (2006), DENIZER et. al. (2007) can be listed as preliminary studies, among others. Non-parametric Data Envelopment Analysis (DEA), and the parametric Stochastic Frontier Approach (SFA), are most widely used methodologies to assess the relative efficiencies of decision making units (DMUs) which are similar in terms of goods and services produced, and it yields a single dimensionless performance index without a priori assumption of some formal analytic production function (MERCAN 2003: 91; COOK and SEIFORD, 2009).

In this study, we perform a performance evaluation and dynamic efficiency analysis dealing with three important complications listed in bank efficiency and performance studies. These are the need for sample homogeneity, proper variable selection, and treating with time series data. (DENIZER et. al., 2007).

Since DEA provides an efficient frontier in terms of comparisons in between DMUs in a sample, homogeneity of the units is a crucial assumption. Utilizing homogeneity can ideally be provided by studying with small samples which contain units having similar characteristics (SARKIS, 2007). To determine homogeneity and heterogeneity of data sets, there are well-known clustering analysis techniques. We used in this study the Ward's method helps identify homogeneous groups on a number of similarity aspects (criteria) (HAIR, et. al., 1998; ROMESBURG, 2004).

Due to the fact that banks perform multi-input / multi-output production processes modeling efficiency measurement approach and selection of inputs and outputs significantly affect the results (MERCAN, et. al., 2003; DENIZER et. al., 2007). This issue is related with the assumption made on the bank production process. Two mainstream approaches in this concept are the "production approach" and the "intermediation approach". The former assumes banks as producers of various services for their customers, and the latter as intermediaries in transferring funds from depositors to lenders for profit.

In this study**,** in order to deal with the proper variables to measure financial performance and to construct an objectively weighted banking sector performance index, the objective importance weights of the pre-selected financial ratios are determined via Shannon's "entropy" measure (SHANNON and WEAVER, 1947). This indicates the contrast intensity of the banking sector in each period with respect to each ratio. With these relative weights, a performance index of the sector during the analysis period is calculated and presented.

The other important issue in efficiency evaluation is related to the use of time series data. DEA is typically applied to cross-section data to analyze productive efficiency but can be applied to panel data to analyze the variation of efficiency over time, as well. There are two main DEA based approaches which utilize dynamic efficiency measurement. One is the "Malmquist DEA" approach which developed by FARE et. al. (1994) and uses DEA to analyze panel data by constructing a Malmquist type of index of productivity change. The other is a technique called "DEA Window Analysis" proposed by CHARNES et. al. (1985), which is an extension of the original version. It uses DEA to analyze panel data by converting a panel into an overlapping sequence of windows (a standard number of sub periods) which are then treated as separate cross sections.

Window analysis assesses the performance of a DMU over time by treating it as a different entity in each time period. It works on the principle of moving averages and is useful to detect performance trends of a unit over time. In doing so, the performance of a unit in a particular period is contrasted with its performance in other periods in addition to the performance of other units. This results in an increase in the number of data points in the analysis, which can be useful when dealing with small sample sizes as the case in this study. Hence, when there are a small number of decision making units and a large number of input output variables and periods it is proper to use this method to detect the efficiency and stability trends over time.

There are a number of studies which utilizes DEA Window Analysis in banking (HARTMAN and STORBECK, 1996; YUE, 1992; WEBB, 2003; ASMILD et. al, 2004). The banking industries which can be defined as oligopolies with a few number of large participants controlling about 90% of the market, as the case in Turkey, to evaluate the industry's performance over time there is a need to deal with the problem of a small number of DMUs compared to the number of relevant inputs and outputs. To overcome this problem using data envelopment analysis (DEA) window analysis might be a proper choice.

In line with above mentioned issues the idea and general formulation of our approach is as follows:

This study provides an analysis on the sector performance, relative efficiency and stability patterns of the largest Turkish commercial banks over the 22 quarter period from the $4^{th}$ quarter of 2003 up to the $1^{st}$ quarter of 2009. The banks initially included in the analyses are ten largest commercial banks operating in Turkey control 86 % of the total bank assets by the end of the analysis period. Three of them are foreign banks, 3 are state-owned banks and 4 are the largest Turkish private banks. All are commercial banks.

In the study, first by using a well known cluster analysis method it is showed that two of the state banks among others had significantly different structural characteristics, hence for the sake of homogeneity, only the results of the performance analysis of eight banks are evaluated and presented. Then a ratio analysis provided and an objectively weighted performance index on the CAMEL ratios is developed. Since we have a small number of banks and a large number of periods, in order to increase the discriminatory power of DEA, we use window analysis technique for the efficiency analysis. Finally, the empirical results and the observed efficiency trends are discussed and interpreted, in terms of the Turkish economic conditions during the study period.

The rest of this paper is organized as follows. In Chapter 2 we provide a brief review of the impacts of the 2001 crises and the period after that until today. Chapter 3 introduces the methodology (Ratio Analysis with the Entropy Method, and DEA window analysis) and data, variables used and the results of the empirical application on performance and efficiency dynamics of Turkish Banking are presented and discussed. Chapter 4 concludes the paper.

## 2. Development in the Turkish Banking Sector After the 2001 Crisis

### *2.1 Impacts of the 2001 Crisis, Structural Reforms and Growth in Turkish Banking Sector in 2002 – 2008 Period*

In the year 2001 a deep financial crises affected all the economy and especially the banking sector in Turkey. Some of the impacts of this crisis on the banking sector can be seen from the Table 1.

It can easily be seen from Table 1 that, between the years 2000 and 2001, all of the indicators of the banking sector worsened. After overcoming the impacts of 2001 crises, i.e., between the years 2003 and 2008, Turkish Banking Sector showed a rapid growth performance. Positive developments recorded by the system due to the favorable domestic and international macro economic situation concurrently with the restructuring process on the banking sector. This process was first started with the “Disinflation Programme” as of end of 1999 and followed by the “Banking Restructuring Program” in 2001. In this period the Banking Regulation and Supervision Authority (BRSA) was established as a regulatory and financial authority with administrational and financial autonomy in banking sector (TBA, 2009 p. 5).

**Table 1 Main Structural Indicators of the Turkish Banking System**

| | ***2000*** | ***2001*** | ***2002*** | ***2003*** | ***2004*** | ***2005*** | ***2006*** | ***2007*** | ***2008*** |
|---|---|---|---|---|---|---|---|---|---|
| *Number of Banks* | **79** | **61** | 54 | 50 | 48 | 47 | 46 | 46 | 45 |
| *Number of Branches* | **8298** | **7386** | 6160 | 6029 | 6440 | 6240 | 6911 | 7700 | 8768 |
| *Share of 10 largest banks by Total Assets (%)* | 69,2 | 79,5 | 80,8 | 82,3 | 84 | 82,9 | 83,5 | 82,5 | 82,8 |
| *Share of Foreign Equity* | **3,4** | **3,0** | 3,3 | 3,0 | 3,5 | 6,3 | 13,1 | 14,0 | 17,0 |
| *Foreign Funds Entry (Billion USD)* | **3,8** | **2,8** | 11 | 17 | 22 | 36 | 49 | 61 | 62 |
| *Liquid Assets (Billion USD)* | **31,9** | **26,6** | 20,9 | 26,0 | 32,2 | 47,1 | 52,8 | 64,5 | 66,3 |
| *Total Assets (Billion USD)* | **154,9** | **115,0** | 129,7 | 179,3 | 229,3 | 295,8 | 344,9 | **484,1** | **463,8** |
| *Financial Assets (net) (Billion USD)* | **17,8** | **11,7** | 52,5 | 76,7 | 92,6 | 106,6 | 119,7 | **151,7** | **136,6** |
| *Borrowed Loans (Billion USD)* | **22,1** | **12,3** | 10,9 | 14,8 | 20,6 | 32,6 | 40,4 | 51,0 | 51,4 |
| *Deposits (Billion USD)* | **101,9** | **80,9** | 86,8 | 115,4 | 147,7 | 188,9 | 222,6 | **307,9** | **297,9** |
| *Loans (Billion USD)* | **50,9** | **28,3** | 34,4 | 50,2 | 77,3 | 114,1 | 155,1 | **241,9** | **241,1** |
| *Non-Performing Loans (Net) (Billion USD)* | **2,17** | **2,97** | 2,28 | 0,71 | 0,57 | 0,57 | 0,54 | **0,98** | **1,6** |
| *Shareholders' Equity (Billion USD)* | **75,1** | **67,3** | 156,7 | 255,1 | 343,9 | 400,5 | 412,5 | **633,9** | **543,4** |

*Source: TBA*

Banking Restructuring Program first coped with solving the financial problems and restructuring of 20 banks under Savings Deposit Insurance Fund (SDIF) control during the period of 1996-2003. Secondly, considerable public resources were transferred to state-owned banks in order to strengthen their capital and to make settlement of the "duty losses", which had reached 50 percent of their balance-sheets at the end of 2000. At the third stage, a program was adopted for reinforcement of the equity capital of private banks whose asset quality was deteriorated and equity capital rapidly melted down. In the restructuring period, as a result of legislative measures implemented by the BRSA, banking legislation was aligned with international regulations, particularly the EU directives, and works for incorporating the infrastructural elements of new Basel Capital Accord (Basel-II) was started. A program, known as the "Istanbul Approach" was also introduced in June 2002 for a period of three years, for restructuring the companies' debt to the financial sector (TBA, 2009: 6).

## *2.2 Global Fluctuations in the analysis period and reflections of 2008 Crisis on the Turkish Banking Sector*

A growth was experienced in the global economy in 2003 but after 2004 in United Kingdom and USA, inflation began to increase. Due to the rigid money policies held by these states in 2004 the short-term interest rates increased, as well. In 2005 raising energy and asset prices caused pressure on inflation. Although in 2006 there were pessimistic expectations on the growth performance rise in USA due to the decline in mortgage demand and industrial production index, these were compensated by sustained growth performance in EURO area and Japan. But, these developments caused expectations on the capital outflow from the developing country economies, such as Turkey, and therefore fluctuations on the financial markets experienced. Thanks to real sector performance which was not affected by these fluctuations, financial sector's recovery happened in a short time period.

Beginning from 2007, global developments led to a rapid contraction in the world economy and financial markets and deceleration in trade volume. Starting from the last quarter of 2008 in particular, the global issues have had considerable reflections in Turkey, whose foreign trade volume reached 50 percent of its gross domestic product. Both domestic demand and external demand decreased. Output and income declined. External financing became more limited and the public sector borrowing requirement increased.

When the global developments began to affect the banking system, the currency risk of banks remained very limited. Due to the reflections of the global crises on the banking sector; the external borrowing possibilities for banks became more limited. Credit risk increased as the ratio of nonperforming loans to total loans (gross) was 3.1 percent in the third quarter of 2008 and rose to 5.2 percent in July 2009. The share of securities-portfolio in the total assets increased by 4 to 30 percent on the year-end (TBA, 2009:6). The effects of the global crises in the Turkish Banking System could also be seen from Table 1. As indicated by bold characters; the indicators of assets, deposits and non-performing loans got worsened at the end of the year 2008.

# 3. Performance and Efficiency Dynamics of Turkish Banking: Methodology, Data and Application

## *3.1 Methodology: Bank Performance and Efficiency Evaluation with Time Series Data*

There are two mainstream approaches in performance evaluation in time periods. In an *intertemporal* efficiency analysis, the observations for the banks in different periods are treated as separate observations, and all are measured against each other. It is reported in ASMILD et. al. ( 2004: 81) that in an efficiency analysis this assumption may not be reasonable due to the changes in technology, regulation, economic conditions or the competitive situation. Hence it would be unfair to make comparisons of DMUs in different periods as if there is a single best practice frontier which spans all over the analysis period. ASMILD et. al, (2004) also state that, alternatively using a number of *contemporaneous analyses* each including only observations from one time period could be an ideal approach. This is, however, not possible for an efficiency evaluation due to the small number of DMUs.

In order to avoid this problem we use a compound ratio analysis on the sector mean values of the selected ratios and utilizing a MCDM approach to evaluate bank sector performances separately for every period. For the efficiency analysis of the banks relatively to each other in a dynamic manner, DEA window analysis approach is selected with a window width of four quarters (a year). This meant that observations are only compared to other observations within a year time span. The window width of four periods is selected to be as small as possible to minimize the problem of unfair comparisons, in order to increase the discrimination power of DEA analysis over time and make the seasonal affects observable.

### 3.1.1 Performance Evaluation via Multi-criterial Weighted Sum Method (WSM) and Determining Criteria Importance

Performance evaluation can be treated as a particular multicriteria problem, in which $n$ Decision Making Units (DMUs_Banks) $A_1 \ldots A_n$ to be evaluated in terms of $m$ criteria (performance indicators), $X_1 \ldots X_m$ forming a decision matrix denoted by $X = (x_{ij})_{n \times m}$ and can be given as

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{bmatrix} \quad (1)$$

where $x_{ij}$ is the performance ratings (financial ratios, values) of each alternative $A_i$ with respect to each criteria $X_j$ (DENG et. al., 2000: 965).

In many applications criteria are grouped into "benefit" and "cost" categories. Benefit or "maximization" criteria (profit, income, etc.) are the ones whose values are considered to be as the larger the better, and the cost criteria (loss, expense, etc.) are required to be "minimized". In order to ensure the commensurability among different criteria and to create an aggregate single index, the decision matrix **(1)** usually needs to be normalized. One of the commonly used normalization method in this context is given as follows (HWANG and YOON, 1982: 30-31)

- for benefit criteria: $z_{ij} = \dfrac{x_{ij}}{x_j^{\max}}$ (2)

- for cost criteria: $z_{ij} = \dfrac{x_j^{\min}}{x_{ij}}$ (3)

where $x_j^{\max} = \max\limits_i x_{ij}, \forall j$ and $x_j^{\min} = \min\limits_i x_{ij}, \forall j$. This normalization provides a linear scale transformation, hence the relative order of values of $z_{ij}$'s and $x_{ij}$'s remain equal. All criteria now can be treated as benefit.

Let $Z = (z_{ij})_{n\times m}$ be the normalized decision matrix which is formed by substituting $z_{ij}$'s into $x_{ij}$'s in **(1)** and $w = (w_1,..w_m)$ be the weight vector of the criteria, which satisfies w ≥ 0 and $\sum_{j=1}^{m} w_j = 1$. Then, according to the Simple Additive Weighting (SAW) method in MCDM, the overall performance value of each DMU is computed by

$$SAW = \sum_{j=1}^{m} z_{ij} w_j \qquad (4)$$

which is a linear function of criteria weights. The bigger SAW rating means a better performance value (HWANG and YOON, 1982: 99).

There are multiple stakeholders or decision makers (DMs) of various interests in a bank performance evaluation problem, so it is a difficult task to reach an agreement on the relative importance of the financial ratios and which should be used. In order to overcome this problem, a number of objective weighting processes are available to determine criteria importance. The objective weights of the financial ratios can be determined by Shannon's entropy concept, (SHANNON and WEAVER, 1947; PALEPU, 1985). This measure is based on the context-dependent concept of informational importance and well suited for measuring the relative contrast intensity of the banks performance ratings with respect to each financial ratio. Hence, weight computed by this measure indicates the amount of decision information that each financial ratio contains (ZELENY, 1982: 189; HWANG and YOON, 1981: 99).

Formally, the entropy method begins with a normalization process using the values of matrix *Z* by the following specific formulation:

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^{m} z_{ij}}, \forall i, j \tag{5}$$

The amount of decision information contained in the matrix $P = (p_{ij})_{n \times m}$ and emitted from each criterion can thus be measured by the entropy value $E_j$ as

$$E_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}, \forall j \tag{6}$$

where $k = 1/\ln n$ is a constant which guarantees $0 \leq Ej \leq 1$.

The degree of divergence, $d_j$, of the average intrinsic information contained by each criterion $X_j$ can be calculated as

$$d_j = 1 - E_j, \forall j \tag{7}$$

where $d_j$ represents the inherent contrast intensity of the criterion $X_j$. The more divergent performance ratings $p_{ij}$ for the criterion $X_j$ and the higher its corresponding $d_j$ means the more important criterion $X_j$ for the problem (DENG, 2000: 190). This reflects that a criterion is less important for a specific problem if all alternatives have similar performance ratings for that criterion.

The objective weight for each criterion Cj is thus given by

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, \forall j \tag{8}$$

Since Ej is less than or equal to one, the entropy weights are therefore always positive.

Calculated objective weights of the criteria then can be used in the equation in **(4)** and SAW performance ratings of DMUs can be determined.

### 3.1.2 Efficiency Evaluation via Data Envelopment Analysis: Basic Models

Data envelopment analysis (DEA) originally introduced by CHARNES et al. (1978) is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision making units (DMUs) in a static manner.

Formally in DEA, considering n DMUs, (i = 1...n), it is assumed that each *i-th* DMU produces an output vector $\mathbf{y}_i = (y_{1_1},..., y_{ik}) \in \mathrm{R}_{+}^{k}$ using an input vector $\mathbf{x}_i = (x_{1_1},..., x_{im}) \in \mathrm{R}_{+}^{m}$. Here, *m* shows the number of inputs and *k* indicates the number of outputs. Hence, the "input matrix", $X \in \mathrm{R}_{+}^{mxn}$, and the "output matrix", $Y \in \mathrm{R}_{+}^{kxn}$, represent the data set for all DMUs. Taking $u \in \mathrm{R}_{+}^{m}$ and $\mathrm{v} \in \mathrm{R}_{+}^{k}$ as the input and output weights respectively for the *i-th* DMU, its relative efficiency score, $h_i$ is obtained by solving the following model:

$$Maks\ h_i = \frac{vY_i}{uX_i} \tag{9}$$

$$s.t. \quad \frac{vY_i}{uX_i} \leq 1 \tag{10}$$

$$u, v \geq 0 \tag{11}$$

The above problem is run n times to identify the relative efficiency scores of all the DMUs. The efficiency of a DMU defined by the above equation is the ratio of a weighted sum of outputs to weighted sum of inputs. Differently from the MCDM approach, here each DMU has a flexibility to select input and output weights that maximize its efficiency score, therefore n sets of optimal weights may vary among each DMUs. In general, a DMU is considered to be efficient if it obtains a score of 1 and a score of less than 1 implies that it is inefficient.

It is difficult to solve **(9-11)** because of its fractional objective function. By forcing either nominator or denominator of the ratio **(9)** to be equal to one and getting a linear objective function; a linear programming problem is obtained and can be solved easily. Additionally, using the duality property in linear programming, one can derive an equivalent "envelopment" form of this problem which is shown below (COELLI et. al., 2005: 163).

$$Min\ \Phi_i \tag{12}$$

$$s.t. \quad Y\lambda \geq y_i \tag{13}$$

$$X\lambda \leq \Phi x_i \tag{14}$$

$$\lambda \geq 0 \tag{15}$$

where $\Phi_i$ is a scalar, whose obtained value indicates the efficiency score for i-th DMU rated relative to the other DMUs. It always satisfies $\Phi_i \leq 1$, with the value of 1 indicating a point on the frontier and hence technically efficient firm according to FARRELL (1957) definition of relative efficiency. Here $\lambda = (\lambda_1, \lambda_2, ..., \lambda n)$ is a nx1 vector of weights assigned to each DMUs. The assumptions made on this vector determine the shape of the efficient frontier (envelopment) and the production return to scale (BANKER and THRALL, 1992).

With the constraint **(15)** above model assumes the Constant Return to Scale (CRS) production frontier, alternatively, with constraints

$$\lambda \geq 0, e^T \lambda = 1 \tag{16}$$

the Variable Return to Scale (VRS) (convexity) assumption is made. Model 12-14 with **(15)** is first introduced by CHARNES et. al. (1978) and with **(16)** is proposed by BANKER et. al. (1984).

This model compares the efficiency of *i-th* DMU with all possible linear combinations of other DMUs, by seeking a virtual unit characterized by inputs $X\lambda$ and outputs $Y\lambda$, which is better than the inputs and outputs of *i-th* DMU, i.e., $X\lambda \leq x_i$ and $Y\lambda \geq y_i$. The *i-th* DMU is rated efficient ($\Phi_i$ =1) if no such a virtual unit exists or if the virtual unit is identical with the unit evaluated, i.e. $X\lambda = x_i$ and $Y\lambda = y_i$. Otherwise it is rated inefficient ($\Phi_i < 1$). The above linear programming problem is run n times to identify the relative efficiency scores of all the DMUs.

### 3.1.3 DEA Model Extension: Detecting Dynamic Efficiency Trends via DEA Window Analysis

In order to capture the variations of efficiency in multiple time periods, "DEA Window analysis" model was proposed by CHARNES et al. (1985) as an extension of the original form **(13-16).** Windows analysis is a time dependent version of DEA. This model assesses the performance of a DMU over time by choosing a "window" of w observations for each DMU, and treating these as if they represented w "different" DMUs. Hence, in the analysis, a total of n x w units are evaluated; w different scores for each DMU are created. Thus, each DMU is not necessarily compared with the whole data set, but instead only with alternative subsets of panel data. In doing so, the performance of a unit in a particular period is contrasted with its performance in other periods in addition to the performance of other units. This results in an increase in the number of data points in the analysis, which can be useful when dealing with small sample sizes.

A DEA window analysis works on the principle of moving averages (YUE 1992), e.g., by moving the window by one period and repeating the analysis, both the stability of a DMU for any point in time across different data sets, as well as efficiency trends across the *w* observations for a DMU within the same data set can be detected.

Formally, consider *n* DMUs *(i = 1,…,n)* which produce *k* outputs by using *m* inputs and which are observed in *T* periods *(t = 1,…,T)*. The sample thus has $n \times T$ observations, and an observation *i* in period *t*, $DMU_i^t$ has an *m*-dimensional input vector $\mathbf{x}_i^t = (x_i^{1t},..., x_i^{mt})$ and *k*-dimensional output vector, $\mathbf{y}_i^t = (y_i^{1t},..., y_i^{kt})$. The window starting at time *s* $(1 \le s \le T)$ and with the width *w* $(1 \le w \le T\text{-}s)$ is denoted by *sw* and has $n \times w$ observations. Then the matrices of inputs and outputs are denoted as follows: (ASMILD et. al, 2004: 70).

$$X_{sw} = \begin{bmatrix} x_1^s & x_2^s & \dots & x_N^s \\ x_1^{s+1} & x_2^{s+1} & \dots & x_N^{s+1} \\ \dots & \dots & \dots & \dots \\ x_1^{s+w} & x_2^{s+w} & \dots & x_N^{s+w} \end{bmatrix}, \quad Y_{sw} = \begin{bmatrix} y_1^s & y_2^s & \dots & y_N^s \\ y_1^{s+1} & y_2^{s+1} & \dots & y_N^{s+1} \\ \dots & \dots & \dots & \dots \\ y_1^{s+w} & y_2^{s+w} & \dots & y_N^{s+w} \end{bmatrix} \tag{17}$$

Substituting these matrices for each DMU ($n \times w$ observations) into models **(13-16)**, the efficiency ratings for each *i-th* DMU in the whole time period *t*, beginning at *s-th* period and the windows with the width of *w*, *i.e.,* the optimal score for $\Phi_i^{swt}$, can be obtained by the following model:

$$Min\, \Phi_i^{swt} \tag{18}$$

$$s.t. \quad Y_{sw}\lambda \ge \mathbf{y}_i^t \tag{19}$$

$$X_{sw}\lambda \le \Phi \mathbf{x}_i^t \tag{20}$$

$$\lambda_n \ge 0, \ (n = 1,\dots, n \times w) \tag{21}$$

The above problem is run n times to compute the relative efficiency scores for each of the DMUs (ASMILD et. al., 2004: 70).

## *3.2 Data, Application and Results*

### 3.2.1 Sample Selection: Clustering Largest Banks

This study provides an analysis on the banking sector performance, relative efficiency and stability patterns of ten largest Turkish commercial banks over the 22 quarters in between 4th quarter of 2003 and 1st quarter of 2009. Financial data of the banks were obtained from the data base released by the Banks Association of Turkey (TBA). The banks initially included in the analyses and their ownership structures with their shares in the sector are given in Table 2 in alphabetical order. These ten largest commercial banks operating in Turkey control 86 % of the total bank assets by the end of the analysis period.

**Table 2 Banks included in the analysis**

| *Bank* | *Abbreviation* | *Ownership Structure** | *Share in The Sector by Total Assets (%)*** |
|---|---|---|---|
| Akbank T.A.S. | AKBNK | Turkish Private | 11,7 |
| Denizbank A.S. | DENIZ | Foreign | 2,8 |
| Finans Bank A.S. | FINBN | Foreign | 3,8 |
| ING Bank A.S. | INGBN | Foreign | 2,2 |
| T.C. Ziraat Bankası A.S. | ZRBNK | State-owned | 15,0 |
| T. Garanti Bankası A.S. | GARAN | Turkish Private | 13,1 |
| T. Halk Bankası A.S. | HALKB | State-owned | 7,3 |
| T. IS Bankası A.S. | ISBNK | Turkish Private | 7,8 |
| T. Vakıflar Bankası T.A.O. | VAKBN | State-owned | 7,8 |
| Yapı Kredi Bankası A.S. | YKBNK | Turkish Private | 9,0 |

(*) BRSA classification. (**) As of March 2009.

Selection of a proper sample as homogeneous as possible is meaningful and required within the DEA relative efficiency measurement. In ALESKEROV et. al. (1997) and ALESKEROV et. al. (2001) it was shown that Turkish banking sector shows a heterogeneous characteristic. It is also stated in MERCAN et. al. (2003: 193) that some banks on their balance sheets may indicate a high share of loans and deposits or a high share of FX, others may rely heavily on funds borrowed from abroad or have a relatively high security stock in their total assets vis-à-vis other banks. Hence, to avoid institution-specific structural characteristics from the sample set is a valuable effort.

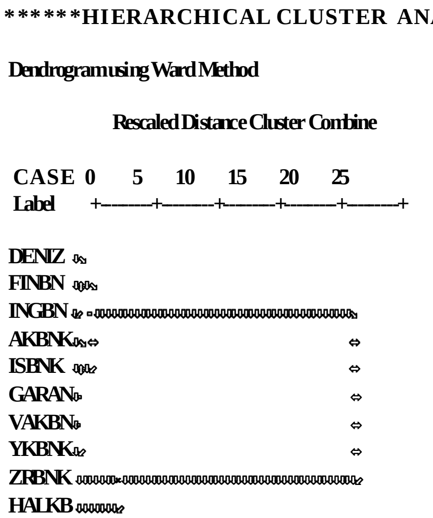
Using the ratios considered in ALESKEROV et. al. (2001), we define four structural characteristics for the banks in order to cluster them into similar groups in terms of these dimensions for the sake of homogeneity. These variables and their representing structure aspects are shown in Table 3.

**Table 3 Financial ratios used for structural clustering: Structural Factors**

| *Variable* | *Abbreviation* | *Representing Structure* |
|---|---|---|
| *Total Loans / Financial Assets (net)* | ASTSTR | Asset Structure |
| (FX Assets – FX Liabilities) / Equity | NGFXPOS | Net General FX Position |
| *Borrowed Loans / Total Deposits* | BLNDEP | Liabilities Structure |
| *Total Loans /Total Deposits* | LNDEP | Liquidity |

A class of techniques used to classify units or cases into relative groups by looking at the similarity between them, known as “Cluster analysis”. A cluster is a group of relatively homogeneous observations. Units in a cluster are similar to each other and dissimilar to units in other clusters. We used agglomerative hierarchical clustering method known as Ward’s method by which clusters are merged so as to reduce the variability within a cluster, e.g., maximizing within-group homogeneity and between-group heterogeneity (ROMESBURG, 2004: 129-135). We applied this on the matrix of the mean values of the above mentioned variables of ten banks between all periods. The generated dendrogram plot diagram is presented in Figure 1.

**Figure 1 Cluster Analysis Results of Ten Largest Banks on Structural Variables**

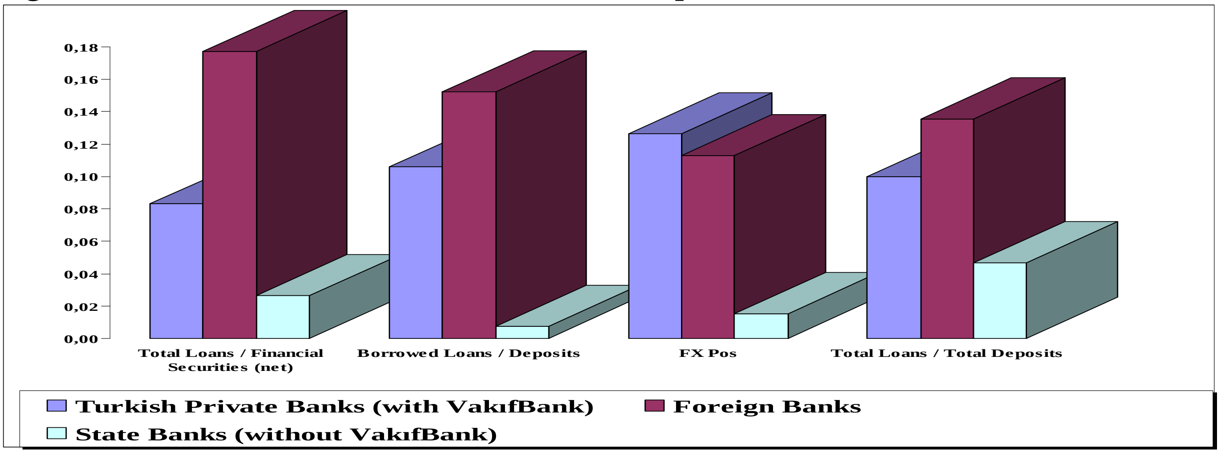



As shown in Figure 1, the two state-owned banks which are TC. Ziraat Bankası (ZRBNK) and T. Halk Bankası (HALKB) were very far grouped from the other banks. Therefore we will omit these from the further analyses. Cluster analysis also show that T. Vakiflar Bankasi (VAKBN) has similar structural characteristics as private Turkish Banks group which is a homogenous group within itself. Foreign banks are grouped together as well.

Consequently we will evaluate the first and the second group together in the same sample set including VAKBN, excluding ZRBNK and HALKB.

As shown in Figure 2 foreign banks have the largest loan ratios to financial securities and total deposits as the mean of the analysis period. Major share in their funds is borrowed loans from abroad which indicates that their borrowing possibilities were better than the other groups of banks.

**Figure 2 Structural Characteristics of Bank Groups**




### 3.2.2 Variable Selection and Computing Performance Indexes via Objective-Weighted Additive Function: Utilizing The Entropy Measure

Selection of proper variables to define and to measure financial performance is always an extremely important decision (MERCAN, et. al., 2003; DENIZER et. al., 2007; SARKIS, 2007). It is in particular so in using DEA for such measurements as different outcomes may result from different sets of variables used on the very set of institutions.

Here the variables represent the dimensions widely used within CAMEL applications of bank-performance measures were selected. Their CAMEL category and expected direction of performance indication is shown in Table 4.

**Table 4 Financial ratios used for CAMEL key performance indicators**

| ***Variable*** | ***Abbr.*** | ***CAMEL Category*** | ***Expected Direction*** |
|---|---|---|---|
| *Shareholders' Equity + Net Profit /Total Assets* | EQPRO | ***C**apital Multiplier* | Benefit |
| *Liquid Assets /Deposits* | LQAST | ***L**iquidity* | Benefit |
| *Total Loans /Deposits* | LNDEP | ***L**iquidity, **A**sset Quality **M**anagement Performance* | Benefit |
| *Non-performing Loans / Total Loans* | NPLN | ***A**sset Quality, Credit Risk **M**anagement Performance* | Cost |
| *FX Assets /FX Liabilities* | FXPOS | *FX **L**iquidity, FX Risk* | Benefit |
| *(Net Interest Income + Net Non-Interest Income) /Total Assets* | NETIN | ***E**arning (Profit) Efficiency **M**anagement Performance* | Benefit |

Since there is a debate on the intertemporal efficiency analysis of banks with one frontier approach, as stated above, we perform a contemporaneous MCDM analysis on the mean values of the eight banks for all 22 quarters. A 22x6 matrix is constructed for the CAMEL performance indicators given in Table 4. After normalizing this matrix by **(2-3)** in order to ensure commensurability we perform an Entropy analysis given in **(5-8).** Then by using obtained weights from the Entropy analysis we aggregate values via SAW in **(4).** This approach is based on the assumption that, in an analysis period, more fluctuated indicator is the more important variable to analyze the performance of the banking sector.

Computed objective weights by Entropy formulations are given in Table 5 with the objective weights of the performance indicators.

**Table 5 Entropy Measures (Diversity) Between Periods**

| | Variable | | | | | |
|---|---|---|---|---|---|---|
| | EQPRO | LQAST | LNDEP | NPLN | FXPOS | NETIN |
| *Equal Weights* | 16,70% | 16,70% | 16,70% | 16,70% | 16,70% | 16,70% |
| *Entropy Weight* | ***9,90%*** | *6,57%* | ***19,04%*** | ***41,03%*** | *1,54%* | ***21,92%*** |

Highlighted values show the most important (most divergent) aspects of performance in the Entropy concept. First it can be seen that asset quality and the intermediation function with the profit generating behavior are more significant decision variables within the analysis period. Both FX position and liquidity of the banks was less fluctuated so we can omit these variables from the second stage efficiency analysis.

**Figure 3 CAMEL Performance Indexes of Turkish Banking Sector with Objective Weights**

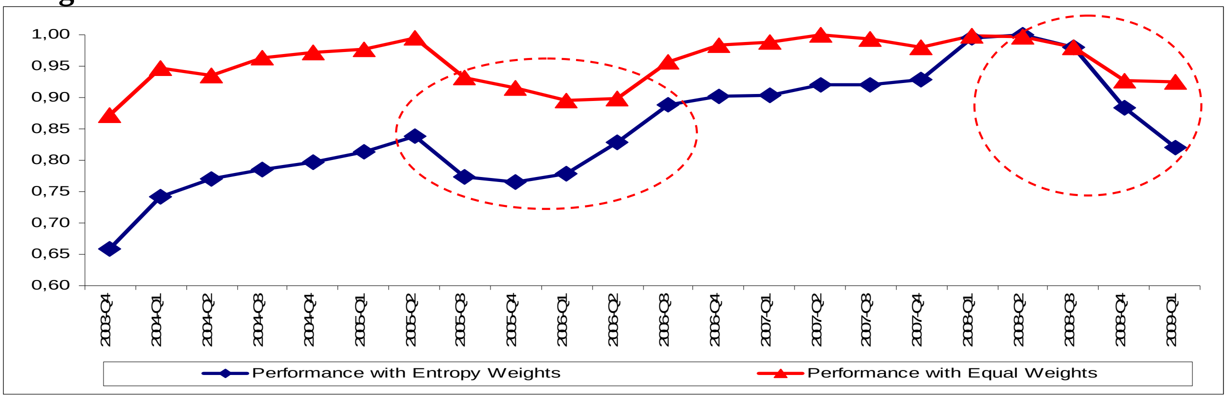



Figure 3 shows that the banking sector performance (calculated from the means of the eight banks in the analysis) is raised over time except fluctuations in between second quarter 2005 – third quarter 2006 and after the second quarter 2008. The difference between two periods is due to the growth performance of the (real) economy, credit risk (NPLN) weighted (entropy) performance index better performed in the first fluctuation period than in the second (which is in 2008). Hence we can conclude that the crises in 2008 affected banking sector on its credit risk loading, so it might be described as a “credit crisis” rather than a “liquidity crises” for banking industry.

Since in the window DEA analysis, DMUs in different periods are treated as different DMUs, results of the Entropy analysis also can be used for the variable selection which ensures discrimination power. We selected the highlighted variables and adjusted them in line with intermediation approach as inputs and outputs. Following the methodology given in YOLALAN (1996), these input output variables are defined as the ratios of total assets. Table 6 shows the variables used in the DEA model in this study.

**Table 6 Selected Variables as DEA Inputs and Outputs**

| ***Variable*** | ***Abbreviation*** | ***Input / Output*** |
|---|---|---|
| *Shareholders’ Equity + Net Profit /Total Assets* | EQPRO | Output |
| *Total Loans /Total Assets* | LOAN | Output |
| *Interest Income + Non-Interest Income / Total Assets* | INCOME | Output |
| *Interest Expenses + Non-Interest Expenses / Total Assets* | EXPENSE | Input |
| *Non-performing Loans / Total Assets* | NPLOAN | Input |
| *Deposits / Total Assets* | DEPO | Input |

### 3.2.3 Dynamic Efficiency Trends of Banks (BANK GROUPS)

The results of the performed DEA window analysis using the model **(9-14 with (16)** in VRS formulation, which is more suitable for banking efficiency studies as stated in STAVÁREK (2006), are shown in Appendix 1 (for bank groups) and on Table 7 for banks in their mean values. Calculations were performed using the program “EMS” provided by SCHEEL (2000).

Table 7 shows means and variances of the efficiency scores obtained by all banks across all windows and the greatest differences by window and by year. Stability in performance is further indicated by the greatest difference scores being the lowest, whether by window (row view), year (column view) or total.

**Table 7 DEA Windows Analysis Results – mean, variance and stability statistics**

| *BANK* | *Ownership Structure*[(a)] | *Mean Efficiency Score* (%) | *Difference W1-W19 (%)* | *Variance* % | *$GD_W$*[(b)] *(%)* | *$GD_P$*[(b)] *(%)* | *$GD_T$*[(b)] *(%)* | *Category*[(c)] |
|---|---|---|---|---|---|---|---|---|
| *AKBNK* | TUR | 99,53 | -0,8 | 0,005 | 7,90 | 7,94 | 7,94 | **(2)** |
| *DENIZ* | FOR | 96,35 | 3,0 | 0,045 | 13,20 | 9,50 | 13,20 | **(2)** |
| *FINBN* | FOR | 99,39 | 0,4 | 0,002 | 6,70 | 6,65 | 6,70 | **(1)** |
| *INGBN* | FOR | 99,83 | -1,3 | 0,002 | 5,70 | 1,30 | 5,70 | **(1)** |
| *GARAN* | TUR | 94,76 | 2,6 | 0,215 | 9,80 | 9,11 | 9,80 | **(4)** |
| *ISBNK* | TUR | 97,91 | -1,9 | 0,017 | 10,30 | 10,30 | 10,30 | **(2)** |
| *VAKBN* | ST | 87,29 | 5,4 | 0,062 | 13,60 | 10,30 | 13,80 | **(4)** |
| *YKBNK* | TUR | 88,10 | -7,5 | 0,692 | 29,60 | 21,64 | 29,60 | **(4)** |
| ***Group Means*** | ***SECTOR*** | ***95,39*** | ***-0,02*** | ***0,022*** | ***5,09*** | ***5,66*** | ***7,44*** | |
| | ***TURKISH*** | ***95,07*** | ***-1,90*** | ***0,052*** | ***8,21*** | ***7,73*** | ***8,21*** | ***(4)*** |
| | ***FOREIGN*** | ***98,52*** | ***0,69*** | ***0,006*** | ***5,08*** | ***4,87*** | ***5,08*** | ***(1)*** |

*Source: Author's calculations*

(a) TUR = Turkish Private Bank, FOR = Foreign Bank, ST = State-Owned Bank

(b) $GD_W$ = Greatest difference within a window; $GD_P$ = Greatest difference within a period; $GD_T$ = Greatest difference within all periods and windows

(c) Category: (1) = Strong – Consistent; (2) = Strong – Inconsistent; (3) = Weak – Consistent; (4) = Weak – Inconsistent

Comparing the mean efficiency of a bank with the mean efficiency of the sector, banks are grouped in "weak" and "strong" categories. Besides, in order to monitor stability, comparing banks' greatest efficiency differences within all periods and all windows stability category is determined as consistent – inconsistent. Results show that there is no bank weak and consistent. Only two foreign banks are strong and consistent within the analysis period. Generally stronger banks are the more consistent ones. This result is in accordance with CHARNES et. al. (1985) which states more performance yields more consistency.

As shown in the Figure 4, foreign banks which can be also characterized as middle-scaled banks performed better and in a more stable pattern in efficiency.

**Figure 4 Efficiency Patterns of the Banks**

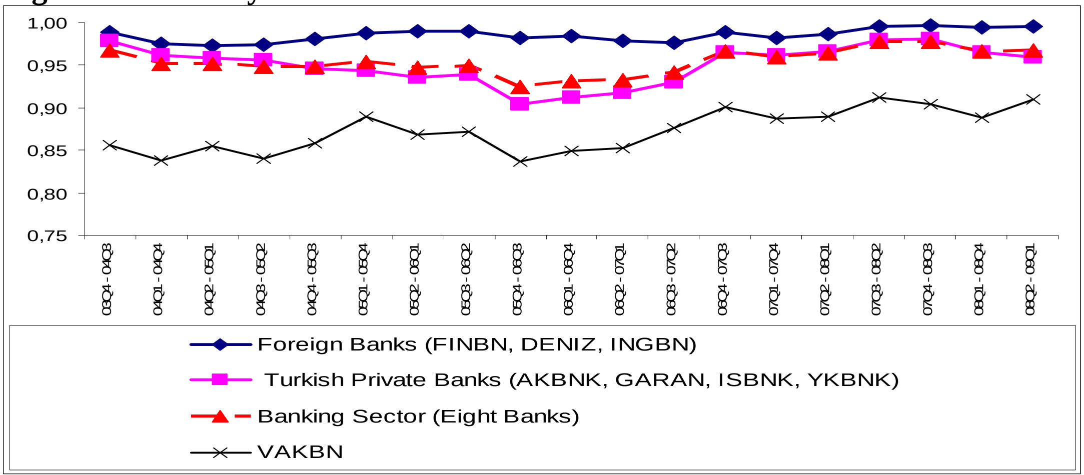


Figure 4 also shows that efficiencies are generally increased over time except fluctuations in 2005-2006 and 2008 periods, as in Figure 3.

## 4. Conclusion

The objective of this paper is to investigate the performance of the Turkish Banking sector performance and the efficiency and stability patterns of the banks in the sector by the end of the year 2003 to the beginning of 2009 in a quarterly basis. Utilizing a MCDM approach with objective weights of CAMEL performance indicators, and a DEA Window analysis with the selected input and output variables, it is shown that using these methods in conjunction gives a wider and cleaner perspective.

Results show that, the performance of the Turkish banking sector generally improved over time, except "fluctuations" in $2^{nd}$ quarter of 2005 – $3^{rd}$ quarter of 2006 and after the second quarter 2008. Fluctuations in 2005 and 2006 were related with liquidity or capital risk, but crisis in 2008 can be characterized by loan and profit losses (credit risk).

After the second quarter of 2008 (in the last three windows), both performance and efficiencies in the sector are decreased through the global crises. Individually, banks exhibit different efficiency and stability patterns relative to each other. Largest Foreign Banks outperform the others in both efficiency means and stability during the period – when we evaluate efficiency in terms of intermediation function.

Overall, the results confirm that credit risk is the main factor to be monitored or to be prevented in Turkish banking system in the near future.

## References


[1] ALESKEROV, F., ERSEL, H., MERCAN, M. Structural Dissimilarity in Turkish Banks 1988-1999. *Bogazici Journal Review of Social Economic and Administrative Studies*. 2001, vol. 15, no.1, pp.57-69

[2] ALESKEROV, F., ERSEL, H., YOLALAN, R. Clustering Turkish Commercial Banks According to Structural Similarities, *Yapı Kredi Research Department Discussion Paper Series*. 1997, no. 97-02., pp. 97-102.

[3] ALESKEROV, F., ERSEL, H., YOLALAN, R. Multicriterial ranking approach for evaluating bank branch performance. *International journal of information technology & decision making*, 2004, vol. 3 no. 2, pp. 321-335.

[4] ASMILD, M., PARADI, J.C., AGGARWALL, A., SCHAFFNIT, C. Combining DEA Window Analysis with the Malmquist Index Approach in a Study of the Canadian Banking Industry, *Journal of Productivity Analysi*s. 2004, vol. 21, pp. 67 – 89.

[5] BANKER, R.D., CHARNES, A., COOPER, W.W. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science.* 2004, vol. 30, 1984, pp. 1078 - 1092.

[6] BANKER, R.D., THRALL, R.M. Estimation of Returns to Scale Using Data Envelopment Analysis. *European Journal of Operational Research*. 1992, no. 62, pp. 74 - 84.

[7] BANKS ASSOCIATION of TURKEY (TBA). *The Financial System and Banking Sector in Turkey*. Istanbul, October 2009.

[8] BERGER, A.N., HUMPHREY, D.B. Efficiency of financial institutions: International survey and directions for future research, *European Journal of Operational Research*. 1997, vol. 98, pp. 175-212.

[9] BROCKETT, P.L., CHARNES, A., COOPER, W.W., HUANG, Z.M., SUN, D.B. Data transformations in DEA cone ratio envelopment approaches for monitoring bank performances, *European Journal of Operational Research.* 1997, *vol.* 98, pp. 250-268.

[10] CHARNES, A., COOPER, W.W., GOLANY, B. A. Developmental Study of Data Envelopment Analysis in Measuring the Efficiency of Maintenance Units in the U.S. Air Forces. *Annals of Operations Research.* 1985, vol. 2, pp. 95–112.

[11] CHARNES, A., COOPER W.W., RHODES E. Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research.* 1978, vol. 2, pp. 429 - 444.

[12] COOK, W.D., SEIFORD, L.M. Data envelopment analysis (DEA) – Thirty years on, *European Journal of Operational Research.* 2009, vol. 192, pp. 1–17.

[13] COELLI, T.J., RAO PRASADA D.S., O'DONNELL C.J., BATTASE, G.E. *An Introduction to Efficiency and Productivity Analysis (Second Edition).* New York: Springer, 2005.

[14] DENG, H., YEH, C-H, WILLIS, R.J. Inter-company comparison using modified TOPSIS with objective weights. *Computers & Operations Research*, 2000, vol. 27, pp. 963-973.

[15] DENIZER, C.A., DINC, M., TARIMCILAR, M. Measuring banking efficiency in the pre-and post-liberalization environment: evidence from Turkish banking system. *Journal of Productivity Analysis.* 2007, vol. 27, pp. 177-195.

[16] DERVIZ, A., PODPIERA, J., 2008. Predicting Bank CAMELS and S&P Ratings. The Case of the Czech Republic, *Emerging Markets Finance & Trade*. 2008, vol. 44, no. 1, pp. 117–130.

[17] DRAKE, L., HALL, J.B.M., SIMPER, R. Bank modeling methodologies: A comparative non-parametric analysis of efficiency in the Japanese banking sector. *International Financial Markets, Inst. and Money.* 2009, vol. 19, pp. 1–15.

[18] DIAKOULAKI, D., MAVROTAS, G., PAPAYANNAKIS, L. Determining objective weights in multiple criteria problems: the CRITIC method. *Computers and Operations Research*. 1995, vol.22, pp. 763-770.

[19] FARE, R., GROSSKOPF, M., NORRIS, M., ZHANG, Z. Productivity growth, technical progress, and efficiency change in industrialized countries. *American Economic Review.* 1994, vol. 84, pp. 66-83.

[20] FARRELL, M.J. The Measurement of Productive Efficiency. *Journal of Royal Statistical Society*. 1957, Serial A, vol. 120, no. 3, pp. 253 - 281.

[21] HAIR, J.F., ANDERSON, R.E., TATHAM, R.L., BLACK, W.C. *Multivariate Data Analysis*. Prentice-Hall, Englewood Cliffs, NJ, 1998.

[22] HARTMAN, T.E., STORBECK, J.E. Input Congestion in Loan Operations. *International Journal of Production Economics*. 1996, no. 46–47, pp. 413–21.

[23] HWANG, C.L, YOON, K.S. *Multiple attribute decision making: methods and applications.* New York: Springer, 1981.

[24] ISIK, I., HASSAN, M.K. Technical, scale and allocative efficiencies of Turkish banking industry. *Journal of Banking & Finance*. 2002, vol. 26, Issue 4, pp. 719-766.

[25] JACKSON, P.M., FETHI, M.D, INAL, G. Evaluating the technical efficiency of Turkish commercial banks: An Application of DEA and Tobit Analysis. *2000, University of Leicester, Mimeo.*

[26] MERCAN, M., REISMAN, A., YOLALAN, R., EMEL, A.B. The effect of scale and mode of ownership on the financial performance of the Turkish banking sector: results of a DEA-based analysis. *Socio-Economic Planning Sciences*. 2003, vol. 37, pp. 185-202.

[27] OZKAN-GUNAY, E.N., TEKTAS, A. Efficiency Analysis of the Turkish Banking Sector in Precrisis and Crisis Period: A DEA Approach. *Contemporary Economic Policy*. 2006, vol. 24, no. 3, pp. 418-431.

[28] PALEPU, K. G. Diversification strategy, profit performance and the entropy measure. *Strategic Management Journal*. 1985, vol. 6, no. 3, pp. 239–255.

[29] ROMESBURG, H.C. *Cluster Analysis for Researchers*. Lulu Press, 2004.

[30] SCHEEL, H. *EMS: Efficiency Measurement System, User's Manual. Version 1.3.* Dortmund, 2000.

[31] SHANNON, C.E., WEAVER, W. *The mathematical theory of communication*. Urbana: The University of Illinois Press, 1947.

[32] SARKIS, J. Preparing Your Data for DEA. In ZHU, J, COOK, W.D. (eds.) *Modeling Data Irregularities and Structural Complexities in Data Envelopment Analysis*. Worcester Polytechnic Institute, New York, Springer, 2007.

[33] SECME, N.Y., BAYRAKDAROGLU, A., KAHRAMAN, C. Fuzzy performance evaluation in Turkish Banking Sector using Analytic Hierarchy Process and TOPSIS. Expert Systems with Applications. 2009, vol. 36, pp. 11699–11709.

[34] STAVÁREK, D. Banking Efficiency in the Context of European Integration. *Eastern European Economics*. 2006, vol. 44, no. 4, pp. 5–31.

[35] THANASSOULIS, E., BOUSSOFIANE, A., DYSON, R. A Comparison of Data Envelopment Analysis and Ratio Analysis as Tools for Performance Assessment. *OMEGA, International Journal of Management Science*. 1996, vol. 24, no. 3, pp. 229-244.

[36] WEBB, R.M. Levels of Efficiency in UK Retail Banks: A DEA Window Analysis. *International Journal of the Economics of Business*. 2003, vol. 10, no.3, pp. 305 – 322.

[37] YEH, C-H. A problem-based selection of multi-attribute decision-making methods. *International Transactions in Operations Research*. 2002, vol. 9, pp. 169-181.

[38] YEH, J-Q. The application of Data Envelopment Analysis in conjunction with financial ratios for bank performance evaluation. *Journal of Operations Research Society.* 1996, vol. 47, pp. 980-988.

[39] YOLALAN, R. Turk Bankacılık Sektoru icin Goreli Mali Performans Olcumu (in Turkish). TBB- Bankacılar Dergisi. 1996, 19, pp. 35-40.

[40] YUE, P. Data Envelopment Analysis and Commercial Bank Performance: A Primer with Applications to Missouri Banks. *Federal Reserve Bank of St. Louis Review*. 1992, vol. 74 no. 1, pp. 31-45.

[41] ZAIM, O. The effect of financial liberalization on the efficiency of Turkish Commercial banks. *Applied Financial Economics*. 1995, vol. 5, pp. 257-264.

[42] ZELENY, M. *Multiple criteria decision making,* New York: McGraw-Hill, 1982.

## Appendix 1: DEA Window Technical Efficiency Scores: Mean Values of Banking Groups

| | 03-Q4 | 04-Q1 | 04-Q2 | 04-Q3 | 04-Q4 | 05-Q1 | 05-Q2 | 05-Q3 | 05-Q4 | 06-Q1 | 06-Q2 | 06-Q3 | 06-Q4 | 07-Q1 | 07-Q2 | 07-Q3 | 07-Q4 | 08-Q1 | 08-Q2 | 08-Q3 | 08-Q4 | 09-Q1 | *Mean* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TURKISH PRIVATE BANKS (AKBNK, GARAN, ISBNK, YKBNK)** | | | | | | | | | | | | | | | | | | | | | | | |
| ***03Q4 - 04Q3*** | 0,955 | 0,989 | 0,981 | 0,992 | | | | | | | | | | | | | | | | | | | 0,979 |
| ***04Q1 - 04Q4*** | | 0,975 | 0,947 | 0,963 | 0,964 | | | | | | | | | | | | | | | | | | 0,962 |
| ***04Q2 - 05Q1*** | | | 0,955 | 0,960 | 0,962 | 0,959 | | | | | | | | | | | | | | | | | 0,959 |
| ***04Q3 - 05Q2*** | | | | 0,954 | 0,958 | 0,953 | 0,962 | | | | | | | | | | | | | | | | 0,956 |
| ***04Q4 - 05Q3*** | | | | | 0,956 | 0,952 | 0,954 | 0,923 | | | | | | | | | | | | | | | 0,946 |
| ***05Q1 - 05Q4*** | | | | | | 0,972 | 0,974 | 0,916 | 0,912 | | | | | | | | | | | | | | 0,943 |
| ***05Q2 - 06Q1*** | | | | | | | 0,975 | 0,921 | 0,912 | 0,936 | | | | | | | | | | | | | 0,936 |
| ***05Q3 - 06Q2*** | | | | | | | | 0,988 | 0,906 | 0,929 | 0,932 | | | | | | | | | | | | 0,939 |
| ***05Q4 - 06Q3*** | | | | | | | | | 0,899 | 0,918 | 0,922 | 0,876 | | | | | | | | | | | 0,904 |
| ***06Q1 - 06Q4*** | | | | | | | | | | 0,918 | 0,940 | 0,890 | 0,901 | | | | | | | | | | 0,912 |
| ***06Q2 - 07Q1*** | | | | | | | | | | | 0,940 | 0,918 | 0,913 | 0,898 | | | | | | | | | 0,917 |
| ***06Q3 - 07Q2*** | | | | | | | | | | | | 0,939 | 0,957 | 0,922 | 0,904 | | | | | | | | 0,931 |
| ***06Q4 - 07Q3*** | | | | | | | | | | | | | 0,978 | 0,967 | 0,952 | 0,964 | | | | | | | 0,965 |
| ***07Q1 - 07Q4*** | | | | | | | | | | | | | | 0,970 | 0,950 | 0,964 | 0,963 | | | | | | 0,962 |
| ***07Q2 - 08Q1*** | | | | | | | | | | | | | | | 0,954 | 0,971 | 0,967 | 0,971 | | | | | 0,966 |
| ***07Q3 - 08Q2*** | | | | | | | | | | | | | | | | 1,000 | 0,977 | 0,979 | 0,965 | | | | 0,980 |
| ***07Q4 - 08Q3*** | | | | | | | | | | | | | | | | | 1,000 | 0,999 | 0,969 | 0,956 | | | 0,981 |
| ***08Q1 - 08Q4*** | | | | | | | | | | | | | | | | | | 1,000 | 0,969 | 0,957 | 0,934 | | 0,965 |
| ***08Q2 - 09Q1*** | | | | | | | | | | | | | | | | | | | 0,972 | 0,962 | 0,945 | 0,960 | 0,960 |
| *Mean* | 0,955 | 0,982 | 0,961 | 0,967 | 0,960 | 0,959 | 0,966 | 0,937 | 0,907 | 0,926 | 0,934 | 0,906 | 0,937 | 0,939 | 0,940 | 0,975 | 0,977 | 0,987 | 0,969 | 0,958 | 0,940 | 0,960 | |
| **FOREIGN BANKS (DENIZ, FINBN, INGBN)** | | | | | | | | | | | | | | | | | | | | | | | |
| ***03Q4 - 04Q3*** | 0,971 | 0,988 | 0,999 | 0,997 | | | | | | | | | | | | | | | | | | | 0,989 |
| ***04Q1 - 04Q4*** | | 0,983 | 0,969 | 0,974 | 0,974 | | | | | | | | | | | | | | | | | | 0,975 |
| ***04Q2 - 05Q1*** | | | 0,955 | 0,972 | 0,968 | 0,997 | | | | | | | | | | | | | | | | | 0,973 |
| ***04Q3 - 05Q2*** | | | | 0,948 | 0,961 | 0,988 | 0,999 | | | | | | | | | | | | | | | | 0,974 |
| ***04Q4 - 05Q3*** | | | | | 0,951 | 0,983 | 0,991 | 1,000 | | | | | | | | | | | | | | | 0,981 |
| ***05Q1 - 05Q4*** | | | | | | 0,980 | 0,982 | 0,997 | 0,992 | | | | | | | | | | | | | | 0,988 |
| ***05Q2 - 06Q1*** | | | | | | | 0,982 | 0,997 | 0,992 | 0,987 | | | | | | | | | | | | | 0,989 |
| ***05Q3 - 06Q2*** | | | | | | | | 0,992 | 0,987 | 0,983 | 0,996 | | | | | | | | | | | | 0,990 |
| ***05Q4 - 06Q3*** | | | | | | | | | 0,984 | 0,975 | 0,995 | 0,973 | | | | | | | | | | | 0,982 |
| ***06Q1 - 06Q4*** | | | | | | | | | | 0,980 | 0,997 | 0,974 | 0,986 | | | | | | | | | | 0,984 |
| ***06Q2 - 07Q1*** | | | | | | | | | | | 0,996 | 0,973 | 0,980 | 0,965 | | | | | | | | | 0,978 |
| ***06Q3 - 07Q2*** | | | | | | | | | | | | 0,978 | 0,988 | 0,966 | 0,975 | | | | | | | | 0,977 |
| ***06Q4 - 07Q3*** | | | | | | | | | | | | | 1,000 | 0,980 | 0,982 | 0,994 | | | | | | | 0,989 |
| ***07Q1 - 07Q4*** | | | | | | | | | | | | | | 0,978 | 0,974 | 0,974 | 1,000 | | | | | | 0,982 |
| ***07Q2 - 08Q1*** | | | | | | | | | | | | | | | 0,973 | 0,972 | 1,000 | 0,999 | | | | | 0,986 |
| ***07Q3 - 08Q2*** | | | | | | | | | | | | | | | | 0,982 | 1,000 | 0,999 | 1,000 | | | | 0,995 |
| ***07Q4 - 08Q3*** | | | | | | | | | | | | | | | | | 0,993 | 0,995 | 1,000 | 1,000 | | | 0,997 |
| ***08Q1 - 08Q4*** | | | | | | | | | | | | | | | | | | 0,995 | 1,000 | 1,000 | 0,981 | | 0,994 |
| ***08Q2 - 09Q1*** | | | | | | | | | | | | | | | | | | | 1,000 | 1,000 | 0,983 | 1,000 | 0,996 |
| *Mean* | 0,971 | 0,985 | 0,974 | 0,973 | 0,963 | 0,987 | 0,989 | 0,996 | 0,989 | 0,981 | 0,996 | 0,975 | 0,988 | 0,972 | 0,976 | 0,981 | 0,998 | 0,997 | 1,000 | 1,000 | 0,982 | 1,000 | |

## Appendix 1 (Continued): DEA Window Technical Efficiency Scores: Banking Groups

| | 03-Q4 | 04-Q1 | 04-Q2 | 04-Q3 | 04-Q4 | 05-Q1 | 05-Q2 | 05-Q3 | 05-Q4 | 06-Q1 | 06-Q2 | 06-Q3 | 06-Q4 | 07-Q1 | 07-Q2 | 07-Q3 | 07-Q4 | 08-Q1 | 08-Q2 | 08-Q3 | 08-Q4 | 09-Q1 | *Mean* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **VAKBN** | | | | | | | | | | | | | | | | | | | | | | | |
| ***03Q4 - 04Q3*** | 0,83 | 0,86 | 0,87 | 0,86 | | | | | | | | | | | | | | | | | | | 0,856 |
| ***04Q1 - 04Q4*** | | 0,86 | 0,85 | 0,83 | 0,80 | | | | | | | | | | | | | | | | | | 0,838 |
| ***04Q2 - 05Q1*** | | | 0,93 | 0,87 | 0,80 | 0,82 | | | | | | | | | | | | | | | | | 0,855 |
| ***04Q3 - 05Q2*** | | | | 0,91 | 0,80 | 0,83 | 0,82 | | | | | | | | | | | | | | | | 0,840 |
| ***04Q4 - 05Q3*** | | | | | 0,80 | 0,92 | 0,87 | 0,83 | | | | | | | | | | | | | | | 0,858 |
| ***05Q1 - 05Q4*** | | | | | | 0,92 | 0,92 | 0,89 | 0,82 | | | | | | | | | | | | | | 0,890 |
| ***05Q2 - 06Q1*** | | | | | | | 0,92 | 0,89 | 0,83 | 0,83 | | | | | | | | | | | | | 0,868 |
| ***05Q3 - 06Q2*** | | | | | | | | 0,92 | 0,86 | 0,85 | 0,86 | | | | | | | | | | | | 0,872 |
| ***05Q4 - 06Q3*** | | | | | | | | | 0,84 | 0,83 | 0,84 | 0,83 | | | | | | | | | | | 0,837 |
| ***06Q1 - 06Q4*** | | | | | | | | | | 0,86 | 0,86 | 0,85 | 0,83 | | | | | | | | | | 0,849 |
| ***06Q2 - 07Q1*** | | | | | | | | | | | 0,87 | 0,87 | 0,86 | 0,82 | | | | | | | | | 0,853 |
| ***06Q3 - 07Q2*** | | | | | | | | | | | | 0,91 | 0,89 | 0,86 | 0,84 | | | | | | | | 0,876 |
| ***06Q4 - 07Q3*** | | | | | | | | | | | | | 0,94 | 0,90 | 0,89 | 0,88 | | | | | | | 0,901 |
| ***07Q1 - 07Q4*** | | | | | | | | | | | | | | 0,89 | 0,88 | 0,88 | 0,89 | | | | | | 0,887 |
| ***07Q2 - 08Q1*** | | | | | | | | | | | | | | | 0,89 | 0,88 | 0,89 | 0,90 | | | | | 0,890 |
| ***07Q3 - 08Q2*** | | | | | | | | | | | | | | | | 0,94 | 0,90 | 0,90 | 0,90 | | | | 0,912 |
| ***07Q4 - 08Q3*** | | | | | | | | | | | | | | | | | 0,92 | 0,90 | 0,90 | 0,89 | | | 0,905 |
| ***08Q1 - 08Q4*** | | | | | | | | | | | | | | | | | | 0,91 | 0,90 | 0,89 | 0,85 | | 0,889 |
| ***08Q2 - 09Q1*** | | | | | | | | | | | | | | | | | | | 0,93 | 0,90 | 0,89 | 0,92 | 0,910 |
| *Mean* | 0,827 | 0,861 | 0,886 | 0,870 | 0,800 | 0,874 | 0,886 | 0,883 | 0,837 | 0,844 | 0,857 | 0,864 | 0,881 | 0,867 | 0,873 | 0,896 | 0,901 | 0,903 | 0,910 | 0,898 | 0,869 | 0,921 | |
| **BANKING SECTOR (8 BANKS)** | | | | | | | | | | | | | | | | | | | | | | | |
| ***03Q4 - 04Q3*** | 0,945 | 0,973 | 0,974 | 0,978 | | | | | | | | | | | | | | | | | | | 0,967 |
| ***04Q1 - 04Q4*** | | 0,964 | 0,944 | 0,951 | 0,948 | | | | | | | | | | | | | | | | | | 0,952 |
| ***04Q2 - 05Q1*** | | | 0,952 | 0,953 | 0,943 | 0,956 | | | | | | | | | | | | | | | | | 0,951 |
| ***04Q3 - 05Q2*** | | | | 0,946 | 0,939 | 0,951 | 0,958 | | | | | | | | | | | | | | | | 0,949 |
| ***04Q4 - 05Q3*** | | | | | 0,935 | 0,960 | 0,958 | 0,941 | | | | | | | | | | | | | | | 0,948 |
| ***05Q1 - 05Q4*** | | | | | | 0,969 | 0,971 | 0,943 | 0,931 | | | | | | | | | | | | | | 0,953 |
| ***05Q2 - 06Q1*** | | | | | | | 0,972 | 0,946 | 0,932 | 0,942 | | | | | | | | | | | | | 0,948 |
| ***05Q3 - 06Q2*** | | | | | | | | 0,981 | 0,930 | 0,939 | 0,948 | | | | | | | | | | | | 0,950 |
| ***05Q4 - 06Q3*** | | | | | | | | | 0,924 | 0,929 | 0,939 | 0,907 | | | | | | | | | | | 0,925 |
| ***06Q1 - 06Q4*** | | | | | | | | | | 0,934 | 0,951 | 0,916 | 0,924 | | | | | | | | | | 0,931 |
| ***06Q2 - 07Q1*** | | | | | | | | | | | 0,952 | 0,932 | 0,931 | 0,913 | | | | | | | | | 0,932 |
| ***06Q3 - 07Q2*** | | | | | | | | | | | | 0,951 | 0,961 | 0,930 | 0,922 | | | | | | | | 0,941 |
| ***06Q4 - 07Q3*** | | | | | | | | | | | | | 0,981 | 0,964 | 0,955 | 0,965 | | | | | | | 0,966 |
| ***07Q1 - 07Q4*** | | | | | | | | | | | | | | 0,963 | 0,951 | 0,957 | 0,968 | | | | | | 0,960 |
| ***07Q2 - 08Q1*** | | | | | | | | | | | | | | | 0,953 | 0,961 | 0,970 | 0,973 | | | | | 0,964 |
| ***07Q3 - 08Q2*** | | | | | | | | | | | | | | | | 0,986 | 0,976 | 0,976 | 0,971 | | | | 0,977 |
| ***07Q4 - 08Q3*** | | | | | | | | | | | | | | | | | 0,988 | 0,985 | 0,973 | 0,965 | | | 0,978 |
| ***08Q1 - 08Q4*** | | | | | | | | | | | | | | | | | | 0,986 | 0,973 | 0,965 | 0,942 | | 0,966 |
| ***08Q2 - 09Q1*** | | | | | | | | | | | | | | | | | | | 0,977 | 0,969 | 0,952 | 0,970 | 0,967 |
| *Mean* | 0,945 | 0,968 | 0,956 | 0,957 | 0,941 | 0,959 | 0,965 | 0,953 | 0,929 | 0,936 | 0,947 | 0,926 | 0,949 | 0,943 | 0,945 | 0,967 | 0,975 | 0,980 | 0,973 | 0,966 | 0,947 | 0,970 | |