Efficiency, Productivity and Risk Analysis in Turkish Banks: A Bootstrap DEA Approach

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Abstract

This paper, by using Data Envelopment Analysis (DEA) and Malmquist Productivity Index, addresses the impacts of 2007 global financial crisis on the efficiency and productivity of Turkish banks, during 2003-2010 periods. Moreover, a risk taking measure is introduced for each bank and two-stage regression is used to analyze the determinants of DEA efficiency scores. However, because of the existence of inherent dependency among DEA efficiency scores, the basic assumption of regression analysis, i.e., independence within the sample is violated. Hence, to overcome the dependency problem and to be able to make valid statistical inferences, bootstrapping method is applied. This paper attempts to extend the existing DEA literature by applying some of the remarkable methods suggested to improve DEA efficiency and productivity estimates altogether, for the case of Turkey to observe the impacts of recent 2007 global financial crisis.

Key Words: *Data Envelopment Analysis, Malmquist Productivity Index, Efficiency and Productivity, Bootstrapping*

JEL Classification: *C14, G21, G14, C23*

Özet – Türk Bankalarında Etkinlik, Verimlilik ve Risk Analizi: Bootstrap Veri Zarflama Analizi Yaklaşımı

Bu makale, Veri Zarflama Analizi (VZA) ve Malmquist Üretkenlik Endeksi'ni kullanarak 2007 küresel ekonomik krizinin Türk Bankacılık Sektörü üzerindeki etkilerini 2003-2010 dönemi boyunca incelemiştir. Ayrıca, risk ölçümü amacıyla her banka için risk ölçüsü tanımlanmış ve VZA yöntemiyle elde edilmiş olan etkinlik skorlarının belirleyicilerini analiz etmek amacıyla iki adımlı regresyon yapılmıştır. Ancak VZA etkinlik skorları arasındaki bağımlılık sebebiyle, regresyon analizinin temel varsayımlarından biri olan örneklemin bağımsızlığı ihlal edilmiştir. Bu nedenle, söz konusu ihlali gidermek ve analizden geçerli istatistiksel çıkarımlar yapabilmek amacıyla analizde bootstrapping yöntemi uygulanmıştır. Bu makale, VZA etkinlik ve üretkenlik endekslerini geliştirmek amacıyla literatürde önerilen dikkate değer bazı metodları, 2007 krizinin Türkiye üzerindeki etkilerini incelemek amacıyla bir arada uygulayarak mevcut DEA literatürüne katkıda bulunmayı amaçlamaktadır.

Anahtar Kelimeler: *Veri Zarflama Analizi, Malmquist Üretkenlik Endeksi, Etkinlik ve Üretkenlik, Bootstrapping*

JEL Sınıflaması: *C14, G21, G14, C23*

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Bu çalışmada belirtilen görüşler yazarına ait olup, Bankacılık Düzenleme ve Denetleme Kurumunun görüşlerini yansıtmamaktadır.

1. Introduction

During the last few decades, Turkish economy has undergone a transformation period consisting series of reforms to pass from a centralized economy to a well-integrated market economy. During 1980s, which is characterized by financial deregulation, series of financial reforms were implemented in order to limit the state intervention and to enhance the role of market forces. Moreover, the determination of Turkey to become a permanent member of European Union (EU) in this period motivated banking authorities to implement regulations that are in harmony with those in EU (Isik and Hassan, 2003). As a result of those reforms, new entrants to the market were allowed, new types of financial institutions emerged, new banking products were introduced and interest and foreign exchange rates were permitted to fluctuate.

With this new framework, banks' scope of intermediation activities had extended through the introduction of asset-backed securities, mutual funds, interest and currency rate forwards and swaps, repo transactions, trading in government and private securities, consumer credits and financial consultation. Moreover, as domestic market opened up, Turkish banks gained interest in opening up branches and representative offices abroad.

The new liberal era brought about strong incentives for Turkish banks to compete internationally through terminating their unprofitable ventures, investing into heavy technology and using their resources more efficiently. In such an environment where competitive pressures dominate, the efficiency and productivity of banks have gain particular importance in the establishment of solid financial system which is mainly composed of banks. In other words, measuring the level of efficiency and detecting the causes of inefficiency would be highly essential for bank managers and regulators in order to survive in the new regulatory framework in which inefficient banks would be driven out or acquired by efficient banks.

Following the financial deregulation, during 1990-2000, instabilities in the global economy had increased significantly. More specifically, global capital flows accelerated and Turkish economy was often exposed to currency crisis in this period. The weak growth performance, high public sector imbalances, high and volatile inflation combined with current account deficit gave way to February 2001 crisis, eventually. However, soon after the crisis, in May 2001, The Banking Sector Restructuring Program was put into effect. The aim is the restructuring of public banks, resolution of banks taken over by Saving Deposit Insurance Fund (SDIF), rehabilitation of private banking system, strengthening the surveillance and supervision frame, increasing competition and efficiency in the sector. Due to the crisis, 22 banks were transferred to SDIF in this period. The cost of restructuring of those banks and public banks was USD 53,6 billion, a one third of national income.

Thanks to measures taken after the crisis, the sector had improved rapidly. In the post crisis period, the amount of nonperforming loans contracted while loans had expanded. The sector's free capital base exhibited a constant growth, profitability increased and gained a sustainable quality, while the deposit and loan interest rates decreased rapidly, burden on credit customer (i.e. intermediation costs) decreased. This trend had continued up to mid-2006. However, mid-2006 onwards increased financial globalization, rise in the type and the number of complex financial instruments (i.e. derivatives) where the risks are further decomposed and transferred caused recurrent turbulences on a world wide scale. Those turbulences finally gave way to 2007 global financial crisis which is also experienced by Turkey.

The initial impact of the crisis has been on the contraction of liquidity and credit channels. Due to the squeeze in financial conditions and decrease in demand, growth performance decreased, unemployment increased and expectations worsened all over the world. However, several measures were put into effect following the crisis. In order to increase system's liquidity, Central Banks declined interest rates and launched programs to strengthen the capital adequacy of financial institutions. In Turkey, depending on the decreased trade volume and economic slowdown, the banking sector has faced with a decrease in credit growth, deterioration in asset quality and an increase in non-performing loan ratio. Banks began to decrease volume of loans which is more risky now meanwhile, increase the volume of their securities portfolio. Moreover, since the funding sources from abroad has squeezed, banks began to rely on more volatile funding sources. Another problem of the Turkish banking sector has been the maturity mismatch between assets and liabilities (i.e. long term loans funded with short term deposits). However, a series of measures have been implemented by Central Bank of the Republic of Turkey-CBRT (macro level) and Banking Regulation and Supervision Agency-BRSA (micro level) to mitigate the impacts of the crisis. Macro level measures include, CBRT's resume of its activities as an intermediary in the foreign exchange (FX) deposit market, raising of transaction limits twice and extending the lending maturity from 1 week to 1 month in FX deposit market, reducing reserve requirement ratio for FX liabilities and increasing the exports rediscount credit limit. Micro level measures implemented by BRSA include, subjecting banks to get permission for the distribution of 2008 earnings, allowing banks to reclassify the securities in their balance sheet from trading portfolio to investment portfolio for once only and allowing banks to restructure the loans apparently posing no problems in order to ensure smooth functioning of the loan relations between banks and non-financial institutions.

As summarized so far, during the last three decades, continuous legal and structural changes were occurred not only in Turkish financial sector, but also all over the world's financial systems. However, the point is that although financial sector has undergone rapid changes all around the globe, the efficiency and productivity research has not kept pace with these recent changes in terms of scope and up-to-dateness.

In this field, several number of papers have been published in which the efficiency and productivity of Turkish banking sector has been studied. Zaim and Ertuğrul (1996) is one of the preceeding papers investigating the effects of financial liberalization on Turkish banking sector in the period of 1981-1990 by using Data Envelopment Analysis. The result suggests that differences in bank efficiency scores are eliminated during liberalization. Similarly, Jackson et al. (1998) examines the impacts of financial liberalization policies adopted in 1980 on bank efficiency and productivity during 1992-1996, by using Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI)[1] and finds that in general Turkish banking sector experienced productivity growth with the exception of 1993-94, and that private and foreign banks showed greater productivity growth

[1] Hereafter DEA is used as an abbreviation for Data Envelopment Analysis and MPI is used as an abbreviation for Malmquist Productivity Index.

compared to state owned banks. Cingi and Tarım (2000) study the efficiency of banking sector between 1989 and 1996 by employing DEA and reported that there is high degree of concentration in the sector and the inefficiency of public banks could be attributed to scale inefficiencies. Isik and Hassan (2003) investigate the performance of Turkish banks during 1981-1990 period by using DEA and MPI. The results suggest that the average managerial efficiency in Turkish banks has substantially improved after deregulation. More recently, Aras and Kurt (2007), use DEA to analyze the efficiency of banks operating in Turkey, in the period of 1992-2003 and concludes that banks transferred to SDIF had extreme and low efficiency scores and they had been carrying out high risk before transferred.

This study, on the other hand, presents an empirical analysis of the relative efficiency, productivity and risk-taking tendency of Turkish banking system before and after the 2007 global financial crisis by using a rich panel data set observed during 2003-2010 periods. The methods used to assess relative efficiency and productivity are DEA and MPI. This paper differs from other papers on Turkish banking sector in some respects. First, after calculating efficiency and productivity measures through DEA method, a procedure called *bootstrapping* that permits to estimate bias corrected efficiency scores and productivity indices is applied in order to obtain bias corrected efficiency and productivity scores. Although the method is widely used in papers investigating bank performances of various developed and developing countries, there are few studies for the case of Turkey. Secondly, since efficiency measures are not sufficient to assess the overall performance of a bank, a risk-taking measure based on Laeven (1997) remarkable study on DEA is introduced in order to estimate risk appetite of banks. Thirdly, fixed effects panel data regression analysis has been used to analyze the determinants of DEA efficiency scores. Finally, the study aims to find out the impacts of recent financial crisis on the Turkish banking sector. The study covers a time period which is not examined and fulfilled with adequate number of studies yet. In over all, this paper attempts to extend the DEA literature by bringing together some of the methods suggested to improve DEA efficiency and productivity estimates for the case of Turkey in order to observe the impacts of recent 2007 global financial crisis.

The results that are strongly supported by the September, 2007 global financial crisis indicate that during 2003-2008, efficiency and productivity of Turkish banking sector had improved gradually and uninterruptedly, however in 2008-2009 sudden decreases in efficiency and productivity are detected. From 2009 to 2010, we, however, observe gradual recovery. Another finding is that return on assets has the largest positive impact on the efficiency whereas GDP growth and the ratio of nonperforming loans to total assets have the largest negative impact on efficiency scores, respectively. Also the risk taking measure indicates that in the pre crisis period banking sector's risk taking measure is positive but in the post crisis period it is negative depending on the reduced efficiency scores.

The organization of the paper is as follows: The next chapter is devoted to the survey of DEA and MPI literature. Chapter 3 explains the methodology used to measure bank efficiency and productivity. Chapter 4 provides information on the data used and describes the main variables employed in the efficiency model and in the regression. Chapter 5 discusses empirical results of the analysis. Finally, Chapter 6 concludes.

2. Literature Survey

Next sub section, summarizes the existing literature on DEA technique, and the following sub section summarizes the literature on Malmquist Productivity Index.

2.1. Data Envelopment Analysis (DEA)

In the literature, there are two empirical ways to measure efficiency: *non parametric programming* introduced by Charnes et al. (1978) and *parametric stochastic frontier technique* introduced by Aigner et al. (1977). The most popular non parametric technique is *Data Envelopment Analysis (DEA)* and the most popular parametric technique is *Stochastic Frontier Analysis (SFA)*. The fundamental difference between both techniques is that the non parametric techniques involve use of linear programming methods to construct a non-parametric piece-wise frontier whereas parametric techniques postulate a parametric frontier, based on a behavioral maximization hypothesis and assume that maximizing behavior is present and that it is exhibited by the most efficient firms in the sample. However, as argued by Laeven (1997), often there do not exist any *a priori* grounds for making this assumption.

In fact, there is no consensus in the literature to use either DEA or SFA in the measurement of efficiency. The main advantage of DEA over SFA is that DEA can be used even when conventional cost and profit functions that depend on optimizing reactions to prices cannot be justified (Laeven, 1997). Another advantage of DEA, as pointed out by Amoda and Dyson (2006), is that if the specific functional form chosen for the stochastic production frontier does not represent the actual technology, the specification bias may lead to misleading efficiency measurements. On the contrary, since DEA involves the use of linear programming methods to construct a non-parametric piece-wise frontier over the data, efficiency measures that are calculated relative to this frontier will not carry a specification bias and hence will be more accurate.

As pointed by Schmidt (1986), opponents of DEA claim that DEA estimates give only an upper bound to efficiency measures, it does not assume statistical noise, which means that all the the error term in the estimation is attributed to inefficiency and so tend to underestimate efficiency scores and efficiency scores generated by DEA are not very robust and are highly sensitive to sample selection, that's to say DEA efficiency scores are dependent on each other due to the nature of the estimation technique which is based on the construction of best practice frontier from the sample in hand to assess relative performance.

However, to remove those anomalies inherent in DEA estimators and to be able to make statistical inferences based on DEA estimates, in their challenging studies Simar and Wilson (1998, 1999, 2000) developed various measures based on the idea of *bootstrapping* initially proposed by Efron (1979). Moreover, Wilson (2008) developed a distinguished software package called *Frontier Efficiency Analysis with R* (FEAR) that incorporates the idea of bootstrapping to compute not only DEA estimates of technical, allocative and overall efficiency while assuming either variable, non-increasing or constant returns to scale but also MPIs and scale efficiency measures. In their papers, Xue and Harker (1999) and Casu and Molyneux (2000) also use bootstrapping to overcome the inherent dependency of DEA efficiency scores. Based on those challenging works, this paper uses DEA and employs bootstrapping method in the measurement of efficiency and productivity.

In the DEA literature, determination of choice variables, namely bank inputs and outputs deserves particular attention because it significantly affects the results. There are two different approaches that dominate DEA literature: *production and intermediation approach*[2].

Under the *production approach*, pioneered by Benston (1965), a financial institution is defined as a producer of services for account holders, that is, they perform transactions on deposit accounts and process documents such as loans. Hence, according to this approach, the number of accounts or its related transactions is the best measure for output, while the number of employees and physical capital are considered as inputs (Sufian, 2009). In the *intermediation approach*, however, banks are regarded as intermediators that accumulate deposits and other funds and transfer such funds to loans and other interest income producing assets. In this approach, banks' total loans and securities are assumed as outputs whereas deposits along with physical capital and labor are assumed as inputs. Moreover, under this approach, in contrast to the production approach, monetary values of accounts are used as choice variables.

More recently, there are several studies employing *mixed approach* in terms of the definition of bank inputs and outputs. In the mixed approach, banks are regarded as enterprises providing intermediation services and meanwhile engaging in production. Thus, under this approach measurement of inputs and outputs do not comply with either of the two previously mentioned approaches.

In the light of those approaches, this paper, regards banks as financial institutions trying to maximize profit through competition in the deposits and loan markets. On this basis, some leading indicator ratios regarding profitability, income, loans and deposits are used as bank inputs and outputs. In this approach, since a bank is regarded as a competitor, that's to say, producer of loans and deposits in the market, the study complies with the production approach. However, the data used in this study are not represented in terms of *account numbers* as in the production approach, but in terms of *monetary values* as in the intermediation approach. On the other hand, by using monetary values to form ratios the study diverges from intermediation approach, either. Therefore, the inputs and outputs used in this study should be classified under the *mixed approach*.

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[2] Besides those two major approaches there are also asset, user-cost and value added approaches used in various studies in the DEA literature. For detailed discussion of the issue see Favero and Papi (1995).

There are number of papers aiming to measure efficiency of banks by using DEA technique. However, in DEA literature, different input and output combinations are used in the calculation of bank efficiency. Table below summarizes those combinations used in selected studies of the banking literature.

Table 1: Studies on the Efficiency of Banking

Author	Observation Period	Countries Analysed	Inputs	Outputs	Method	Approach
Favero Papi (1995)	1991	Italy	Labor Capital Loanable Funds	Loans Securities Non-interest Income	DEA 2-Stage Regression	Intermediation Asset
Zaim Ertuğrul (1996)	1981-1990	Turkey	Number of Employees Total Interest Expenses Amortisation Costs Other Costs	Volume of Short and Long Term TL Deposits Volume of Short and Long Term TL Loans	DEA	Value Added
Laeven (1997)	1992-1996	Korea, Malaysia, Philippines, Thailand	Interest Expense Labor Expense Other Operating Expense	Loans Securities	DEA 2-Stage Regression	Intermediation
Jackson Fethi İnal (1998)	1992-1996	Turkey	Number of Employees Non-Labor Operating Expenses	Loans Deposits	DEA	Value Added
Saha Ravishankar (1999)	1991-1995	India	Number of Branches Number of Staff Establishment Expenditure Non-establishment Expenditure	Deposits Advances Investments Total Income	DEA	Production
Cingi Tarım (2000)	1989-1996	Turkey	Various Ratios	Various Ratios	DEA	Production
Casu Molyneux (2000)	1993-1997	EU Countries (France,Germany Italy, Spain, UK)	Total Costs Total Deposits	Loans Other Earning Assets	DEA 2-Stage Regression Bootstrap	Intermediation
Vujcic Jemric (2001)	1995-2000	Croatia	Fixed Assets Number of Employees Deposits	Loans Short Term Securities	DEA	Operating Intermediation
Çolak Altan (2002)	1999-2000	Turkey	Various Ratios	Various Ratios	DEA	Production
Isık Hassan (2003)	1981-1990	Turkey	Labor Capital Loanable Funds (deposit+non-deposit)	Short Term Loans Long Term Loans Off-Balance Sheet Items Other Earning Assets	DEA	Intermediation
Rezitis (2006)	1982-1997	Greece	Labor Capital Expenses Deposits	Loans Investment Assets	DEA 2-Stage Regression	Intermediation
Aras Kurt (2007)	1992-2003	Turkey	Various Ratios	Various Ratios	DEA	Mixed
Singh Singh Munisamy (2008)	2006	Asia Pacific Countries	Deposits Assets	Loans Interest Income	DEA	Intermediation
Sufian (2009)	2001-2004	Malaysia	Deposits Labor Fixed Assets	Loans Total Income	DEA	Intermediation
Thangavelu Findlay (2010)	1994-2008	Korea, Malaysia, Philippines, Thailand,Vietnam Singapore	Personnel Expenses Book Value of Fixed Assets Loanable Funds	Loans Non-interest Income	DEA 2-Stage Regression	Intermediation
Andries (2010)	2004-2008	Bulgaria,Czech R Poland, Romania, Slovakia ,Slovenia Hungary	Deposits Fixed Assets Operational Expenses	Loans Total Investments Other Incomes	SFA DEA	Intermediation

As depicted in Table-1, one of the preceding papers for Turkey is prepared by Zaim and Ertuğrul (1996). The paper investigates the effects of financial liberalization on Turkish banking sector in the period of 1981-1990 by using DEA. The paper adopts value added approach that considers balance sheet items with a substantial share of value added as outputs (i.e. both deposits and loans are considered as outputs) in the identification of inputs and outputs and finds that differences in bank efficiency scores are eliminated during liberalization. Similarly, Jackson et al. (1998) examines the impacts of financial liberalization policies adopted in 1980 on bank efficiency and productivity during 1992-1996, by using DEA and employing value added approach and finds that in general Turkish banking sector experienced productivity growth with the exception of 1993-94, due to the impacts of economic crisis and that private and foreign banks showed greater productivity growth compared to state owned banks.

In contrast to the previous studies, Cingi and Tarım (2000) adopt production approach in the identification of inputs and outputs and instead of monetary values, the study uses various ratios regarding the banking sector to observe the impacts of financial deregulation. The period under consideration is 1989-1996. Their finding supports Jackson et al. (1998) by concluding that in overall, the performance of private banks is higher than that of state owned banks and that inefficiency of public banks could be attributed to scale inefficiencies. In the same way, Çolak and Altan (2002) assume production approach and use various ratios in the measurement of Turkish banking sector efficiency during the 1999-2000 period.

More recently, Isik and Hassan (2003) investigate the performance of Turkish banks during 1981-1990 period, however by adopting intermediation approach. Besides what has been done in the previous studies, this paper also takes into consideration bank's off balance sheet items, loans to special sectors, inter-bank funds and investment securities in the calculation of efficiency. The results suggest that the average managerial efficiency in Turkish banks has substantially improved after deregulation. The decline in the level of efficiency during the initial years of financial deregulation is attributed to the strong increases in input volumes of banks and financial distress experienced because of some broker-age house and bank failures between 1983 and 1984. However, this period was followed by rapid growth in efficiency which is to some extent due to the utilization of idle capacity created in the advent of deregulation.

Similar to what is assumed in this study, a paper prepared by Aras and Kurt (2007) also assumes mixed approach and uses various ratios in the assessment of the performance of Turkish banks in the period of 1992-2003. In addition to previous studies, the paper takes into account bank risk factors in measuring the efficiency and finds out that banks transferred to SDIF had extreme loan growth and low efficiency scores and they had been carrying out high risk before transferred.

Besides the studies examining the Turkish banking sector, there are also several studies investigating the efficiency of various developed and developing countries banking systems as well, as summarized in Table-1. In addition to measuring banking sector efficiency by using DEA, in the studies of Favero and Papi (1995), Laeven (1997), Casu and Molyneux (2000), Rezitis (2006) and Thangavelu and Findlay (2010), a two-stage regression analysis is used to analyze the determinants of DEA efficiency scores as a second stage of the analysis.

In addition, in its remarkable study, Laeven (1997) introduces risk measure which is ignored by DEA efficiency estimators in order to fully take into account East Asian banks' performances during the pre-crisis period of 1992-96. The results suggest that foreign owned banks were among the most risky banks, together with company owned banks and that restructured banks after the 1997 crisis were the banks that had excessive loan growths.

Casu and Molyneux (2000), on the other hand, extend the existing literature by applying bootstrapping technique to efficiency estimators obtained by DEA in order to remove inherent dependency problem of DEA efficiency scores. The paper investigates whether the productive efficiency of European banking systems has improved and converged towards a common European frontier between 1993 and 1997, following the process of EU legislative harmonization. They find that since the EU's single market programme, there has been a small improvement in bank efficiency levels, although there is little evidence to suggest that these have converged and that efficiency differences across European banking markets appear to be mainly determined by country-specific factors.

This paper, however, after obtaining DEA efficiency and MPI productivity scores of Turkish banks at the first stage of the analysis, applies bootstrapping technique to remove inherent dependency problem and to be able to make valid statistical inferences based on those estimates and uses two-stage regression analysis at the second stage to find out determinants of bank efficiency. Moreover, based on Laeven's work, a risk taking measure is introduced for each bank. Therefore, this paper attempts to extend the DEA literature by bringing all the methods discussed above together for the case of Turkey in order to observe the impacts of recent 2007 global financial crisis.

2.2. Malmquist Productivity Index (MPI)

The Malmquist productivity index is used to measure and compare the productivity growth of different producing units from one period to another. Measurement is based on constructing best practice frontiers for adjacent years by using data on inputs and outputs of all producing units in the sample and then computing the output growth that is caused by shift of the frontier for each individual producing unit. What distinguishes MPI from the other alternative productivity indices such as Törnquist and Fischer is that since it is composed of distance functions it does not require any information on prices to calculate the productivity. That is, MPI is based only on quantity data and does not make any assumption on the functional form for the technology employed. Hence, MPI is considered as superior to alternative indices, particularly in cases when researcher does not have any information regarding prices.

Another advantage of MPI is that since it can be decomposed into two components, one which measures changes in technical efficiency (i.e. whether firms are getting closer to the production frontier over time), and one which measures changes in technology (i.e. whether the production frontier is moving outwards over time), it can provide additional insights.

MPI is named after Stan Malmquist's (1953) study. The path breaking paper that was proposed by Caves et al. (1982a) redefined the index as a ratio of distance functions and later, Fare et al. (1989b) showed how this index could be calculated by using non parametric linear programming methods. As a result of those successful attempts, the index has gained popularity in applied studies.

Based on those papers, Caves et al. (1982a, 1982b) showed how MPI could be decomposed into two as efficiency change and technical change. Ray and Desli (1997) has further decomposed MPI as technical change, efficiency change and scale efficiency change. More recently, based on the inverse relationship between output distance functions and output oriented technical efficiency measures, Fare et al. (1994b) proposed a method to calculate the MPI relative to non parametric frontier.

Those successful theoretical studies are followed by large number of applied studies in various fields. Up to now, MPI has been applied to public sector, agriculture, banking, electric utilities, transportation, insurance companies, agriculture and countries to measure productivity.

In the literature, MPI has been widely used in measuring the productivity of banking sector as well. In this field, the first attempt came from Berg et al. (1992). They searched for the impacts of deregulation on the productivity of the Norwegian banks throughout 1980's. The results indicate that while the banking sector experienced deterioration during the first years of deregulation, an improvement is observed in the following years.

Following this first attempt, several papers measuring total factor productivity growth of Turkish banking sector by using MPI technique are published. One of the preceding papers for Turkey is prepared by Jackson et al. (1998). The paper aims to analyze the technical efficiency and productivity change over the period 1992-1996, following the financial deregulation, by utilizing DEA and MPI. The paper concludes that in general Turkish banking sector experienced productivity growth with the exception of 1993-94, due to the impacts of the economic crisis. Another finding is that among the three ownership types, private and foreign banks showed greater productivity growth compared to the state owned banks.

Cingi and Tarım (2000) examined the total factor productivity growth of Turkish banking sector by using MPI during 1989-1996. Their finding supports the previous work by concluding that in overall, the performance of private banks is higher than that of state owned banks. Another paper in this field is prepared by Isik and Hassan (2003). Similar to the previous studies, by using MPI, they investigate the effects of financial deregulation on all banks operating in Turkey during 1981-1990 period. Their findings suggest that all form of Turkish banks have recorded significant productivity gains driven mostly by efficiency increases rather than technical progress and that private banks began to close their performance gap with public banks in the new environment.

More recently, Karacabey and Arslan (2004) applied MPI technique to 43 Turkish commercial banks over the period 1997-2000. The results indicate that most banks experienced productivity loss due to the negative technological change during the entire period. The results of the productivity change analysis according to banks' ownership structures and scales shows that all the groups experienced similar production changes, which indeed indicates that the banks productivity change is mainly a consequence of the domestic economy's cycles. Öncü and Aktaş (2007), measure the changes in total factor productivity of Turkish banks over 2001-2005, during the restructuring period of Turkish banking sector. This study finds that Turkish banks experienced productivity gains in 2001-2005 period, which was mainly attributed to technical progress rather than efficiency increases.

Ceyhan (2007) and Aysan and Ceyhan (2008) are the other remarkable studies applying MPI technique to measure productivity. Ceyhan's 2007 paper aims to find the effects of globalization on the performance of Turkish banking sector during 1990-2006, with an emphasis to the period after 2001 crisis. By using MPI and its mutually exclusive and exhaustive components of efficiency and technological changes and by further decomposing efficiency change component into two as pure technical and scale efficiency changes, the paper finds that the productivity of the banking sector have increased due to the technological improvement. Moreover, with respect to ownership, foreign banks were the most efficient group until 2001 after which state banks captured the first place and with respect to size, before 2000, the most efficient bank group was the medium-scale banks.

Similarly, Aysan and Ceyhan (2008) aims to measure the productivity change of Turkish banks as a result of increasing foreign bank entry, during 1990-2006 with MPI, by using a sample of 20 commercial banks. The study concludes that Turkish economy experienced productivity increase which is predominantly attributed to both technological and efficiency improvement when the benchmark years were

1990 and 2001. After 2000, however, the productivity increase was solely due to technological improvement reflecting the existence of structural changes in the Turkish banking sector. Also, after 2000, pure technical efficiency of the sector increased reflecting the fact that the quality of bank management has been of increasing importance.

The literature survey on MPI reveals that MPI is an efficient way of measuring the total factor productivity change from one period to another and it allows to find the main sources of improvement in the productivity, as well.

3. Methodology

This chapter describes the methodology used in this paper to measure bank efficiency and productivity. The first sub section is devoted to DEA. The following sub section describes the methodology underlying bootstrapping technique. Finally, the last sub section explains the methodology of MPI.

3.1. DEA Technique

In a simple production technology, there exist two main variables, namely inputs and outputs. On this basis, a multi-input and multi-output production technology involving N number of inputs and M number of outputs could be defined as follows:

(3.1.1) $$T = \left\{(x, y) \in R_{+}^{M+N} : x \text{ can produce } y\right\}$$

where $x = (x_1, ..., x_N) \in R_{+}^{N}$ represents vector of inputs and $y = (y_1, ..., y_M) \in R_{+}^{M}$ represents the vector of outputs. Intuitively, production set T consists of all combinations of inputs and outputs such that x can produce y.

Production technology could equivalently be represented by output set (also known as production possibility set) which is defined as:

(3.1.2) $$P(x) = \left\{ y \in R_{+}^{M} : (x, y) \in T \right\}$$

Given the notation presented above, we now move onto the definition of output distance function which is very useful tool in describing the technology in such a way that it enables us to measure efficiency and productivity in a reliable manner. Distance function is simply based on radial contractions and expansions.

Malmquist (1953) and Shephard (1953) introduced this notion, independently in their own studies. The advantage of using distance functions is that it allows defining multi input and multi output production technology without the need to specify a behavioral objective such as cost minimization or profit maximization (Coelli et al., 2005). A researcher could either use input or output distance functions depending on the objective of the analysis. Particularly, input distance function concentrates on the idea of minimal proportional contraction of the input vector, given the output vector whereas output distance function concentrates on the idea of maximal proportional expansion of the output vector, given the input vector. In this paper, since banks are regarded as decision making units trying to maximize their profits (i.e. outputs) given the funds available (i.e. inputs), it would be more appropriate to use output oriented DEA. Hence, given the input vector, one can define the output distance function as follows:

(3.1.3) $$D_O(x,y) = \min\{\, \mu : (y/\mu) \in P(x) \,\}$$

where $0 \le D_O(x,y) \le 1$.[3] Choice of orientation to calculate the efficiency is not the end of the story. Since it is possible to have firms that are efficient both technically and allocatively but that are not operating at an optimal scale, one should also be careful in choosing the appropriate returns to scale technology that will be applied in the analysis.

Efficiency could either be estimated assuming constant returns to scale (CRS), variable returns to scale (VRS) or non increasing returns to scale (NIRS) technology[4]. However, the CRS assumption holds when all banks are operating at an optimal scale, but this becomes very unrealistic when imperfect competition, government regulations, constraints on finance etc. are considered. Moreover, assuming CRS, when not all banks are operating at an optimal scale would result in technical efficiency measures confounded by scale efficiencies (Coelli et al., 2005). Hence, in such cases, it would be more appropriate to assume VRS yielding technical efficiency estimates that are free of scale efficiency effects.

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[3] Efficiency scores could either be estimated by using Shephard or Farrell distance functions. Since Farrell distance functions are nothing more than the inverse of Shephard distance functions, a researcher could use any one of them. In this study, efficiency scores are calculated in terms of Shephard distance functions.
[4] For graphical representation and detailed discussion of the issue see Diler (2009).

Another advantage of VRS specification over the CRS is that this approach forms a convex hull of intersecting planes that envelope the data points more closely than the CRS and NIRS conical hull. Moreover, the more developed banking system is, the more likely it is that the banks face non-constant returns to scale (McAllister and McManus, 1993 and Wheelock and Wilson, 1995).In terms of banking, some papers use CRS approach with the motivation of being more conservative in the measurement of bank efficiency scores, because efficiency scores obtained under CRS assumption would certainly be smaller than scores obtained under VRS assumption. However, when we estimate efficiency scores under two approaches we observe that the scores are very close to each other. Therefore, for the reasons explained above, in this paper we assume VRS for the Turkish banking sector[5].

Based on the notation explained so far and the discussion above, the DEA model that is used in this paper could be formulated as follows:

Assume that there exist $k = 1,...K$ observations in the sample. Hence, given our data set, for VRS specification, an output set that holds for every period and for all observations can be constructed in the following way:

(3.1.4) $$P(x) = \left\{ y \in R_{+}^{M} : \sum_{k=1}^{K} z_k y_{km} \geq y_m \right.^{6} \qquad m = 1,...M$$

$$\sum_{k=1}^{K} z_k x_{kn} \leq x_n \qquad n = 1,...N$$

$$z_k \geq 0 \qquad k = 1,...K$$

$$\left. \sum_{k=1}^{K} z_k = 1 \right\}^{7}$$

[5] Several number of papers aiming to measure bank efficiency in the literature adopts VRS assumption. For the detailed discussion of the issue, see McAllister and McManus (1993), Wheelock and Wilson, (1995), Sufian (2009), Casu and Molyneux (2000).

[6] It is the direct consequence of strong disposability of outputs. For a detailed discussion see Fare and Grosskopf (1998-2000).

[7] Convexity constraint that imposes the VRS assumption . It ensures that an inefficient firm is only benchmarked against firms of a similar size. That's, the projected point for that firm on the DEA frontier is a convex combination of observed firms.

where z_k 's stand for the intensity variables (weights) assigned to each observation while constructing the production set. Thus, given the production set and constraints specified above, the fractional programming problem that should be solved by DEA (i.e. output oriented VRS DEA model) for each k, would be as follows:

(3.1.5)
$$D_O(x,y) = \min_{\mu,z}\left\{ \mu : \sum_{k=1}^{K} z_k y_{km} \geq y_m / \mu \qquad m = 1,...M \right.$$
$$\sum_{k=1}^{K} z_k x_{kn} \leq x_n \qquad n = 1,...N$$
$$z_k \geq 0 \qquad k = 1,...K$$
$$\left. \sum_{k=1}^{K} z_k = 1 \right\}$$

However, the software used in the analysis is designed to solve only linear programming problems. So, the algorithm transforms the fractional programming problem in (3.1.5) to the linear programming problem as follows[8]:

(3.1.6)[9]
$$\theta_k^* = (D_O(x,y))^{-1} = \max_{\theta,z}\left\{ \theta : \sum_{k=1}^{K} z_k y_{km} \geq \theta y_m \qquad m = 1,...M \right.$$
$$\sum_{k=1}^{K} z_k x_{kn} \leq x_n \qquad n = 1,...N$$
$$z_k \geq 0 \qquad k = 1,...K$$
$$\left. \sum_{k=1}^{K} z_k = 1 \right\}$$

[8] The fractional programming problem in (3.1.5) and the linear programming problem in (3.1.6) are trivially identical. However, (3.1.5) is transformed into (3.1.6) through $\theta = 1/\mu$, to make it linear.

[9] The linear programming model discussed here is originally developed by Charnes, Cooper and Rhodes (1978, 1979) and is known as CCR model. This model measures the efficiency under CRS assumption. Based on this study, Banker et al. (1984) extended the CCR model by relaxing the CRS assumption. The resulting "BCC" model uses VRS assumption. In this paper, we assume VRS in the linear programming problem to be solved for each bank to obtain efficiency scores. For the transition of linear programming problem from the CCR model to the linear programming model based on Shephard distance function see Banker, Charnes and Cooper (1984).

By taking the inverse of efficiency score obtained from (3.1.6.), the algorithm returns the output oriented Shephard distance function, namely Do(x,y) which lies between zero and one, for each bank.

3.2. Bootstrapping

More recently, in their 1998 and 2000 papers, for multi-input and multi-output model, Simar and Wilson suggested the use of bootstrapping technique which was originally developed by Efron (1979) in order to be able to assess statistical properties of non-parametric efficiency estimates derived from some unobservable data generating process, to remove inherent dependency among efficiency scores and eventually to obtain bias corrected DEA efficiency scores.

To begin with, suppose a data generating process (DGP), φ generating a random sample of:

(3.2.1.) $$S = \{ (x_k, y_k) : k = 1,...K \}$$

By some method *M,* this sample defines estimators of T and $P(x)$ discussed in the previous section, namely $\hat{T}$ and $\hat{P(x)}$. Given those, for k*th* observation, the output oriented technical efficiency score at point (x_k, y_k) can be calculated as follows:

(3.2.2) $$\hat{\theta}_k = \max\{ \theta : \theta y \in \hat{P(x)} \}$$

which is the estimator of the true but unobserved population efficiency score θ_k. The problem is that sampling distributions of $\hat{T}$ and $\hat{P(x)}$ could not be inferred because φ is unknown and the complexity of *M* makes it almost impossible to determine it. However, bootstrapping technique which is based on the idea that there exists a consistent estimator of , φ namely $\hat{\varphi}$, enables us to obtain consistent estimators of T and $P(x)$, even though φ is unknown.

Now, suppose that, given the sample S, by using our knowledge, we can produce a consistent estimator of φ namely, $\hat{\varphi}$. Then, consider another sample S^* which is generated by $\hat{\varphi}$ through random resamplings with replacement from S. Formally, (3.2.3) $$S^* = \left\{ (x_k^*, y_k^*) : k = 1,...K \right\}$$

Similar to S, by some method *M,* this pseudo sample also defines corresponding estimators of T and P(x) that are $\hat{T}^*$ and $\hat{P(x)}^*$ respectively. Thus, for any pair of (x_k^*, y_k^*), the corresponding output oriented technical efficiency score is given by:

(3.2.4) $$\hat{\theta}_k^* = \max\left\{ \theta : \theta y \in \hat{P(x)}^* \right\}$$

Expression (3.2.4) could equivalently be defined as a linear programming problem:

(3.2.5) $$\hat{\theta}_k^* = \max_{\theta,z} \left\{ \begin{array}{ll} \theta : \sum_{k=1}^{K} z_k y_{km}^* \geq \theta y_m & m = 1,...M \\ \sum_{k=1}^{K} z_k x_{kn}^* \leq x_n & n = 1,...N \\ z_k \geq 0 & k = 1,...K \\ \sum_{k=1}^{K} z_k = 1 & \end{array} \right\}$$

In this case, however, since the underlying DGP, $\hat{\varphi}$ is already known, the sampling distributions of the estimators $\hat{T}^*$ and $\hat{P(x)}^*$ are completely known, although it may be difficult to estimate analytically. Nevertheless, the sampling distributions could easily be approximated by Monte Carlo methods. The steps of the approximation can be summarized as follows:

1. Use $\hat{\varphi}$ to generate B number of pseudo samples such that S_b^*, where $b = 1,...B.$
2. Apply M to each of those samples and obtain the estimators $\hat{\mathrm{T}}_{b*}$ and $\hat{\mathrm{P(x)}}_{b*}$ for $b = 1,...B.$
3. Obtain $\hat{\theta}_{kb}^*$ for each k, where $k = 1,...K$ and $b = 1,...B.$

This procedure allows us to estimate the empirical density function of $\{\hat{\theta}^*_{kb}\}^B_{b=1}$ which is nothing more than the Monte Carlo approximation of the distribution of $\hat{\theta}^*_{kb}$ conditional on $\hat{\varphi}$. Intuitively, by repeatedly simulating or mimicking the DGP through resampling with replacement and through applying the original estimator to each simulated sample, we could approximate the sampling distributions of the original estimator.

Given the assumption[10] that $\hat{\varphi}$ is a consistent estimator of φ, the bootstrap method concludes that the known bootstrap distributions obtained by the procedure described above will mimic the original unknown sampling distributions of the estimators of interest (Simar and Wilson, 1998)[11]. More formally,

(3.2.6) $$\left(\hat{\theta}^*_k - \hat{\theta}_k\right) \mid \hat{\varphi} \sim \left(\hat{\theta}_k - \theta_k\right) \mid \varphi$$

That's to say, *within the true world*, $\hat{\theta}_k$ is an estimator of θ_k based on the sample S, generated from some DGP, φ whereas, *in the bootstrap world*, $\hat{\theta}^*_k$ is an estimator of $\hat{\theta}_k$ based on the sample S* generated from $\hat{\varphi}$. On this basis, we can estimate:

(3.2.7) $$bias_{\varphi,k} = E_{\varphi}\left(\hat{\theta}_k\right) - \theta_k$$

by using its bootstrap estimate given by:

(3.2.8) $$bias_{\hat{\varphi},k} = E_{\hat{\varphi}}\left(\hat{\theta}^*_k\right) - \hat{\theta}_k$$

which could be approximated by Monte Carlo realizations $\hat{\theta}^*_{kb}$:

(3.2.9) $$b\hat{i}as_k = \frac{1}{B}\sum_{b=1}^{B}\hat{\theta}^*_{kb} - \hat{\theta}_k = \overline{\theta}^*_k - \hat{\theta}_k \qquad \text{for } b = 1,\ldots B$$

Thus, bias corrected estimator of $\hat{\theta}_k$ is given by:

[10] See Hall (1992).
[11] For more detailed discussion and derivations, see Simar and Wilson (1998, 2000).

(3.2.10) $$\tilde{\theta}_k = \hat{\theta}_k - b\hat{i}as_k = 2\hat{\theta}_k - \bar{\theta}_k^*$$

The standard error of $\hat{\theta}_k$ can be estimated by:

(3.2.11) $$s\hat{e} = \left\{ \frac{1}{B-1} \sum_{b=1}^{B} \left(\hat{\theta}_{kb}^* - \bar{\theta}_k^* \right)^2 \right\}^{1/2}$$

The confidence interval for θ_k for some values a_α and b_α given by:

(3.2.12) $$Prob\left\{ -b_\alpha \le \left(\hat{\theta}_k - \theta_k \right) \le -a_\alpha \right\} = 1 - \alpha$$

can easily be calculated by using its bootstrap estimate for some bootstrap values a_α^* and b_α^* which is given by:

(3.2.13) $$Prob\left\{ -b_\alpha^* \le \left(\hat{\theta}_{kb}^* - \hat{\theta}_k \right) \le -a_\alpha^* \;\middle|\; S^* \right\} = 1 - \alpha \qquad \text{for } b = 1, \ldots B$$

substituting a_α^* and b_α^*, for a_α and b_α in (3.2.12), combined with (3.2.13) leads to the bootstrap approximation:

(3.2.14) $$Prob\left\{ -b_\alpha^* \le \left(\hat{\theta}_k - \theta_k \right) \le -a_\alpha^* \;\middle|\; S^* \right\} \approx 1 - \alpha$$

Therefore,

(3.2.15) $$\hat{\theta}_k + a_\alpha^* \le \theta_k \le \hat{\theta}_k + b_\alpha^*$$

3.3. Malmquist Productivity Index

Malmquist Productivity Index (MPI) is the total factor productivity index that measures the change in total productivity of the factors between the two time periods by calculating the ratio between the distance from each point observed in the respective technology. There exists input and output oriented MPI introduced by Caves et al. (1982) which are composed of Shephard (1970) input and output distance functions discussed in the previous section[12]. Following Fare et al. (1994b), output oriented MPI used in this study based on output distance functions is defined as[13]:

(3.3.1) $$M_O\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \left[\frac{D^t_{O,CRS}\left(x^{t+1}, y^{t+1}\right)}{D^t_{O,CRS}\left(x^t, y^t\right)} \times \frac{D^{t+1}_{O,CRS}\left(x^{t+1}, y^{t+1}\right)}{D^{t+1}_{O,CRS}\left(x^t, y^t\right)} \right]^{1/2}$$

A value of M_o greater than 1 indicates improvement in productivity whereas a value less than 1 indicates deterioration from time t to t+1. We must note that equation (3.3.1) is actually geometric mean of two indices. The first one is evaluated in relation to the technology of time t, and the second one relative to the technology of period t+1. Therefore, MPI can be decomposed into two different components, namely efficiency change (MEFFCH) and technical change (MTECH) defined as follows[14]:

(3.3.2) $$MEFFCH_t^{t+1} = \frac{D^{t+1}_{O,CRS}\left(x^{t+1}, y^{t+1}\right)}{D^t_{O,CRS}\left(x^t, y^t\right)}$$

(3.3.3) $$MTECH_t^{t+1} = \left[\frac{D^t_{O,CRS}\left(x^{t+1}, y^{t+1}\right)}{D^{t+1}_{0,CRS}\left(x^{t+1}, y^{t+1}\right)} \times \frac{D^t_{O,CRS}\left(x^t, y^t\right)}{D^{t+1}_{O,CRS}\left(x^t, y^t\right)} \right]^{1/2}$$

Equation (3.3.1) combined with (3.3.2) and (3.3.3), together imply that:

(3.3.4) $$M_t^{t+1} = MEFFCH_t^{t+1} \times MTECH_t^{t+1}$$

The first component measures the change in technical efficiency between time t and t+1, and hence whether the production is getting closer to the best practice frontier for all observations in the sample (Zaim and Taşkın, 1997). The second component shows the shift in frontier between time t and t+1. Overall, index

[12] In this section to conserve space, output oriented MPI is discussed. Input oriented MPI involves a straightforward translation of the notation explained in this section.
[13] $D_0^{t+1}(x^t, y^t)$,for example, measures the distance of bank at time t relative to the frontier at time t+1. Thus, the superscript on the distance function denotes the reference technology whereas superscripts on inputs and outputs denote the time period under consideration.
[14] For graphical representation and derivation of MPI components, see Diler (2009).

values greater than one indicates improvement in productivity whereas values less than one indicates deterioration in productivity.

However, Fare et al. (1994b) further decomposed efficiency change component of equation (3.3.4) as pure efficiency change and scale efficiency change defined by:

(3.3.5) $$PUREEFFCH_t^{t+1} = \frac{D_{O,VRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{O,VRS}^{t}\left(x^{t}, y^{t}\right)}$$

(3.3.6) $$SCALEEFFCH_t^{t+1} = \frac{D_{O,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right) / D_{O,VRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{0,CRS}^{t}\left(x^{t}, y^{t}\right) / D_{O,VRS}^{t}\left(x^{t}, y^{t}\right)}$$

In this decomposition, efficiency change (MEFFCH) refers to efficiency change calculated under CRS assumption whereas pure efficiency change (PUREEFFCH) refers to efficiency change calculated under VRS. Therefore, scale efficiency change (SCALEEFFCH) corresponds to residual scale component which captures changes in the deviation between CRS and VRS technology. An improvement in efficiency which is attributed to the pure efficiency change, also known as managerial efficiency change, reflects managers' correct policy making in allocating facilities and sources whereas an improvement in efficiency which is attributed to the scale efficiency change rather than pure efficiency change reflects that the firm is operating at the increasing returns to scale portion of its long run average cost curve and there is still room for this firm to benefit from economies of scale by expanding production. Similar to the other components of MPI, a value greater than one indicates improvement in that component whereas values less than one indicates deterioration.

Hence, (3.3.5) and (3.3.6) combined with (3.3.4) implies that,

(3.3.7) $$M_t^{t+1} = PUREEFFCH_t^{t+1} \times SCALEEFFCH_t^{t+1} \times MTECH_t^{t+1}$$

The estimation of MPI requires the estimation of four different output distance functions explained in the previous section. However, similar to DEA estimators, MPI is also obtained by non parametric DGP based on the estimation of true but unobserved best practice frontier and this introduces dependency and bias to MPI, as well. Hence, to remove this bias, based on their 1998 paper, Simar and Wilson (1999) suggested applying bootstrapping technique to MPI. The procedure is similar to the one explained for DEA estimators[15]. In this context, bootstrapping technique provides confidence intervals for MPI that enable us to assess whether productivity changes as measured by the MPI are significant in a statistical sense. If it is significant, then the results imply a real change in productivity, otherwise it should be considered as nothing more than a trick of sampling noise. Therefore, in this paper bootstrapped, namely bias corrected, MPI obtained through 2000 random resamplings is used to evaluate bank productivity.

4. Data

The data used in this study are taken from The Bank Association of Turkey, which is a rich source for balance sheet and profit & loss account data for individual banks. The data is on 22 Turkish commercial deposit banks[16] for the years 2003-2010.

Given the data set, banks are divided into five groups as public banks, private 1 banks, private 2 banks, private 3 banks and private 4 banks, according to their scale and size, placing the largest private banks into private 1 group and smallest banks into private 4 group[17]. It is important to note that, this paper uses bank peer grouping developed especially for ratio analysis by BRSA for internal reporting systems and updated regularly according to the sights and reports of on-site supervisory staff. The criteria in BRSA's categorization are bank's functioning group and its asset size. In this categorization banks are divided into 6 as public, investment and development, participation, private (private 1, 2, 3 and 4 based on asset size), SDIF and foreign bank branch. Only public and private banks are considered in the analysis. In this categorization, foreign banks that have only branches in Turkey are grouped under foreign bank branch category whereas foreign banks that have head offices in Turkey (like HSBC, ING and Citibank) are grouped under private banks category and placed into the appropriate private

[15] For theory and methodology of estimating and bootstrapping MPI, see Simar and Wilson (1999).
[16] In DEA analysis, working with a sample including similar decision making units in terms of scale, size and ownership is essential for the sake of the analysis. Since incentives for managers to efficiently allocate resources might differ under different ownership arrangements, this study eliminates 6 foreign bank branches in total of 31 commercial banks. Also, one bank transferred to SDIF and 2 banks which should be considered as an outlier in terms of its inputs and outputs are eliminated from the analysis to obtain a homogeneous sample. Hence, we are left with 22 commercial banks.
[17] Banking groups, together with banks covered, could be seen in Table 3 in the next section.

bank group according to their asset sizes. Hence, based on BRSA's peer grouping, in contrast to the studies on mainstream banking DEA literature, the foreign-owned banks are not considered as a separate sub group in this paper[18].

The coverage of data is quite good. In terms of bank loans and deposits, the coverage of the total commercial banking system by our sample is about 90,8% for loans and 94,4% for deposits. In terms of number of commercial banks, the coverage by our sample is 68,8%.

Appendix A.1 and A.2 summarize the data used in this study. According to the data, during 2003-2010 period, Turkish banking sector experienced extreme loan growth (728,3%). Public banks and small scale private banks (private 4), were the banks that had the largest loan growth among other groups. Moreover, net profit and total assets of the banking sector[19] increased sharply during this period. Also, it is important to note that although private 4 banks were the banks that had extreme loan growth, their net profit growth was the smallest among the others. During this period, however, non performing loans increased by 157,6%. This indicates that in overall, while experiencing growth, Turkish banking sector had also incurred risks, but growth of nonperforming loans were relatively moderate when compared to the loan, asset and net profit growth rates. Also, we observe conservative growth rates in noninterest expenses and securities during 2003-2010.

In 2003-2004 which is considered as a restructuring period for the Turkish banking sector following the 2001 crisis and in 2007-2008 periods which is the period hit by recent global financial crisis, we observe decrease in net profits of the banking sector. Also, it is important to note that soon after the 2007 crisis, total equity of the banking sector increased by 28,9% from 2007 to 2008. The idea was that increased equity could serve as a buffer against crisis.

As discussed in the previous section, in the literature, there is no consensus regarding inputs and outputs that should be used in the efficiency analysis of

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[18] Although the peer grouping used in this paper disregards foreign-owned banks as a sub category, we believe that it would not be inappropriate to use a peer grouping developed especially for ratio analysis in the study which is composed of several ratios regarding banks. Also, the empirical results for bank groups do not suggest irrelevancy given the expectations for the period under consideration. However, the appropriateness of the grouping is open to discussion for different input-output combinations, other than ratios.

[19] In this study, banking sector corresponds to 22 commercial banks. Therefore, total amounts regarding the banking sector were the totals of those 22 commercial banks that cover more than 90% of the total banking sector in terms of loans and deposits.

banks. For the reasons explained previously, this study adopts *mixed approach* and uses 8 ratios (5 inputs and 3 outputs) to measure bank efficiency[20].

The inputs used for each bank are:

- ✓ Securities / Total Assets
- ✓ Deposits / Total Assets
- ✓ Non Performing Loans (Gross) / Total (Cash) Loans[21]
- ✓ Total Loans / Total Assets[22]
- ✓ Non Interest Expense / Total (Average) Assets

The outputs used are:

- ✓ Return on Average Assets (ROA): Net Profit (Loss) / Total (Average) Assets
- ✓ Return on Average Equity (ROE): Net Profit (Loss) / Total (Average) Equity
- ✓ Net Interest Income / Total Income

To further investigate the determinants of bank efficiency we follow the so called Two-Step approach, as suggested by Coelli et al. (1998). Using the efficiency measures derived from the DEA estimations as the dependent variable, we then estimate the following fixed effect regression model:

$$\hat{\theta}_k^* = b0 + b1\,ROA + b2\,LNTA + b3\,LOANSTA + b4\,NPLTA(-1)$$
$$+ b5\,CAR + b6\,DLNRGDP + b7\,NIM + b8\,INF + b9\,LNDEP + ei$$

where:

ROA: Return on average assets

LNTA: Logarithm of total assets

LOANSTA = Total Loans / Total Assets

NPLTA(-1): Non Performing Loans (Gross) / Total (Cash) Loans with one period lag

CAR: Capital adequacy ratio

[20] Similar output and input combinations have been used in studies of Charnes (1990), Çolak and Altan (2002), Cingi and Tarım (2000) and Aras and Kurt (2007).

[21] Since this ratio is considered to be bad (undesirable) output i.e. output that is tried to be minimized by banks, it is regarded as an input in this study. See Pasuphaty (2002) for more detailed discussion of the issue.

[22] Although in terms of intermediation and production approaches loans are regarded as output of a bank, the ratio of total loans to total assets are regarded as input in this study. The reason is that this ratio is regarded as an indicator of asset management and quality from the view point of the bank management. The concern of the bank management is not the production of loans, but careful placements of loans. So, when a bank extends its credits it would incur more risks and since bank wants to minimize the risk incurred, the ratio is classified as an input.

DLNRGDP: Logarithm difference of real GDP

NIM: Net interest margin i.e. spread between deposit and loan rates

INF: Inflation (% change in CPI, annually)

LNDEP: Logarithm of total deposits

5. Empricial Result

To obtain empirical results, output oriented DEA model under the assumption of VRS and output oriented MPI is used as formulated in methodology described in section 3. All the computational work is done by software package *Frontier Efficiency Analysis with R (FEAR) 1.11* developed by Wilson (2008)[23]. What distinguishes FEAR from the alternative software packages like DEAP or STATA is that it permits to estimate not only non parametric DEA estimates of technical, allocative, scale and overall efficiency (while assuming either CRS, NIRS or VRS) and MPIs but also it permits to estimate bootstrapped (i.e. bias corrected) efficiency scores which eventually enables us to do statistical inference based on those findings. In the first sub section of this part, bootstrapped efficiency scores of banks are discussed. The second sub section is devoted to the bootstrapped MPI scores of banks. The third sub section discusses the risk measurement issue. Finally, in the last sub section results of two-stage regression analysis are discussed.

5.1. DEA Efficiency Scores of Banks

Based on the previously mentioned data, DEA efficiency scores are estimated for each bank, for the period 2003-2010. On this basis, as explained in the data section, banks are grouped into 5 as public, private 1, private 2, private 3 and private 4 banks according to their status and size, with private 4 being the bank group comprised of the smallest scale private banks. In the efficiency estimation a common frontier is assumed for all bank groups. Following the procedure described in Isik and Hassan (2002), the hypothesis of identical frontiers for each year under consideration is tested both by ANOVA (parametric) and Kruskal-Wallis (non parametric) tests. As a result, both test statistics given in the following table fail to reject the null hypothesis of identical frontier between groups. Therefore,

[23] For further discussion on FEAR, see FEAR 1.11 Command Reference or User Guide, Wilson (2008)

bootstrapping technique is applied to the efficiency scores estimated from identical frontier assumption.

Table 2: Summary of ANOVA and Kruskal-Wallis Tests

	ANOVA Test (parametric)*	*Kruskal-Wallis Test (non parametric)*
2003 (probability)	1,276 (0,318)	2,972 (0,563)
2004 (probability)	0,605 (0,664)	1,827 (0,768)
2005 (probability)	0,684 (0,613)	2,304 (0,680)
2006 (probability)	1,244 (0,330)	1,263 (0,868)
2007 (probability)	0,712 (0,595)	2,105 (0,717)
2008 (probability)	1,040 (0,416)	2,672 (0,614)
2009 (probability)	0,593 (0,673)	1,596 (0,810)
2010 (probability)	1,376 (0,284)	2,272 (0,686)

(*)degrees of freedom is 4,17

Table 3 below summarizes the results and compares DEA efficiency scores with bootstrapped DEA efficiency scores of banks.

Table 3: Comparison of DEA and Bootstrap Efficiency Scores, 2003-2010

	2003	2003*	2004	2004*	2005	2005*	2006	2006*	2007	2007*	2008	2008*	2009	2009*	2010	2010*
T.C. ZİRAAT BANKASI A.Ş.	1,000	0,789	1,000	0,697	1,000	0,808	1,000	0,796	1,000	0,903	1,000	0,943	1,000	0,824	1,000	0,763
TÜRKİYE HALK BANKASI A.Ş.	1,000	0,732	1,000	0,708	0,657	0,587	0,792	0,719	0,871	0,827	0,971	0,946	1,000	0,849	1,000	0,768
PUBLIC	*1,000*	*0,760*	*1,000*	*0,703*	*0,811*	*0,689*	*0,890*	*0,757*	*0,933*	*0,864*	*0,986*	*0,944*	*1,000*	*0,837*	*1,000*	*0,765*
TÜRKİYE VAKIFLAR BANKASI T.A.O.	0,725	0,632	1,000	0,799	0,833	0,756	1,000	0,907	1,000	0,904	1,000	0,940	0,975	0,909	0,840	0,762
AKBANK T.A.Ş.	1,000	0,644	1,000	0,707	1,000	0,806	1,000	0,858	1,000	0,930	1,000	0,939	1,000	0,912	1,000	0,772
TÜRKİYE GARANTİ BANKASI A.Ş.	1,000	0,646	0,744	0,676	0,853	0,791	0,860	0,791	1,000	0,899	1,000	0,942	1,000	0,894	1,000	0,839
TÜRKİYE İŞ BANKASI A.Ş.	0,478	0,414	0,739	0,672	0,898	0,817	0,834	0,776	0,744	0,704	0,790	0,769	0,859	0,806	0,876	0,808
YAPI VE KREDİ BANKASI A.Ş.	0,280	0,238	0,443	0,405	0,677	0,639	0,759	0,699	0,686	0,661	0,953	0,926	0,870	0,820	1,000	0,886
PRIVATE 1	*0,627*	*0,482*	*0,754*	*0,636*	*0,845*	*0,759*	*0,885*	*0,803*	*0,874*	*0,812*	*0,945*	*0,900*	*0,939*	*0,867*	*0,940*	*0,812*
TÜRK EKONOMİ BANKASI A.Ş.	1,000	0,631	1,000	0,711	0,955	0,858	1,000	0,839	0,894	0,850	1,000	0,941	0,770	0,715	0,907	0,821
FORTİS BANK A.Ş.	1,000	0,636	0,662	0,587	0,809	0,749	0,952	0,880	0,900	0,865	0,901	0,876	0,685	0,642	0,765	0,717
ING BANK A.Ş.	0,847	0,711	1,000	0,752	1,000	0,811	0,974	0,894	0,899	0,854	0,745	0,724	1,000	0,823	1,000	0,852
FİNANSBANK A.Ş.	0,901	0,764	1,000	0,748	1,000	0,797	1,000	0,803	1,000	0,928	0,901	0,878	0,876	0,817	1,000	0,893
HSBC BANK A.Ş.	1,000	0,650	1,000	0,706	1,000	0,803	1,000	0,797	1,000	0,900	1,000	0,939	1,000	0,904	1,000	0,908
DENİZBANK A.Ş.	0,775	0,666	0,901	0,803	0,938	0,841	0,998	0,909	0,862	0,826	1,000	0,940	1,000	0,819	1,000	0,852
PRIVATE 2	*0,916*	*0,675*	*0,917*	*0,714*	*0,948*	*0,809*	*0,987*	*0,853*	*0,924*	*0,870*	*0,920*	*0,879*	*0,879*	*0,782*	*0,941*	*0,838*
ŞEKERBANK T.A.Ş.	1,000	0,745	1,000	0,862	0,950	0,877	0,747	0,692	0,904	0,869	0,964	0,940	0,884	0,832	0,804	0,747
CITIBANK A.Ş.	1,000	0,836	0,787	0,717	1,000	0,805	1,000	0,828	1,000	0,897	1,000	0,957	0,800	0,748	1,000	0,767
TEKSTİL BANKASI A.Ş.	1,000	0,637	1,000	0,700	0,757	0,684	1,000	0,812	1,000	0,901	1,000	0,939	1,000	0,898	0,913	0,836
ALTERNATİFBANK A.Ş.	0,549	0,486	0,374	0,335	0,782	0,709	1,000	0,795	1,000	0,899	1,000	0,940	1,000	0,920	0,691	0,631
ANADOLUBANK A.Ş.	1,000	0,619	1,000	0,703	0,749	0,669	0,840	0,763	1,000	0,896	1,000	0,940	1,000	0,822	1,000	0,748
PRIVATE 3	*0,887*	*0,654*	*0,783*	*0,633*	*0,841*	*0,745*	*0,911*	*0,776*	*0,980*	*0,892*	*0,993*	*0,943*	*0,933*	*0,842*	*0,873*	*0,743*
ARAP TÜRK BANKASI A.Ş.	1,000	0,628	1,000	0,714	1,000	0,812	1,000	0,803	1,000	0,897	1,000	0,941	1,000	0,820	1,000	0,759
TURKISH BANK A.Ş.	1,000	0,652	1,000	0,701	1,000	0,800	1,000	0,801	1,000	0,901	1,000	0,941	1,000	0,816	1,000	0,759
TURKLAND BANK A.Ş.	0,767	0,662	0,714	0,640	0,747	0,691	0,422	0,394	0,840	0,814	1,000	0,940	0,907	0,847	0,616	0,577
EUROBANK TEKFEN A.Ş.	0,700	0,601	0,731	0,658	0,633	0,582	0,702	0,648	1,000	0,900	1,000	0,940	0,401	0,371	0,347	0,315
PRIVATE 4	*0,856*	*0,635*	*0,850*	*0,678*	*0,829*	*0,715*	*0,738*	*0,636*	*0,957*	*0,877*	*1,000*	*0,941*	*0,776*	*0,677*	*0,680*	*0,569*
BANKING SECTOR	**0,831**	**0,620**	**0,841**	**0,669**	**0,865**	**0,754**	**0,888**	**0,772**	**0,932**	**0,862**	**0,962**	**0,915**	**0,895**	**0,798**	**0,877**	**0,748**

(*) Bootstrapped DEA efficicency scores.

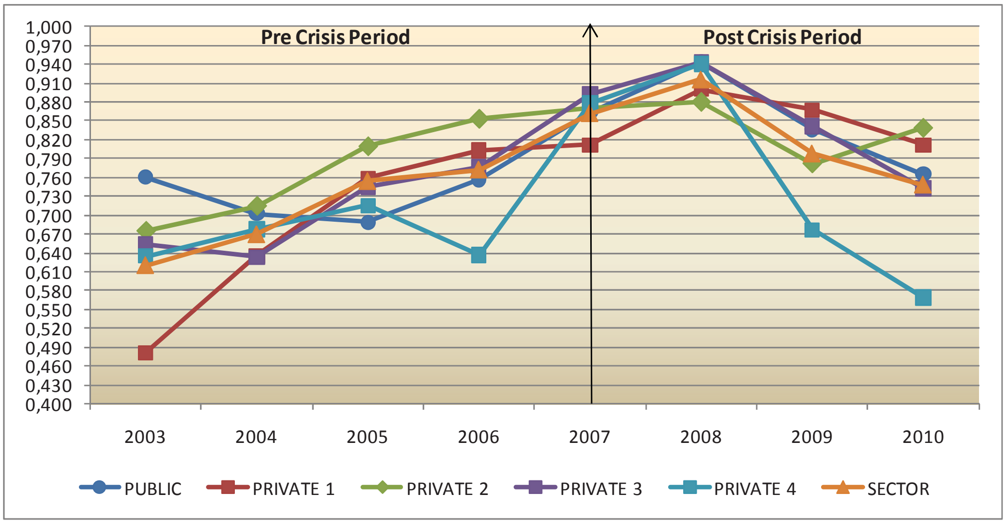
The banks with an efficiency score of 1,000 are regarded as efficient banks whereas banks with efficiency scores below 1 are regarded as inefficient by an amount below 1. The group efficiency scores equals to geometric means of efficiency scores of banks within that group.

Comparison of DEA efficiency scores with bootstrapped efficiency scores show that banks which are indicated as inefficient by the ordinary DEA procedure are actually more inefficient than it is thought to be due to the bias inherent in ordinary DEA scores. So, DEA efficiency scores tend to overestimate the actual efficiency of banks.

During the period under study, bootstrapped efficiency scores vary between 0,5 and 0,9 for the bank groups and 0,6 and 0,9 for the banking sector. The following Figure-1 together with the Table-3 above allows us to follow the trend in bank groups during 2003-2010.

As it is seen from the Figure 1, in terms of the evaluation of DEA scores, performance of Turkish banks could be studied by dividing the time period under consideration into two: 2003-2008 period (upward trend) and 2008-2010 period (downward trend). In the 2003-2008 period, Turkish banking sector efficiency score has improved from 0,62 to 0,92, but decreased to 0,75 thereafter.

Figure 1: Evaluation of Bootstrapped Bank Efficiency Scores, 2003-2010



It is observed that during 2003-2008, efficiency scores of bank groups had increased gradually and uninterruptedly, except public and private 4 banks[24]. In contrast to the other banking groups, public banks had suffered during 2003-2005 period, but caught the increasing trend thereafter. It is examined that decline in Halk Bank's ROA and ROE ratios is responsible for the downward trend in 2003-2005 period in public banks. As it could be seen in the figure above, another exception to the general upward trend is the decline in efficiency scores of private 4 banks from 2005 to 2006. Within the group, the poorest performance belongs to the Turkland bank which obtained net loss and thus negative ROA and ROE ratios in 2005-2006. Moreover, it is the only bank obtaining net loss in this period among all other banks in the sector.

After the year 2008, however, all bank groups experienced declines in their efficiency scores as suggested by Figure-1. The main reason of the decline during 2008-2010 period is the global financial crisis which was initiated by the USA economy in September 2007 and which extended through the most of European economies thereafter. According to the results, impacts of global financial crisis began to be experienced by the Turkish banking sector 2008 onwards. The sharpest decline was observed in private 4 banks (0,3 units). Other sharp declines were experienced by public and private 3 banks, respectively. It is known that in crisis periods, depending on the reduced GDP growth which is accompanied by lower household incomes, the probability of credits to default increases. So, by increasing loans especially in those periods, banks would obviously incur more risks than normal times. So, keeping pre-crisis loan growth rates in crisis periods would be riskier for banks and decrease efficiency. Our finding is supported by the fact that from 2008 to 2009, the largest loan growth rates are observed in private 4 (23,4%), public (22,3%) and private 3 banks (10,1%) (see Appendix A.1), meanwhile, according to the Figure-1, the banks that suffer most in terms of efficiency are private 4, public and private 3 banks, respectively. Also it is important to note that not only largest loan growth rates but also the largest rates in nonperforming loans are also observed by private 4 banks (99%) in this period (see Appendix A.1). On the contrary, private 1 and private 2 banks decreased both their loan growth rates and loan shares in the market in crisis

[24] Also, private 3 banks encountered decline in their efficiency scores from 2003 to 2004, however the decline is ignorable.

period (see Appendix A.1), so they experienced relatively smoother and milder decline in their efficiency scores.

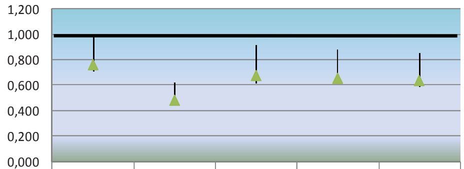
Private 2 banks is an exception to 2008-2010 period. In contrast to other bank groups, private 2 banks improved their efficiency from 2009 to 2010. The reason of this performance could be attributed to the relatively conservative approach of private 2 banks. That's to say, while other bank groups, especially private 4 banks, continue to grow in the market by increasing their deposits and loans further, private 2 banks seems to decrease their deposit and loan growth rates (see Appendix A.1.). Those decreases in deposit and loan growth rates were accompanied by sharp declines in NPLRs which finally brought improvement in efficiency scores. So, it could be concluded that, in the crisis environment, decreased deposit and loan growth rates could serve as a buffer against crisis.

An advantage of bootstrapping is that it predicts the efficiency scores within a confidence interval which enables us to do statistical inferences. More specifically, bootstrapping allows assessing whether the efficiency scores obtained are statistically significant. If it is significant, then the results explained above show real efficiency level of the banks, otherwise it should be considered as nothing more than a trick of sampling noise. Hence, if the efficiency score obtained by DEA falls into the confidence interval, then one can infer that efficiency score is statistically significant and efficiency score could be used in statistical analysis. On this basis, Figure-2 below shows confidence interval widths for bias corrected (bootstrapped) efficiency scores of bank groups[25]. According to the figures, all banks are below the efficiency level of 1,00 during 2003-2010.

[25] Upper and lower bounds of confidence intervals and bias corrected efficiency scores for bank groups are obtained through calculating geometric means of confidence intervals and efficiency scores of banks for each group.

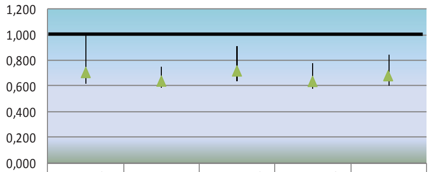
Figure 2: Confidence Intervals for Bias Corrected Efficiency Scores[26]

2003



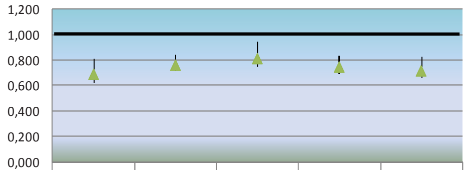
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,992	0,622	0,908	0,879	0,849
lb	0,709	0,440	0,614	0,612	0,582
▲ deabc	0,760	0,482	0,675	0,654	0,635

2004



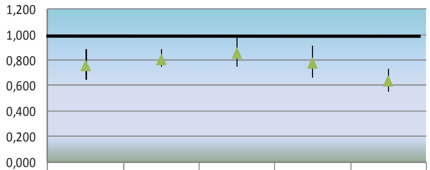
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,994	0,749	0,912	0,778	0,845
lb	0,619	0,584	0,638	0,579	0,603
▲ deabc	0,703	0,636	0,714	0,633	0,678

2005



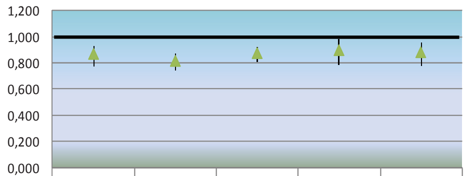
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,806	0,840	0,942	0,836	0,824
lb	0,622	0,714	0,745	0,688	0,661
▲ deabc	0,689	0,759	0,809	0,745	0,715

2006



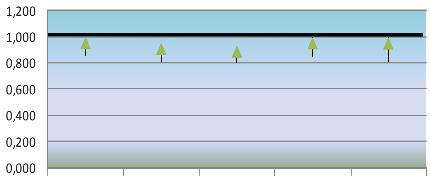
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,885	0,881	0,982	0,906	0,734
lb	0,645	0,749	0,744	0,666	0,552
▲ deabc	0,757	0,803	0,853	0,776	0,636

2007



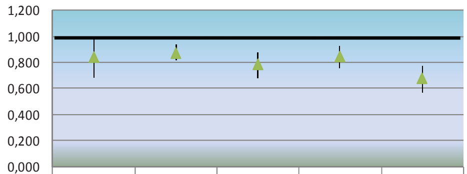
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,931	0,872	0,922	0,977	0,954
lb	0,770	0,737	0,808	0,783	0,774
▲ deabc	0,864	0,812	0,870	0,892	0,877

2008



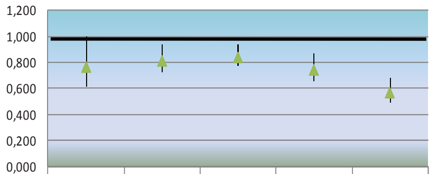
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,984	0,943	0,918	0,992	0,999
lb	0,854	0,805	0,795	0,840	0,805
▲ deabc	0,944	0,900	0,879	0,943	0,941

2009



	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,995	0,935	0,876	0,929	0,773
lb	0,676	0,813	0,682	0,753	0,566
▲ deabc	0,837	0,867	0,782	0,842	0,677

2010



	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0,994	0,935	0,935	0,868	0,676
lb	0,610	0,726	0,777	0,653	0,489
▲ deabc	0,765	0,812	0,838	0,743	0,569

[26] In the following figures, ub stands for upper bound of the confidence interval whereas lb stands for lower bound and deabc denotes the bias corrected (bootstrapped) DEA efficiency score.

First figure suggests that, efficiency scores of all bank groups are within confidence interval and vary between 0,6 and 0,8 range, except private 1 banks which should be considered as significantly more inefficient than other bank groups in 2003. In other words, efficiency differences between private 1 banks and other bank groups are significant in a statistical sense in 2003. The most efficient bank group in this period was public banks.

However, by the year 2005 banks efficiency scores began to converge each other and come closer to the fully efficient level of 1,00. From 2003 to 2005, efficiency of all private bank groups improved whereas efficiency of public banks deteriorated. In contrast to the 2003, the most efficient bank group became private 2 and private 1 banks, respectively and the least efficient bank group became public banks.

In 2006, all bank groups' efficiency scores increased compared to the 2005. Performances of Turkish banks continued to increase until 2008 and reached top levels in the year 2008. Also it is important to note that confidence intervals became narrower compared to the previous years in this period. This means increase in accuracy of our estimation and assessments based on those estimations. In this period, bank efficiency scores vary between 0,8 and 1,0. Public banks and private 3 banks became the most efficient banks in 2008.

However, in 2009, we observe decreases in bank efficiency scores due to the impacts of global financial crisis occurred in September, 2007. Banks began to diverge from each other in terms of efficiency. Moreover, efficiency range fell to 0,6 - 1,00 interval. The largest decrease in efficiency was observed in private 4 banks. Based on the confidence intervals, figure suggests that in this period, performance of private 4 banks are significantly lower than other bank groups. In 2010, private 4 banks deteriorated further. All bank groups efficiency scores decreased, except private 2 banks in this period.

5.2. Malmquist Productivity Index of Banks

The output oriented bootstrapped Malmquist productivity index (MPI) with its components is estimated for all bank groups in the sample over the period 2003-2010 through 2000 random resamplings. Bank by bank results are displayed in Appendix C.

Table-4 below summarizes MPI scores[27] (malm) and its components, namely technical change (tech), efficiency change (eff) which is further decomposed as pure efficiency change (pure.eff) and scale efficiency change (scale) for bank groups and the following Figure-3 shows the *cumulative* MPI scores[28] obtained for each group of bank and allows us to assess the productivity changes over 2003-2010. It is important to note that Table-4 shows one period change in productivity from time t to t+1 whereas Figure-3 shows the cumulative change in the productivity over the period under consideration. As noted earlier, a value greater than unity indicates improvement in that component whereas a value less than unity indicates deterioration.

On this basis, as table and figure suggest, during 2003-2010, we observe significant deteriorations in MPI scores from 2007 to 2008. This fact is supported by the global financial crisis initiated on September, 2007. From 2008 to 2009, however, we observe improvements. 2009 improvements are followed by small scale and ignorable deteriorations in MPI scores in 2010.

According to Table-4, from 2003 to 2004, bank groups that experienced improvements in their productivity, i.e. bank groups that have MPI greater than unity are private 1 and public banks[29]. Private 1 banks' improvement could largely be attributed to the efficiency change whereas technical change is responsible for the improvement in productivity of public banks. In other words, from 2003 to 2004 private 1 banks came closer to the best practice frontier by benefiting both from pure (1.202) and scale efficiency (1.167) changes while public banks managed to shift their production frontier further away. In banking literature, this implies that in this period, private 1 banks managed to use their existing funding sources (inputs) in more profitable instruments (outputs), as a result of correct managerial policies and economies of scale, on the other hand public banks expand their intermediation activities further. Especially, restructuring reforms implemented soon after the 2001 crisis in Turkey to remove the inefficiencies inherent to public banks were responsible for the high performance of public banks in this period. In overall, sector's productivity has increased in this period.

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[27] MPI score for each group of bank is obtained by calculating geometric mean of MPI scores of banks within that group.
[28] In the calculation of cumulative MPI, for each group of bank, MPI in 2003 is assumed to be 1,00 and the MPI in 2004 is estimated by multiplying 1,00 with MPI score for that group in 2004 and MPI in 2005 is estimated by multiplying MPI score of 2004 obtained in the previous step with that of 2005 and so on.
[29] Private 3 bank groups' productivity improvement is negligible, namely it's 1,001.

Table 4: MPI and Its Components for Bank Groups, 2003-2010

MPI (2003-2004)	malm	eff	tech	pure.eff	scale
PUBLIC	1.121	0.950	1.180	1.000	0.950
PRIVATE 1	1.435	1.404	1.022	1.202	1.167
PRIVATE 2	0.956	1.013	0.944	1.002	1.011
PRIVATE 3	1.001	0.910	1.100	0.883	1.031
PRIVATE 4	0.874	1.002	0.873	0.993	1.009
SECTOR	1.058	1.056	1.001	1.013	1.043

MPI (2004-2005)	malm	eff	tech	pure.eff	scale
PUBLIC	0.970	0.861	1.127	0.811	1.062
PRIVATE 1	1.107	0.999	1.108	1.121	0.891
PRIVATE 2	1.340	0.996	1.346	1.033	0.964
PRIVATE 3	1.124	1.002	1.121	1.075	0.933
PRIVATE 4	0.986	0.911	1.082	0.976	0.934
SECTOR	1.132	0.969	1.168	1.028	0.943

MPI (2005-2006)	malm	eff	tech	pure.eff	scale
PUBLIC	1.101	1.099	1.002	1.098	1.002
PRIVATE 1	1.054	1.167	0.903	1.047	1.114
PRIVATE 2	0.988	1.053	0.938	1.042	1.010
PRIVATE 3	1.022	1.098	0.931	1.083	1.014
PRIVATE 4	0.743	0.927	0.801	0.889	1.043
SECTOR	0.969	1.067	0.907	1.027	1.039

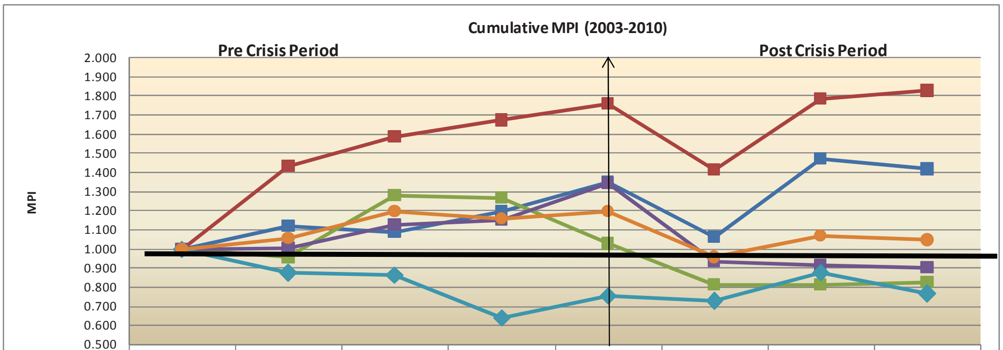
MPI (2006-2007)	malm	eff	tech	pure.eff	scale
PUBLIC	1.126	1.047	1.075	1.049	0.998
PRIVATE 1	1.052	0.980	1.074	0.987	0.993
PRIVATE 2	0.812	0.927	0.875	0.936	0.991
PRIVATE 3	1.170	1.152	1.015	1.076	1.071
PRIVATE 4	1.181	1.259	0.938	1.298	0.970
SECTOR	1.032	1.055	0.979	1.049	1.006

MPI (2007-2008)	malm	eff	tech	pure.eff	scale
PUBLIC	0.789	1.058	0.745	1.056	1.002
PRIVATE 1	0.804	1.101	0.730	1.081	1.018
PRIVATE 2	0.793	1.020	0.777	0.995	1.025
PRIVATE 3	0.694	0.993	0.699	1.013	0.980
PRIVATE 4	0.961	1.006	0.956	1.045	0.963
SECTOR	0.799	1.032	0.774	1.033	1.000

MPI (2008-2009)	malm	eff	tech	pure.eff	scale
PUBLIC	1.384	1.015	1.364	1.015	1.001
PRIVATE 1	1.261	0.997	1.265	0.994	1.003
PRIVATE 2	0.996	0.943	1.057	0.956	0.986
PRIVATE 3	0.981	0.941	1.042	0.940	1.001
PRIVATE 4	1.206	0.883	1.366	0.776	1.138
SECTOR	1.117	0.949	1.177	0.930	1.021

MPI (2009-2010)	malm	eff	tech	pure.eff	scale
PUBLIC	0.963	1.000	0.963	1.000	1.000
PRIVATE 1	1.024	1.005	1.020	1.002	1.003
PRIVATE 2	1.019	1.024	0.995	1.070	0.957
PRIVATE 3	0.986	0.915	1.077	0.935	0.978
PRIVATE 4	0.872	0.840	1.038	0.876	0.959
SECTOR	0.979	0.957	1.024	0.980	0.976

Figure 3: Cumulative MPI Scores, 2003-2010



	2003	2004	2005	2006	2007	2008	2009	2010
PUBLIC	1.000	1.121	1.087	1.197	1.347	1.062	1.471	1.417
PRIVATE 1	1.000	1.435	1.588	1.673	1.761	1.415	1.784	1.827
PRIVATE 2	1.000	0.956	1.281	1.265	1.027	0.814	0.811	0.827
PRIVATE 3	1.000	1.001	1.125	1.150	1.346	0.934	0.916	0.903
PRIVATE 4	1.000	0.874	0.862	0.641	0.757	0.727	0.877	0.765
SECTOR	1.000	1.058	1.197	1.160	1.197	0.956	1.068	1.046

From 2004 to 2005, except private 4 banks, all private bank groups experienced improvements in their productivity which is attributed to the technical change rather than efficiency change. This finding is supported by the fact that following the 2001 Turkish banking crisis which had long lasting effects on banks up to 2003, intermediation activities had gained pace once again. After then, private banks began to expand their intermediation activities and hence improved their performances based on the restored financial stability. However, it is observed that in this period, although pure efficiency change component of private banks improved, they suffered from deterioration in their efficiency change due to worsening in scale efficiency component. This implies that by expanding their intermediation activities those banks have reached decreasing returns to scale portion of their long run average cost curve. This means that there is no room left for those banks to benefit from economies of scale by expanding production further.

In 2005-2006 period, banking sector encountered negligible decrease in productivity which stem from the sharp deterioration in productivity of private 4 banks as suggested by the figure. Although both efficiency and technical change scores of private 4 banks was below unity in this period, the reason of worsening in productivity could largely be attributed to the deterioration in technical change. Furthermore, in this period, loan, deposit and asset shares of private 4 banks in the market decreased whereas shares of other private bank groups increased. So, it could be argued that other private bank groups expanded at the expense of the private 4 banks in this period. On the contrary, from 2006 to 2007, we observe deterioration only in the productivity of private 2 banks. However, both private 4 and private 2 banks productivity scores were below the sector's average, but in overall sector's productivity improved.

In contrast to the previous years, from 2007 to 2008, depending on the global financial crisis, we observe sharp deteriorations in productivity of all bank groups as suggested by the Figure-3. According to the Table-4, the reason of decline is the worsening in technical change rather than efficiency change. This implies large contractions in best practice frontiers of banking groups. In banking terms, this means reduction in intermediation activities of banks due to the uncertainty and financial instability created by the global financial crisis. On the other hand, we observe that efficiency change component is above unity in this period. The reason is that since best practice frontier contracted, banks are getting closer to the frontier.

Soon after the crisis, from 2008 to 2009, we observe improvements in sector-wide, with negligible deteriorations in productivity of private 2 and private 3 banks. The reason of improvements is the advance in technical change. So, by considering the reason of worsening in the previous period, it could be argued that technical change rather than efficiency change is more responsive to financial crisis. Moreover, in this period, except public banks, all bank groups suffered from deterioration in their pure efficiency change scores as suggested by Table-4. This reflects poor managerial policy actions taken soon after the crisis. Also, base year effect seems to dominate in this period and banks' productivity scores have improved in 2009 compared to 2008 which is the year hit most severely by the crisis. According to the figure, private 1 and public banks' productivity scores are above the sector average whereas other bank groups' performances are below the sector in 2009.

Finally, from 2009 to 2010, we observe that the base year effect had eliminated and banks began experience small decreases in their productivity in 2010 compared to 2009. According to Table-4, private 1 and private 2 bank groups are the only ones experiencing productivity improvement in this period.

Although all components of MPI is above 1 for private 1 banks, the main reason of improvement is the technical change. However, the reason of improvement for private 2 banks is the efficiency change which stems from pure efficiency change. Overall, sector's productivity suffered from deterioration in efficiency change (both pure and scale efficiency changes) component from 2009 to 2010. Poor managerial decision strategies together with contractionary policies could be responsible for this outcome.

Another finding is that, as suggested by Figure-3, from 2003 to 2007 public, private 2 and private 3 banks converge to each other in terms of productivity whereas private 1 and private 4 banks diverge from the rest. That's to say, productivity of private 1 banks are seem to outperform the rest whereas productivity of private 4 banks fall behind. However, private banks began to diverge from each other by the year 2007. The reason may be the differentiation in banking products among bank groups. Introduction of new products i.e. derivatives, advantageous and competitive consumer credits could help that bank group to perform better. Finally, in 2010, it is observed that private 1 and public banks diverge from the rest and surpass other bank groups and private bank groups converge to each other once again in terms of cumulative MPI calculated over 2003-2010.

Similar to the bootstrapped efficiency scores, bootstrapped MPIs are also predicted within a confidence interval which allows us to do statistical inferences based on those estimates. Figure-4 below depicts the confidence interval widths for bias corrected (bootstrapped) MPIs of bank groups. As seen from the figure, the rigidity of estimated confidence intervals shows the accuracy of the estimation.

According to the figure, from 2003 to 2004, public and private 1 banks encountered improvements whereas other bank groups encountered deterioration in their productivity scores. Bootstrapping enables us to conclude that those bank groups' productivity scores were also significantly different from public and private 1 banks in a statistical sense.

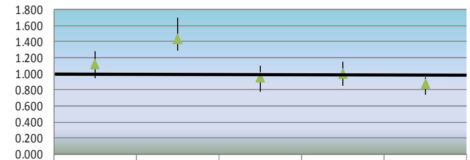
From 2004 to 2005, the only bank groups that we observe deterioration in their productivity scores are the public and private 4 banks. However, the deterioration is ignorable. Moreover, bank groups' productivity scores began to converge each other, with private 2 banks being an exception due to its high productivity score. From 2005 to 2006, the convergence trend among bank groups in terms of productivity became more apparent. The only exception to the trend in this period is the private 4 banks whose productivity score is significantly lower than the rest.

During 2007-2008 and 2008-2009 periods, trend toward convergence was broken down and due to the impacts of global financial crisis on the banking sector; we observe divergence among bank productivity scores. More specifically, from 2007 to 2008, all bank groups experienced deterioration in their productivity scores as seen from the Figure-4.

Soon after the crisis, from 2009 to 2010, similar to what we observe in bank efficiency scores, a gradual recovery of banking sector is detected. Public and private 4 banks are the only bank groups that experienced deterioration in their productivity scores. Moreover, convergence trend observed in the pre crisis period is attained again in this period.

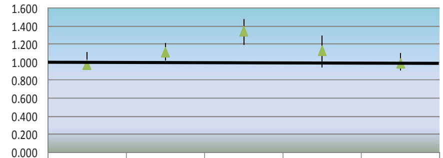
Figure-4: Confidence Intervals for Bias Corrected MPIs[30]

2003-2004



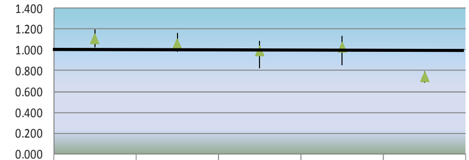
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	1.275	1.698	1.095	1.150	0.955
lb	0.939	1.290	0.779	0.855	0.741
MPI(bc)	1.121	1.435	0.956	1.001	0.874

2004-2005



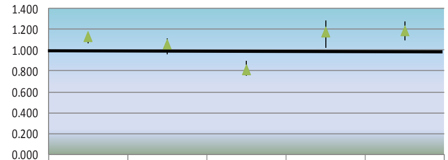
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	1.107	1.213	1.481	1.293	1.097
lb	0.918	1.022	1.187	0.942	0.909
MPI(bc)	0.970	1.107	1.340	1.124	0.986

2005-2006



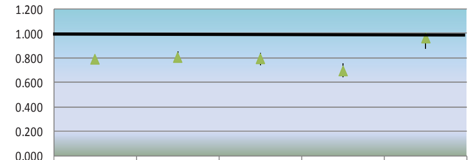
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	1.190	1.167	1.080	1.132	0.795
lb	1.019	0.978	0.821	0.853	0.683
MPI(bc)	1.101	1.054	0.988	1.022	0.743

2006-2007



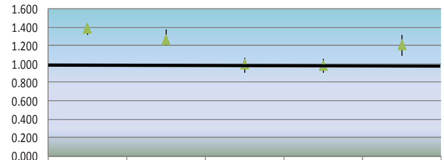
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	1.173	1.109	0.889	1.279	1.270
lb	1.060	0.963	0.758	1.025	1.088
MPI(bc)	1.126	1.052	0.812	1.170	1.181

2007-2008



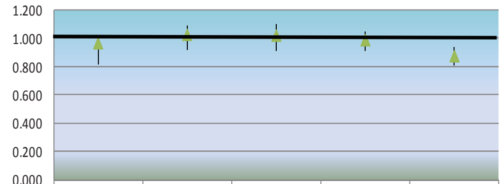
	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	0.820	0.849	0.843	0.761	1.007
lb	0.772	0.767	0.741	0.646	0.876
MPI(bc)	0.789	0.804	0.793	0.694	0.961

2008-2009



	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	1.406	1.375	1.068	1.058	1.314
lb	1.311	1.200	0.910	0.909	1.084
MPI(bc)	1.384	1.261	0.996	0.981	1.206

2009-2010



	PUBLIC	PRIVATE 1	PRIVATE 2	PRIVATE 3	PRIVATE 4
ub	1.001	1.091	1.098	1.046	0.933
lb	0.820	0.919	0.911	0.909	0.805
MPI(bc)	0.963	1.024	1.019	0.986	0.872

30 In the following figures, ub stands for upper bound of the confidence interval whereas lb stands for lower bound and MPI(bc) stands for the bias corrected (bootstrapped) MPIs.

5.3. Risk Measurement

The main shortcoming of efficiency measurement models is that although they are able to show the extent to which the banks are successful in transforming the inputs into outputs, i.e. both bad and good loans, they are not equipped to take into account risk factors. In other words, they assume that banks are risk neutral. However, by expanding loans and collecting deposits banks do not only increase their output and efficiency but also incur risks in the financial markets while carrying out intermediation activities.

Another limitation regarding efficiency measurement models is that book values of net loans are assumed to be equal to the market values of gross loans. So, while assessing efficiency, the amount of banks' nonperforming loans should also be taken into consideration. Based on those shortcomings, it could be argued that the most efficient banks indicated by efficiency measurement models are not necessarily the least risky banks. This paper, however, improves upon the DEA literature by introducing risk taking measure for each bank. Based on Laeven's (1997) and Aras and Kurt's (2007) papers, a risk taking measure is defined and calculated for each bank during 2003-2010, in separation of pre-crisis (2003-2007) and post-crisis periods (2007-2010).

Since the technical bank efficiency measure cannot distinguish between excessive risk taking and increased bank performance, the risk taking measure is developed on the basis of excessive loan growth. If the loans provided by a bank in a certain period exceed the quantity of loan which can be provided by the bank using efficiently the inputs in the same period, the difference is called excessive loan growth (Aras and Kurt, 2007).

Based on this definition, let $y_1^{f,t}$ be the amount of loans provided by bank f in base year t and $y_1^{f,(t+T)}$ be the amount of loans provided by bank f in year t+T and $\theta_y^{f,t}$ be the inverse of the output oriented efficiency measure of bank f in year t estimated in section 5.1. Therefore, the efficient level of loans for bank f in year t given its inputs in year t would be $\theta_y^{f,t} * y_1^{f,t}$ and similarly, the efficient level of loans for bank f in year t+T given its inputs in year t+T would be $\theta_y^{f,(t+T)} * y_1^{f,(t+T)}$. However, with T small, there is no *a priori* reason to assume a major change in efficiency, hence in θ_y^f from year t to t+T. Therefore, the efficient level of loans in year t+T is expected to be equal to

(5.3.1) $\theta_y^{f,(t+T)} * y_1^{f,(t+T)} / \theta_y^{f,t}$,

instead of actual level $y_1^{f,(t+T)}$. So, the amount of excessive loans would be defined as,

(5.3.2.) $y_1^{f,(t+T)} - (\theta_y^{f,(t+T)} * y_1^{f,(t+T)} / \theta_y^{f,t})$

Based on this definition, excessive loan growth would be equal to

(5.3.3.) $[y_1^{f,(t+T)} - (\theta_y^{f,(t+T)} * y_1^{f,(t+T)} / \theta_y^{f,t})] / y_1^{f,t}$

Equivalently, excessive loan growth could be re defined as,

(5.3.4.) $(y_1^{f,(t+T)} / y_1^{f,t}) * [1- (\theta_y^{f,(t+T)} / \theta_y^{f,t})]$

Therefore, based on the assumption that t is the base year i.e. benchmark and that the efficiency remains constant during the period under consideration, the risk taking measure from year t to t+T is defined as,

(5.3.5.) $R_y (\theta_y^{f,t}, \theta_y^{f,(t+T)}) = (y_1^{f,(t+T)} / y_1^{f,t}) * [1- (\theta_y^{f,(t+T)} / \theta_y^{f,t})]$

where $y_1^{f,(t+T)}$ and $y_1^{f,t}$ are the loan levels of bank f in year t and t+T, and $\theta_y^{f,(t+T)}$ and $\theta_y^{f,t}$ are the inverses of the output oriented, bootstrapped DEA bank efficiency measures for the years t and t+T calculated in section 5.1.

Risk taking measures calculated on a bank by bank basis are given in Table-5 below.

Table 5: Risk Taking Measures of Banks, 2003-2010

	R (2003-2010) Overall					R (2003-2007) Pre-Crisis Period					R (2007-2010) Post-Crisis Period				
Bank	R 2003-2010	NPLR 2003	NPLR 2010	Change in NPLR	Credit Growth	R 2003-2007	NPLR 2003	NPLR 2007	Change in NPLR	Credit Growth	R 2007-2010	NPLR 2007	NPLR 2010	Change in NPLR	Credit Growth
T.C. ZİRAAT BANKASI A.Ş.	-0,40	32,70	1,50	-31,20	10,44	0,54	32,70	1,83	-30,87	3,27	-0,49	1,83	1,50	-0,33	1,68
TÜRKİYE HALK BANKASI A.Ş.	0,81	31,63	3,88	-27,75	16,50	0,82	31,63	5,49	-26,14	6,15	-0,19	5,49	3,88	-1,61	1,45
PUBLIC	*0,21*	*32,17*	*2,69*	*-29,48*	*12,48*	*0,68*	*32,17*	*3,66*	*-28,51*	*4,24*	*-0,34*	*3,66*	*2,69*	*-0,97*	*1,57*
TÜRKİYE VAKIFLAR BANKASI T.A.O.	1,61	14,03	4,85	-9,18	8,44	1,47	14,03	4,72	-9,31	3,90	-0,36	4,72	4,85	0,13	0,93
AKBANK T.A.Ş.	1,03	1,29	2,39	1,10	5,16	1,31	1,29	2,71	1,42	3,27	-0,30	2,71	2,39	-0,32	0,45
TÜRKİYE GARANTİ BANKASI A.Ş.	2,25	4,46	2,96	-1,50	8,80	1,57	4,46	2,28	-2,18	4,60	-0,13	2,28	2,96	0,68	0,75
TÜRKİYE İŞ BANKASI A.Ş.	3,57	11,89	3,70	-8,19	6,33	1,58	11,89	4,35	-7,54	2,85	0,25	4,35	3,70	-0,65	0,91
YAPI VE KREDİ BANKASI A.Ş.	4,76	8,45	3,54	-4,91	5,50	2,28	8,45	5,89	-2,56	2,56	0,46	5,89	3,54	-2,35	0,83
PRIVATE 1	*2,64*	*8,02*	*3,49*	*-4,54*	*6,60*	*1,64*	*8,02*	*3,99*	*-4,03*	*3,34*	*-0,01*	*3,99*	*3,49*	*-0,50*	*0,75*
TÜRK EKONOMİ BANKASI A.Ş.	2,34	2,12	3,06	0,94	9,12	1,53	2,12	1,78	-0,34	4,95	-0,06	1,78	3,06	1,28	0,70
FORTİS BANK A.Ş.	0,45	3,69	4,74	1,05	2,98	0,72	3,69	4,29	0,60	1,72	-0,30	4,29	4,74	0,45	0,46
ING BANK A.Ş.	0,91	1,01	3,18	2,17	4,49	0,65	1,01	1,31	0,30	2,86	0,00	1,31	3,18	1,87	0,42
FİNANSBANK A.Ş.	1,37	3,37	6,62	3,25	8,42	0,94	3,37	2,77	-0,60	4,32	-0,07	2,77	6,62	3,85	0,77
HSBC BANK A.Ş.	1,47	1,97	8,94	6,97	4,19	1,41	1,97	3,23	1,26	4,07	0,01	3,23	8,94	5,71	0,02
DENİZBANK A.Ş.	2,59	5,85	4,92	-0,93	10,89	1,31	5,85	2,38	-3,47	5,77	0,05	2,38	4,92	2,54	0,76
PRIVATE 2	*1,52*	*3,00*	*5,24*	*2,24*	*6,42*	*1,09*	*3,00*	*2,63*	*-0,38*	*3,79*	*-0,06*	*2,63*	*5,24*	*2,62*	*0,55*
ŞEKERBANK T.A.Ş.	0,03	11,71	6,01	-5,70	9,42	0,73	11,71	4,00	-7,71	4,10	-0,34	4,00	6,01	2,01	1,04
CITIBANK A.Ş.	-0,36	6,17	12,28	6,11	3,02	0,22	6,17	5,72	-0,45	2,33	-0,21	5,72	12,28	6,56	0,21
TEKSTİL BANKASI A.Ş.	0,84	0,34	4,94	4,60	2,54	1,16	0,34	1,41	1,07	2,97	-0,07	1,41	4,94	3,53	-0,11
ALTERNATİFBANK A.Ş.	1,90	11,06	4,63	-6,43	7,26	2,25	11,06	3,47	-7,59	3,90	-0,72	3,47	4,63	1,16	0,69
ANADOLUBANK A.Ş.	1,01	1,92	2,89	0,97	4,84	1,07	1,92	1,63	-0,29	2,47	-0,33	1,63	2,89	1,26	0,68
PRIVATE 3	*0,68*	*6,24*	*6,15*	*-0,09*	*5,54*	*1,09*	*6,24*	*3,25*	*-2,99*	*3,16*	*-0,33*	*3,25*	*6,15*	*2,90*	*0,57*
ARAP TÜRK BANKASI A.Ş.	1,63	22,72	1,57	-21,15	8,45	0,93	22,72	4,70	-18,02	2,10	-0,55	4,70	1,57	-3,13	2,04
TURKISH BANK A.Ş.	4,02	5,49	4,29	-1,20	27,61	2,51	5,49	0,93	-4,56	8,10	-0,59	0,93	4,29	3,36	2,14
TURKLAND BANK A.Ş.	-1,29	7,13	3,99	-3,14	7,77	0,71	7,13	2,15	-4,98	2,77	-0,96	2,15	3,99	1,84	1,33
EUROBANK TEKFEN A.Ş.	-9,36	4,34	6,67	2,33	9,34	1,81	4,34	3,82	-0,52	4,46	-3,51	3,82	6,67	2,85	0,89
PRIVATE 4	*-1,25*	*9,92*	*4,13*	*-5,79*	*9,50*	*1,49*	*9,92*	*2,90*	*-7,02*	*3,76*	*-1,40*	*2,90*	*4,13*	*1,23*	*1,21*
SECTOR	*0,76*	*11,87*	*4,34*	*-7,53*	*7,28*	*1,20*	*11,87*	*3,28*	*-8,59*	*3,53*	*-0,43*	*3,28*	*4,34*	*1,06*	*0,83*

The risk taking measure greater (smaller) than zero indicates that loan growth rate is multiplied by the increased (decreased) bank efficiency scores from time t to t+T. In other words, our risk taking measure is positively related with output oriented bootstrapped DEA efficiency scores and negatively related with θ_y^f (inverse of output oriented bootstrapped DEA efficiency score), by definition.

It is important to note that as suggested by Laeven (1997) the risk measure defined in equation 5.3.5. is a function of the change in bank efficiency. Therefore, any relationship found between the change in efficiency and the risk taking measure would be an artifact of our definition. However, this problem does not arise when we relate risk taking to the initial level of efficiency in the base year t only (see eqn. 5.3.1.). Moreover, in the assessment of risk level of banks, risk taking measure is evaluated together with the changes in bank's nonperforming loan ratio in order to avoid flawed interpretations regarding bank riskiness.

As it can be seen in Table-5 initially, risk measure is calculated for the entire time period under the analysis. We then divide the entire time period into two as pre and post crisis periods to see whether there is a structural change in risk profile of Turkish banks before and after the crisis. To evaluate pre crisis period, the year 2003 is taken as benchmark and to evaluate post crisis period the year 2007 is taken as benchmark. In overall terms, the results indicate that from 2003 to 2010, the only bank group experiencing decline in riskiness is private 4 banks. Meanwhile, on the average they encountered 9,5% credit growth, together with 5,8 points decline in their NPLR. This implies that during 2003-2010, private 4 banks expanded their loans, at the same time, they managed to decrease nonperforming loans and so the risk. Investing into relatively secure loans may be the reason of this outcome.

On the other hand, public banks and private 3 banks incur moderate risks while private 1 and private 2 banks become the banks with the highest risk taking measure, respectively in this period. When combined with our previous findings, we observe that from 2003 to 2010 efficiency of private 2 banks increased from 0,675 to 0,838, however risk taking measure is positive and NPLR increased by 2,2 points, together with 6,4% credit growth. So, it may be concluded that in this period, while private 2 banks increased their efficiency score by increasing output, i.e. loans, they incurred more risks through expanding loans to customers with high probability of default, a finding supported by increased NPLR.

In overall, banking sector's risk taking measure is above zero whereas smaller than 1 in 2003-2010 period. This indicates that from 2003 to 2010, Turkish banking sector incurred moderate risks with decline in its NPLR, while expanding loans. In fact, for a developing country, this could be considered as an indicator of healthy growth of banking sector.

When we divide time period under consideration into two, we observe that in the pre crisis period (2003-2007), banking sector's risk taking measure is positive but in the post crisis period it is negative depending on the reduced efficiency scores. During pre crisis period, moderate credit growth rates were accompanied by reduced NPLRs. So, it can be concluded that although the risk level of Turkish banks increased, banks were able to monitor and manage expanded loans in 2003-2007. This fact could explain quick recovery of Turkish banking sector from 2007 financial crisis. The highest risk taking measure belongs to private 1 banks and the lowest risk taking measure belongs to public banks in pre crisis period.

On the contrary, during post crisis period (2007-2010), we observe decline in risk taking measures. However, although risk taking measures decreased in post crisis period both for the sector and on a bank by bank basis, lower credit growth rates accompanied by increases in NPLRs in private 2, private 3 and private 4 banks. So, it may be inferred that following the 2007 global financial crisis, banks began to contract their previously expanded credits and suffered from higher NPLRs in 2010 compared to 2007. The contraction in credits brought relatively more secure balance sheets to banks and decreased their efficiency due to the trade-off between efficiency and riskiness. In other words, banks had come up with healthier financial statements in return for reduced growth and hence, efficiency in the post crisis period.

5.4. Two-Stage Regression Analysis

Based on Laeven (1997), Coelli et al. (1998), Sufian (2009) and McDonald (2009) to explain the variation in changes in output efficiencies through time a two-stage ordinary least squares (OLS) regression model is specified as a fixed effects model:

$$\hat{\theta}_k^* = b0 + b1\,ROA + b2\,LNTA + b3\,LOANSTA + b4\,NPLTA(-1)$$
$$+ b5\,CAR + b6\,DLNRGDP + b7\,NIM + b8\,INF + b9\,LNDEP + ei$$

In the regression, return on assets (ROA) is used as a proxy for bank profitability, logarithm of total loans (LNTA) is used as a proxy of bank size to capture the possible cost advantages associated with size, namely, economies of scale. The ratio of loans to total assets (LOANSTA) is used as an indicator for bank liquidity which is an indication of bank's ability to meet its customers' day-to-day cash needs and respond to sudden cash withdrawals. The ratio of nonperforming loans to total assets with one period lag (NPLTA(-1)) is used as an indicator of risk in case banks extend their loans. Since the ratio is expected to have impacts on banks' balance sheet with a time lag we take the ratio with a one period lag. Capital adequacy ratio (CAR) is used as a proxy for capital adequacy and a cushion against future losses. Logarithm of real gross domestic product growth (DLNRGDP) and inflation (INF) are employed as a proxy for economic conditions. Logarithm of deposits (LNDEP) is used as a proxy of market share. On the other hand, dependent variable is assumed to be the bootstrapped bank efficiency scores obtained in the first step, in the previous section. This is why regression analysis is called two-stage in the literature.

Annual panel data from 2003 to 2010, for 22 commercial banks is used in the regression. Regression is run by assuming fixed effects model, instead of random effects model. The advantage of fixed effects model is that it imposes time independent bank specific effects that are possibly correlated with regressors whereas random effect model assumes no fixed, individual effects for banks. In other words, fixed effect models controls for the unobserved heterogeneity in the sample when this heterogeneity is constant over time and correlated with independent variables. In fixed effects model time independent bank specific effects can be removed from the data through differencing, for example, taking the first difference will remove any time invariant components of the model. So, to take into account the impacts of bank specific effects, we use fixed effects model. Table below summarizes OLS regression results. (see Appendix B for more detailed regression results).

Table 6: Two-Stage Regression Analysis

	Coefficient	Std. Error	t-Statistics	Prob.
C	1,153	0.158160	7,289	0.0000
ROA	1,831	0.594996	3,078	0.0026
LNTA	-0,133	0.031347	-4,226	0.0000
LOANSTA	-0,143	0.038402	-3,733	0.0003
NPLTA(-1)	-1,106	0.426295	-2,594	0.0106
CAR	-0,084	0.072124	-1,159	0.2486
DLNRGDPSA	-1,311	0.200330	-6,545	0.0000
NIM	-0,062	0.007385	-8,370	0.0000
INF	-0,006	0.003175	-1,729	0.0863
LNDEP	0,143	0.032955	4,351	0.0000

According to the regression results, CAR and INF are insignificant whereas the rest of the variables are significant in a statistical sense. So, the effects of those variables are ignorable in the evaluation of DEA efficiency scores.

The results suggest that ROA has the largest impact in the determination of DEA efficiency scores. Following this variable, DLNRGDP and NPLTA(-1) have the largest impacts on the efficiency scores among other variables. That's to say, 1 unit increase in ROA, i.e. profitability, increases efficiency score by 1,8 units. This implies that more profitable banks tend to exhibit higher efficiency. Also, banks reporting higher profitability ratios are usually preferred by clients and attract the larger share of deposits and it would be easier for those banks to find funding sources in international markets. Such conditions would obviously create a favorable environment for profitable banks to be more efficient in terms of intermediation activities.

It is expected that the demand for financial services tends to grow as economies expand and households become wealthier. However, it is observed that DLNRGDP is statistically significant and has negative sign. Hence, a 1 unit increase in DLNRGDP, decreases efficiency score by 1,3 units. The explanation could be that during the period under consideration, Turkey experienced volatile growth rates, ranging from 6,2% annual growth in 2001 to 9,4% in 2004, falling into a recession with growth rate of -4,8% in 2009 before covering to 9% in 2010, annually. Therefore, the volatile economic growth could have resulted in banks to suffer from lower demand for their financial services, increased loan defaults, and thus lower output.

Another factor which could explain Turkish banks' efficiency is non performing loans to total assets ratio. It is observed that a 1 unit increase in NPLTA(-1) decreases efficiency by 1,1 units, as expected. This implies that higher the amount of loan defaults lower the efficiency for that bank. So, banks should carefully monitor the counter party before extending its loans.

LNTA is statistically significant and has negative sign. So, one could argue that the larger the size of a bank, the more inefficient the bank would be. So, economies of scale argument does not hold for the Turkish banks. The possible explanation could be that Turkish banks are already in the decreasing returns to scale portion of their long run average cost curve.

LOANSTA is also statistically significant and has negative sign. The finding implies that the banks with higher loans to asset ratio tend to have lower efficiency scores. This finding could also be supported by the previous findings on LNTA and NPLTA(-1). That's to say, as banks extend their loans, due to the decreasing returns to scale their efficiency would decrease, moreover, if banks do not monitor their customers carefully while increasing loans, they would probably suffer from the loan defaults and hence nonperforming loans. Bearing in mind that, ROA is positively related with efficiency, it could be argued that banks could increase their efficiency by investing various instruments, and by decreasing their concentration into relatively riskier loans, especially in crisis times. Furthermore, Figure-1 and Figure-3 combined with table in Appendix A.1. also suggest that the banks which decrease their loan growth rates during crisis periods suffer less and so have greater efficiency and productivity scores.

LNDEP is statistically significant and has positive sign, suggesting that the more efficient banks are associated by larger market share. The possible explanation could be that banks could increase their efficiency by obtaining funds from market and so by increasing their deposit share, and then investing those funds to profitable instruments, other than risky loans in risky periods.

NIM, namely, spread between loan and deposit rates is statistically significant and has negative sign. There is no a priori expectation for the sign of this variable; it could either be positive or negative depending on the balance sheet position and the amount of interest sensitive assets and liabilities of the banking sector. For Turkish banks, it is observed that as spread increases, efficiency decreases.

6. Conclusion

A linear programming technique called Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI) is used to estimate the efficiency and productivity of 22 commercial deposit banks in Turkey for the years 2003-2010. Given the data set, banks are divided into five groups as public banks, private 1, 2, 3 and private 4 banks, according to their scale and size, placing the largest private banks into private 1 group and smallest banks into private 4. The bank grouping employed in this paper is the bank peer grouping developed especially for ratio analysis by BRSA in internal reporting systems. However, it is important to note that the appropriateness of this peer grouping is debatable for different input and output combinations, other than ratios.

In the estimation of efficiency, output oriented VRS DEA model is used. Inputs and outputs are determined according to the mixed approach in banking literature. The inputs used are the ratio of securities to total assets, the ratio of deposits to total assets, the ratio of nonperforming loans (gross) to total (cash) loans, the ratio of total loans to total assets and the ratio of non interest expense to total (average) assets. The outputs used are the ratio of net interest income to total income, return on (average) assets and return on (average) equity.

We then extend the established literature on the estimation of DEA efficiency scores by recognizing the problem of the inherent dependency of DEA efficiency scores when used in the regression analysis or when used to make statistical inferences. To overcome the dependency problem, we follow the approach suggested by Simar and Wilson (1998, 2000) and apply a bootstrapping technique to our DEA efficiency scores. Bootstrapping allows us to assess the statistical significance of the efficiency scores obtained. Results reveal that our estimates are statistically significant and could be used in statistical inference making, i.e. in the regression analysis.

It is observed that except public and private 4 banks, efficiency scores of all bank groups had increased uninterruptedly and gradually up to 2008. And bank groups' efficiency scores began to converge each other, with private 4 banks being an exception due to the lower efficiency scores during this period. However, due to the impacts of 2007 global financial crisis, all bank groups' efficiency scores decreased 2008 onwards, with private 4 banks having the poorest performance. Banks' efficiency scores began to diverge from each other in 2010 compared to 2008. Also, it is observed that the bank groups that continued to keep pre-crisis loan growth rates are the banks that suffer most in crisis period.

To measure the change in total factor productivity between two time periods, output oriented MPI is used. Bootstrapping technique is also applied to the MPI to get unbiased productivity scores. The advantage of MPI is that unlike alternative productivity indices, MPI does not require any information of prices of inputs and outputs. It is observed that productivity of all bank groups, except private 4 banks, increased continuously during 2003-2007, cumulatively. During this period, private 1 group banks became the best performer whereas private 4 banks became the worst performer among all bank groups. As in the case in efficiency, our findings on productivity are also supported by the 2007 global financial crisis. Sharp decreases in productivity scores of all bank groups are observed 2007 onwards. The best performers of post-crisis periods became public and private 1 banks that have productivity scores above the sector's average. Also, it is found that technical change i.e. shift of production frontier further away rather than efficiency change i.e. getting closer to the production frontier is more responsive to the financial crisis and is the main determinant of bank productivity.

To measure risk-taking levels of Turkish banks a risk measure based on the studies of Laeven (1997) and Aras and Kurt (2007) is introduced into the analysis.

The measure indicates that in the pre crisis period banking sector's risk taking measure is positive but in the post crisis period it is negative depending on the reduced efficiency scores. However, during the pre crisis period, moderate credit growth rates were accompanied by reduced NPLRs. This implies that although Turkish banking sector incurred risks in this period, the risks were well-managed and monitored.

Finally, to analyze the determinants of bootstrapped DEA efficiency scores obtained in the first stage of the analysis, a two-stage (second-step) fixed effects regression model is estimated. The model controls for bank heterogeneity and endogeneity issues by adopting the two-stage ordinary least square estimation of fixed effects. In the regression, annual panel data set for 22 commercial banks, during 2003-2010 is used. It is found that return on assets has the largest positive impact on the efficiency whereas GDP growth and the ratio of nonperforming loans to total assets have the largest negative impact on efficiency scores, respectively.

To sum up, this study observes that during 2003-2008, efficiency and productivity of Turkish banking sector had improved gradually and uninterruptedly, however in 2008-2009 sudden decreases in efficiency and productivity are detected. From 2009 to 2010, we, however, observe gradual recovery. Our findings are strongly supported by the September, 2007 global financial crisis that was also experienced in Turkey. In overall, it can be concluded that by the end of 2010, the impacts of crisis on Turkish banking sector have mitigated.

APPENDIX A.1

Summary of Data for 22 Commercial Banks (2003-2010)

(Million TL)	2003	2004	2005	2006	2007	2008	2009	2010	Growth (%) (2003-2010)
NON PERFORMING LOANS									
PUBLIC	3.531	1.601	1.516	1.405	1.424	1.856	2.523	2.613	-26,0
PRIVATE 1	3.055	3.264	4.151	5.110	6.230	7.743	11.490	9.753	219,2
PRIVATE 2	344	489	712	886	1.428	2.445	4.810	4.746	1.279,9
PRIVATE 3	188	194	361	406	387	723	1.176	1.118	494,6
PRIVATE 4	28	27	27	28	51	106	211	181	547,4
TOTAL	**7.146**	**5.575**	**6.767**	**7.835**	**9.519**	**12.872**	**20.210**	**18.410**	**157,6**
SECURITIES									
PUBLIC	40.813	53.225	54.164	58.839	59.188	73.920	88.724	92.678	127,1
PRIVATE 1	47.412	52.636	68.952	83.330	84.560	95.912	143.475	157.709	232,6
PRIVATE 2	6.968	7.115	8.721	9.186	12.581	14.213	17.284	22.512	223,1
PRIVATE 3	2.457	2.489	2.595	3.254	2.456	4.162	5.014	5.046	105,4
PRIVATE 4	399	388	439	479	1.717	2.145	2.128	2.086	422,8
TOTAL	**98.049**	**115.853**	**134.872**	**155.089**	**160.502**	**190.352**	**256.626**	**280.030**	**185,6**
DEPOSITS									
PUBLIC	47.353	64.397	72.094	84.961	96.644	120.569	139.265	173.965	267,4
PRIVATE 1	76.245	90.284	125.625	159.549	182.850	236.645	264.663	312.199	309,5
PRIVATE 2	16.297	22.101	27.648	39.152	47.366	57.358	62.723	74.608	357,8
PRIVATE 3	5.315	6.037	6.926	10.156	11.816	15.650	16.124	18.180	242,0
PRIVATE 4	785	772	996	1.407	1.835	2.808	3.201	3.435	337,3
TOTAL	**145.995**	**183.591**	**233.290**	**295.225**	**340.512**	**433.030**	**485.976**	**582.386**	**298,9**
NET PROFIT									
PUBLIC	1.558	2.058	2.334	2.964	3.482	3.153	5.142	5.723	267,2
PRIVATE 1	2.443	2.672	641	5.055	7.752	6.760	10.667	12.201	399,4
PRIVATE 2	628	679	1.256	1.584	1.544	1.339	1.936	2.049	226,2
PRIVATE 3	132	160	221	205	467	378	423	422	218,6
PRIVATE 4	22	17	18	20	23	26	50	45	98,9
TOTAL	**4.785**	**5.585**	**4.471**	**9.827**	**13.268**	**11.656**	**18.219**	**20.440**	**327,2**
NET INTEREST INCOME									
PUBLIC	4.854	4.974	3.783	4.771	5.342	5.953	8.562	7.957	63,9
PRIVATE 1	3.142	7.843	9.230	10.307	12.544	14.317	20.724	19.252	512,7
PRIVATE 2	1.399	2.221	2.919	3.399	4.454	5.836	7.338	6.794	385,5
PRIVATE 3	227	586	706	808	1.219	1.527	1.609	1.325	483,1
PRIVATE 4	94	78	76	77	124	196	235	211	124,0
TOTAL	**9.717**	**15.703**	**16.714**	**19.363**	**23.684**	**27.829**	**38.468**	**35.539**	**265,7**
NON INTEREST EXPENSES									
PUBLIC	3.917	3.362	2.375	3.034	3.192	4.468	4.588	4.727	20,7
PRIVATE 1	8.101	9.776	13.308	12.027	14.575	18.261	20.565	19.030	134,9
PRIVATE 2	2.278	3.113	3.276	4.275	5.585	8.315	9.406	8.956	293,2
PRIVATE 3	699	841	999	1.271	1.570	1.968	1.947	1.747	149,9
PRIVATE 4	113	121	114	140	157	290	322	393	248,3
TOTAL	**15.108**	**17.212**	**20.072**	**20.746**	**25.080**	**33.302**	**36.827**	**34.852**	**130,7**
LOANS									
PUBLIC	7.386	12.864	19.523	28.289	38.689	54.954	67.191	99.564	1.248,1
PRIVATE 1	36.035	53.259	82.215	122.384	156.222	203.801	205.190	273.729	659,6
PRIVATE 2	11.221	19.150	28.596	41.722	53.780	63.748	65.670	83.225	641,7
PRIVATE 3	2.657	4.124	5.241	8.017	11.055	12.265	13.508	17.372	553,9
PRIVATE 4	322	486	725	1.079	1.530	2.025	2.499	3.376	949,5
TOTAL	**57.620**	**89.883**	**136.301**	**201.491**	**261.276**	**336.793**	**354.057**	**477.266**	**728,3**
ASSETS									
PUBLIC	66.016	82.704	92.103	107.241	121.389	155.734	185.594	224.448	240,0
PRIVATE 1	120.988	148.518	208.814	268.804	309.205	388.536	444.230	528.425	336,8
PRIVATE 2	26.644	37.466	50.138	68.467	83.610	103.756	106.324	132.181	396,1
PRIVATE 3	7.733	9.516	11.165	17.646	18.922	23.631	23.564	29.052	275,7
PRIVATE 4	1.490	1.720	2.031	2.664	4.490	6.124	6.994	7.832	425,6
TOTAL	**222.872**	**279.924**	**364.251**	**464.822**	**537.615**	**677.782**	**766.706**	**921.938**	**313,7**
EQUITY									
PUBLIC	8.401	8.056	8.993	10.359	11.601	11.650	16.114	20.903	148,8
PRIVATE 1	17.792	23.688	25.869	28.977	38.218	42.651	56.648	69.930	293,0
PRIVATE 2	3.903	5.013	6.137	7.310	9.934	11.982	14.312	16.872	332,3
PRIVATE 3	798	1.084	1.339	1.746	2.539	3.106	3.635	4.050	407,6
PRIVATE 4	252	301	316	372	565	883	1.091	1.129	347,8
TOTAL	**31.146**	**38.142**	**42.654**	**48.764**	**62.857**	**70.271**	**91.801**	**112.883**	**262,4**

APPENDIX A.2

Summary Statistics of Inputs/Outputs Used for 22 Commercial Banks (2003-2010)

Variable	Year	Statistics	Public	Private 1	Private 2	Private 3	Private 4
ROA	2003	mean	2.61	2.15	2.75	1.71	1.91
		std dev	0.03	1.73	0.85	1.07	0.33
	2004	mean	2.66	2.00	2.03	1.56	1.24
		std dev	0.27	1.46	0.59	1.18	0.66
	2005	mean	2.55	-0.51	2.83	2.12	1.18
		std dev	0.71	6.61	1.17	1.70	0.64
	2006	mean	2.92	2.19	2.36	1.51	0.83
		std dev	0.29	0.58	1.50	0.49	0.91
	2007	mean	3.08	2.69	1.98	2.53	0.54
		std dev	0.04	0.93	0.86	0.70	0.41
	2008	mean	2.30	1.92	1.37	1.69	0.63
		std dev	0.11	0.32	0.29	0.82	0.66
	2009	mean	3.00	2.58	1.73	1.76	0.98
		std dev	0.10	0.51	0.65	0.95	1.30
	2010	mean	2.88	2.52	1.50	1.51	0.88
		std dev	0.11	0.50	0.94	0.90	1.08
ROE	2003	mean	21.00	16.57	18.61	19.42	9.60
		std dev	0.03	10.62	5.40	13.72	1.78
	2004	mean	24.76	16.77	15.24	16.97	6.26
		std dev	7.47	15.79	4.91	16.32	2.98
	2005	mean	26.32	-0.72	21.99	16.24	6.10
		std dev	12.42	43.83	8.92	8.17	3.51
	2006	mean	31.47	20.66	21.37	14.33	5.62
		std dev	7.79	5.82	12.57	5.97	6.68
	2007	mean	39.48	27.37	18.71	25.57	4.03
		std dev	6.32	13.51	6.33	8.72	4.53
	2008	mean	33.26	19.17	13.30	14.22	3.53
		std dev	7.59	3.73	3.60	7.09	3.19
	2009	mean	44.91	23.71	15.05	13.47	4.32
		std dev	8.46	3.85	7.40	7.71	4.22
	2010	mean	37.07	21.46	12.89	10.57	3.82
		std dev	1.25	3.69	8.82	6.38	3.20
Net Interest Income / Total Income	2003	mean	27.35	11.64	27.40	12.62	38.24
		std dev	3.72	12.74	10.23	16.35	13.91
	2004	mean	32.94	31.80	34.67	29.10	34.49
		std dev	5.52	9.42	5.48	9.32	16.37
	2005	mean	25.99	33.57	37.61	32.70	32.66
		std dev	7.00	4.15	2.86	5.99	6.98
	2006	mean	28.49	28.03	31.97	31.21	22.92
		std dev	5.08	2.24	3.57	6.95	6.05
	2007	mean	27.42	26.50	32.53	33.90	28.51
		std dev	3.04	2.99	3.25	1.71	5.33
	2008	mean	26.46	26.07	32.51	35.25	31.95
		std dev	0.70	1.64	6.26	3.06	12.10
	2009	mean	37.97	37.70	41.45	41.17	38.45
		std dev	2.21	2.76	5.88	3.00	15.64
	2010	mean	37.14	35.67	41.23	39.11	35.19
		std dev	3.87	2.44	7.41	5.91	14.92
Securities / Total Assets	2003	mean	62.90	38.59	24.34	28.98	29.17
		std dev	3.67	8.83	10.96	14.75	18.86
	2004	mean	65.06	34.70	18.32	23.68	24.94
		std dev	2.63	7.37	7.11	9.59	18.94
	2005	mean	59.96	31.82	17.88	21.95	24.49
		std dev	3.95	5.15	5.39	10.78	19.02
	2006	mean	53.49	30.48	14.20	17.09	21.95
		std dev	5.51	3.47	7.10	9.23	16.31
	2007	mean	45.93	26.84	15.73	11.47	29.79
		std dev	11.99	4.61	7.02	5.74	18.29
	2008	mean	44.05	24.09	13.46	15.88	26.71
		std dev	14.17	4.38	4.06	7.54	19.24
	2009	mean	44.18	31.18	16.44	18.59	26.24
		std dev	15.00	8.82	4.19	7.21	17.45
	2010	mean	37.44	28.84	16.84	15.66	22.80
		std dev	15.73	7.71	2.14	3.99	12.76

Variable	Year	Statistics	Public	Private 1	Private 2	Private 3	Private 4
Deposits / Total Assets	2003	mean	71.61	63.82	61.71	66.11	48.40
		std dev	0.43	5.29	8.97	10.15	26.97
	2004	mean	77.24	61.24	59.60	60.97	41.60
		std dev	2.35	5.89	8.46	7.78	21.96
	2005	mean	77.53	62.24	55.66	59.56	44.30
		std dev	2.58	7.13	6.48	11.94	24.99
	2006	mean	78.21	59.87	57.49	57.02	46.12
		std dev	4.05	3.66	7.51	12.25	26.48
	2007	mean	77.96	59.79	56.68	61.68	37.50
		std dev	7.03	4.15	6.58	6.65	17.18
	2008	mean	76.88	61.57	55.06	63.77	40.82
		std dev	2.25	4.94	7.17	10.09	23.13
	2009	mean	73.39	60.05	58.40	67.22	43.15
		std dev	6.82	4.12	6.07	4.22	26.14
	2010	mean	75.55	59.20	55.23	62.03	40.94
		std dev	7.98	4.66	4.30	5.58	26.95
Nonperforming Loans / Total Loans	2003	mean	32.17	8.02	3.00	6.24	9.92
		std dev	0.76	5.23	1.70	5.16	8.61
	2004	mean	13.20	5.92	2.52	3.99	5.67
		std dev	12.64	3.09	1.64	2.74	5.24
	2005	mean	9.29	5.35	2.44	5.94	3.81
		std dev	9.88	2.79	1.48	5.95	3.09
	2006	mean	5.28	4.20	2.08	4.21	2.74
		std dev	4.84	2.16	1.06	4.17	2.13
	2007	mean	3.66	3.99	2.63	3.25	2.90
		std dev	2.59	1.49	1.06	1.78	1.69
	2008	mean	3.37	3.75	3.78	5.29	4.06
		std dev	1.97	1.11	1.33	2.91	2.10
	2009	mean	3.68	5.36	6.89	8.13	5.93
		std dev	1.88	0.97	2.56	5.12	4.02
	2010	mean	2.69	3.49	5.24	6.15	4.13
		std dev	1.68	0.92	2.23	3.61	2.09
Total Loans / Total Assets	2003	mean	11.67	30.02	40.57	35.98	22.93
		std dev	1.65	4.12	6.28	7.81	19.29
	2004	mean	15.87	36.17	48.50	44.57	27.60
		std dev	1.17	3.40	9.77	6.72	14.84
	2005	mean	21.68	40.63	54.86	49.02	34.42
		std dev	1.67	5.99	5.56	10.45	16.32
	2006	mean	28.10	46.34	60.67	50.48	38.46
		std dev	6.85	5.65	5.49	14.50	17.59
	2007	mean	34.89	51.40	62.26	60.08	36.99
		std dev	12.80	5.97	5.47	10.44	20.29
	2008	mean	38.71	53.20	59.66	51.89	34.79
		std dev	14.19	4.45	3.31	5.78	13.70
	2009	mean	40.18	47.41	59.77	59.62	37.57
		std dev	16.44	6.66	2.16	12.37	16.76
	2010	mean	48.22	52.93	61.06	61.56	43.74
		std dev	15.74	6.66	4.46	14.35	13.89
Non Interest Expense / Total (Avg) Assets	2003	mean	6.47	7.60	10.14	9.87	9.48
		std dev	0.25	1.35	3.14	3.59	3.37
	2004	mean	4.48	7.29	9.68	9.16	8.15
		std dev	0.01	0.76	2.32	2.74	1.57
	2005	mean	2.92	8.67	7.58	8.99	6.63
		std dev	0.46	7.18	1.69	3.46	1.47
	2006	mean	3.23	5.51	7.03	9.18	6.10
		std dev	0.69	2.06	1.33	2.59	1.99
	2007	mean	3.05	5.12	7.50	8.31	5.31
		std dev	0.94	1.45	1.00	2.32	1.55
	2008	mean	3.58	5.22	8.60	8.43	7.32
		std dev	1.29	0.65	1.52	2.39	4.16
	2009	mean	2.91	5.11	9.03	7.98	5.53
		std dev	0.87	0.92	0.93	1.37	1.77
	2010	mean	2.53	4.11	7.81	6.76	5.65
		std dev	0.76	1.03	0.60	1.14	1.64

APPENDIX B

Two-Stage Regression Results

Dependent Variable: DEA
Method: Panel EGLS (Cross-section weights)

Sample (adjusted): 2004 2010
Periods included: 7
Cross-sections included: 22
Total panel (balanced) observations: 154
Linear estimation after one-step weighting matrix
White cross-section standard errors & covariance (d.f. corrected)
WARNING: estimated coefficient covariance matrix is of reduced rank

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.152867	0.158160	7.289246	0.0000
ROA	1.831185	0.594996	3.077644	0.0026
LNTA	-0.132482	0.031347	-4.226245	0.0000
LOANSTA	-0.143336	0.038402	-3.732504	0.0003
NPLTA(-1)	-1.105745	0.426295	-2.593846	0.0106
CAR	-0.083616	0.072124	-1.159343	0.2486
DLNRGDPSA	-1.311146	0.200330	-6.544938	0.0000
NIM	-0.061812	0.007385	-8.370306	0.0000
INF	-0.005489	0.003175	-1.728893	0.0863
LNDEP	0.143402	0.032955	4.351479	0.0000

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.666057	Mean dependent var	1.198761
Adjusted R-squared	0.584607	S.D. dependent var	0.643462
S.E. of regression	0.089723	Sum squared resid	0.990177
F-statistic	8.177534	Durbin-Watson stat	2.148322
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.529470	Mean dependent var	0.796668
Sum squared resid	1.068311	Durbin-Watson stat	1.949412

APPENDIX C *(cont'd on the next page)*

Comparison of Bootstrapped Malmquist Productivity Index, 2003 - 2010

Banka Adı (*)	2003-2004 mpi	mpi lb	mpi ub	eff	tech	pure.eff	scale	2004-2005 mpi	mpi lb	mpi ub	eff	tech	pure.eff	scale
T.C. ZİRAAT BANKASI A.Ş.	1,194	0,895	1,354	1,000	1,194	1,000	1,000	1,158	1,068	1,390	1,000	1,158	1,00	1,000
TÜRKİYE HALK BANKASI A.Ş.	1,052	0,986	1,200	0,902	1,166	1,000	0,902	0,812	0,788	0,882	0,741	1,096	0,657	1,127
PUBLIC (**)	*1,121*	*0,939*	*1,275*	*0,950*	*1,180*	*1,000*	*0,950*	*0,970*	*0,918*	*1,107*	*0,861*	*1,127*	*0,811*	*1,062*
TÜRKİYE VAKIFLAR BANKASI T.A.O.	1,976	1,763	2,172	1,515	1,304	1,380	1,098	0,791	0,739	0,951	0,809	0,979	0,833	0,970
AKBANK T.A.Ş.	0,897	0,864	1,192	1,000	0,897	1,000	1,000	1,157	1,023	1,307	1,000	1,157	1,00	1,000
TÜRKİYE GARANTİ BANKASI A.Ş.	1,515	1,391	1,850	1,296	1,169	0,744	1,742	1,202	1,141	1,254	1,020	1,179	1,147	0,889
TÜRKİYE İŞ BANKASI A.Ş.	1,419	1,240	1,563	1,631	0,870	1,544	1,056	1,242	1,153	1,335	1,128	1,101	1,216	0,928
YAPI VE KREDİ BANKASI A.Ş.	1,596	1,359	1,883	1,701	0,938	1,585	1,073	1,216	1,120	1,262	1,072	1,134	1,517	0,702
PRIVATE 1	*1,435*	*1,290*	*1,698*	*1,404*	*1,022*	*1,202*	*1,167*	*1,107*	*1,022*	*1,213*	*0,999*	*1,108*	*1,121*	*0,891*
TÜRK EKONOMİ BANKASI A.Ş.	0,691	0,607	0,916	1,000	0,691	1,000	1,000	1,211	1,050	1,410	0,897	1,350	0,995	0,939
FORTİS BANK A.Ş.	0,578	0,478	0,663	0,662	0,873	0,662	0,999	1,121	1,053	1,204	1,052	1,065	1,221	0,862
ING BANK A.Ş.	1,293	1,162	1,352	1,209	1,070	1,181	1,024	2,036	1,865	2,199	1,000	2,036	1,00	1,000
FİNANSBANK A.Ş.	1,203	0,808	1,300	1,115	1,079	1,110	1,004	1,254	1,150	1,379	1,000	1,254	1,00	1,000
HSBC BANK A.Ş.	1,117	0,869	1,275	1,000	1,117	1,000	1,000	1,352	1,165	1,559	1,000	1,352	1,00	1,000
DENİZBANK A.Ş.	1,099	0,943	1,270	1,209	0,909	1,162	1,041	1,238	1,015	1,317	1,035	1,196	1,042	0,993
PRIVATE 2	*0,956*	*0,779*	*1,095*	*1,013*	*0,944*	*1,002*	*1,011*	*1,340*	*1,187*	*1,481*	*0,996*	*1,346*	*1,033*	*0,964*
ŞEKERBANK T.A.Ş.	0,979	0,908	1,216	0,957	1,023	1,000	0,957	0,627	0,462	0,681	0,661	0,949	0,990	0,696
CITIBANK A.Ş.	0,655	0,523	0,739	0,683	0,959	0,787	0,867	2,207	1,640	2,559	1,465	1,507	1,270	1,153
TEKSTİL BANKASI A.Ş.	1,149	0,981	1,333	1,000	1,149	1,000	1,000	0,693	0,596	0,886	0,676	1,025	0,757	0,893
ALTERNATİFBANK A.Ş.	0,792	0,631	0,940	0,708	1,119	0,680	1,041	2,432	2,285	2,667	2,083	1,168	2,095	0,994
ANADOLUBANK A.Ş.	1,725	1,548	1,785	1,349	1,279	1,000	1,349	0,769	0,721	0,877	0,742	1,037	0,749	0,990
PRIVATE 3	*1,001*	*0,855*	*1,150*	*0,910*	*1,100*	*0,883*	*1,031*	*1,124*	*0,942*	*1,293*	*1,002*	*1,121*	*1,075*	*0,933*
ARAP TÜRK BANKASI A.Ş.	0,923	0,846	0,957	1,000	0,923	1,000	1,000	0,837	0,818	0,877	1,000	0,837	1,00	1,000
TURKISH BANK A.Ş.	0,746	0,556	0,903	1,000	0,746	1,000	1,000	1,042	0,929	1,301	1,000	1,042	1,00	1,000
TURKLAND BANK A.Ş.	0,895	0,803	0,948	0,948	0,943	0,931	1,019	1,212	1,075	1,307	0,967	1,253	1,046	0,925
EUROBANK TEKFEN A.Ş.	0,950	0,799	1,016	1,063	0,894	1,044	1,018	0,894	0,837	0,971	0,712	1,256	0,866	0,822
PRIVATE 4	*0,874*	*0,741*	*0,955*	*1,002*	*0,873*	*0,993*	*1,009*	*0,986*	*0,909*	*1,097*	*0,911*	*1,082*	*0,976*	*0,934*
SECTOR	1,058	0,899	1,210	1,056	1,001	1,013	1,043	1,132	1,013	1,266	0,969	1,168	1,028	0,943

Banka Adı (*)	2005-2006 mpi	mpi lb	mpi ub	eff	tech	pure.eff	scale	2006-2007 mpi	mpi lb	mpi ub	eff	tech	pure.eff	scale
T.C. ZİRAAT BANKASI A.Ş.	1,036	0,994	1,069	1,000	1,036	1,000	1,000	1,077	1,069	1,091	1,000	1,077	1,000	1,000
TÜRKİYE HALK BANKASI A.Ş.	1,170	1,045	1,325	1,209	0,968	1,205	1,003	1,177	1,052	1,261	1,096	1,073	1,100	0,996
PUBLIC (**)	*1,101*	*1,019*	*1,190*	*1,099*	*1,002*	*1,098*	*1,002*	*1,126*	*1,060*	*1,173*	*1,047*	*1,075*	*1,049*	*0,998*
TÜRKİYE VAKIFLAR BANKASI T.A.O.	1,150	1,104	1,249	1,237	0,930	1,200	1,031	1,008	0,931	1,063	0,964	1,045	1,000	0,964
AKBANK T.A.Ş.	0,837	0,774	0,913	1,000	0,837	1,000	1,000	1,008	0,973	1,059	1,000	1,008	1,000	1,000
TÜRKİYE GARANTİ BANKASI A.Ş.	1,042	0,959	1,134	1,132	0,920	1,008	1,123	1,531	1,238	1,581	1,171	1,307	1,163	1,007
TÜRKİYE İŞ BANKASI A.Ş.	0,844	0,817	0,923	0,999	0,845	0,929	1,076	0,937	0,866	1,000	0,933	1,004	0,893	1,045
YAPI VE KREDİ BANKASI A.Ş.	1,532	1,337	1,808	1,547	0,991	1,121	1,380	0,885	0,851	0,942	0,858	1,032	0,904	0,949
PRIVATE 1	*1,054*	*0,978*	*1,167*	*1,167*	*0,903*	*1,047*	*1,114*	*1,052*	*0,963*	*1,109*	*0,980*	*1,074*	*0,987*	*0,993*
TÜRK EKONOMİ BANKASI A.Ş.	0,918	0,740	0,991	1,115	0,823	1,047	1,065	0,729	0,671	0,830	0,893	0,817	0,894	0,999
FORTİS BANK A.Ş.	1,099	1,052	1,169	1,304	0,843	1,177	1,107	0,883	0,832	0,896	0,834	1,060	0,945	0,882
ING BANK A.Ş.	0,483	0,408	0,557	0,882	0,547	0,974	0,906	0,749	0,708	0,779	1,009	0,742	0,923	1,094
FİNANSBANK A.Ş.	1,252	0,930	1,403	1,000	1,252	1,000	1,000	0,762	0,704	0,928	1,000	0,762	1,000	1,000
HSBC BANK A.Ş.	1,339	1,064	1,423	1,000	1,339	1,000	1,000	0,928	0,860	1,009	1,000	0,928	1,000	1,000
DENİZBANK A.Ş.	1,137	0,973	1,232	1,061	1,072	1,064	0,997	0,840	0,792	0,909	0,847	0,992	0,864	0,981
PRIVATE 2	*0,988*	*0,821*	*1,080*	*1,053*	*0,938*	*1,042*	*1,010*	*0,812*	*0,758*	*0,889*	*0,927*	*0,875*	*0,936*	*0,991*
ŞEKERBANK T.A.Ş.	0,779	0,737	0,860	0,834	0,934	0,786	1,061	1,381	1,325	1,498	1,496	0,923	1,210	1,236
CITIBANK A.Ş.	0,842	0,658	1,021	1,000	0,842	1,000	1,000	0,983	0,812	1,133	1,000	0,983	1,000	1,000
TEKSTİL BANKASI A.Ş.	1,228	1,115	1,312	1,479	0,830	1,321	1,120	0,940	0,843	1,042	1,000	0,940	1,000	1,000
ALTERNATİFBANK A.Ş.	1,375	0,914	1,489	1,151	1,195	1,278	0,901	1,419	1,153	1,513	1,132	1,254	1,000	1,132
ANADOLUBANK A.Ş.	1,007	0,913	1,082	1,125	0,895	1,121	1,004	1,210	1,083	1,279	1,199	1,010	1,191	1,006
PRIVATE 3	*1,022*	*0,853*	*1,132*	*1,098*	*0,931*	*1,083*	*1,014*	*1,170*	*1,025*	*1,279*	*1,152*	*1,015*	*1,076*	*1,071*
ARAP TÜRK BANKASI A.Ş.	0,828	0,799	0,867	1,000	0,828	1,000	1,000	0,784	0,722	0,836	1,000	0,784	1,000	1,000
TURKISH BANK A.Ş.	0,747	0,666	0,788	1,000	0,747	1,000	1,000	0,892	0,786	0,952	1,000	0,892	1,000	1,000
TURKLAND BANK A.Ş.	0,427	0,382	0,448	0,537	0,795	0,565	0,951	2,303	2,269	2,453	2,159	1,067	1,992	1,084
EUROBANK TEKFEN A.Ş.	1,153	1,069	1,310	1,377	0,837	1,108	1,243	1,208	1,087	1,334	1,164	1,038	1,425	0,817
PRIVATE 4	*0,743*	*0,683*	*0,795*	*0,927*	*0,801*	*0,889*	*1,043*	*1,181*	*1,088*	*1,270*	*1,259*	*0,938*	*1,298*	*0,970*
SECTOR	0,969	0,850	1,060	1,067	0,907	1,027	1,039	1,032	0,944	1,111	1,055	0,979	1,049	1,006

(*)"mpi ub" stands for upper bound of the confidence interval for MPI score whereas mpi lb stands for lower bound and eff, tech, pure.eff and scale show the efficiency, technical, pure efficiency and scale efficiency changes, respectively.

(**)MPI score for each group of bank is obtained by calculating geometric mean of MPI scores of banks within that group.

APPENDIX C *(cont'd)*

Comparison of Bootstrapped Malmquist Productivity Index, 2003 - 2010

Banka Adı (*)	2007-2008 mpi	mpi lb	mpi ub	eff	tech	pure.eff	scale
T.C. ZİRAAT BANKASI A.Ş.	0,788	0,781	0,806	1,000	0,788	1,000	1,000
TÜRKİYE HALK BANKASI A.Ş.	0,789	0,763	0,835	1,120	0,704	1,115	1,004
PUBLIC (**)	*0,789*	*0,772*	*0,820*	*1,058*	*0,745*	*1,056*	*1,002*
TÜRKİYE VAKIFLAR BANKASI T.A.O.	0,775	0,723	0,803	0,974	0,795	1,000	0,974
AKBANK T.A.Ş.	0,770	0,743	0,803	1,000	0,770	1,000	1,000
TÜRKİYE GARANTİ BANKASI A.Ş.	0,583	0,561	0,647	1,000	0,583	1,000	1,000
TÜRKİYE İŞ BANKASI A.Ş.	0,857	0,812	0,907	1,057	0,811	1,061	0,996
YAPI VE KREDİ BANKASI A.Ş.	1,125	1,085	1,168	1,568	0,717	1,389	1,129
PRIVATE 1	*0,804*	*0,767*	*0,849*	*1,101*	*0,730*	*1,081*	*1,018*
TÜRK EKONOMİ BANKASI A.Ş.	0,768	0,721	0,797	1,120	0,686	1,119	1,001
FORTİS BANK A.Ş.	1,130	1,094	1,196	1,176	0,961	1,002	1,174
ING BANK A.Ş.	0,588	0,562	0,631	0,833	0,706	0,829	1,005
FİNANSBANK A.Ş.	0,666	0,625	0,724	0,856	0,779	0,901	0,949
HSBC BANK A.Ş.	0,688	0,633	0,739	1,000	0,688	1,000	1,000
DENİZBANK A.Ş.	1,060	0,946	1,112	1,200	0,883	1,160	1,035
PRIVATE 2	*0,793*	*0,741*	*0,843*	*1,020*	*0,777*	*0,995*	*1,025*
ŞEKERBANK T.A.Ş.	0,844	0,796	0,866	1,015	0,831	1,067	0,951
CITIBANK A.Ş.	0,650	0,592	0,734	0,950	0,684	1,000	0,950
TEKSTİL BANKASI A.Ş.	0,778	0,721	0,847	1,000	0,778	1,000	1,000
ALTERNATİFBANK A.Ş.	0,531	0,502	0,612	1,000	0,531	1,000	1,000
ANADOLUBANK A.Ş.	0,711	0,661	0,773	1,000	0,711	1,000	1,000
PRIVATE 3	*0,694*	*0,646*	*0,761*	*0,993*	*0,699*	*1,013*	*0,980*
ARAP TÜRK BANKASI A.Ş.	1,329	1,249	1,345	1,000	1,329	1,000	1,000
TURKISH BANK A.Ş.	0,791	0,686	0,872	1,000	0,791	1,000	1,000
TURKLAND BANK A.Ş.	1,169	1,026	1,213	1,311	0,892	1,191	1,101
EUROBANK TEKFEN A.Ş.	0,695	0,670	0,724	0,780	0,891	1,000	0,780
PRIVATE 4	*0,961*	*0,876*	*1,007*	*1,006*	*0,956*	*1,045*	*0,963*
SECTOR	0,799	0,749	0,850	1,032	0,774	1,033	1,000

Banka Adı (*)	2008-2009 mpi	mpi lb	mpi ub	eff	tech	pure.eff	scale
T.C. ZİRAAT BANKASI A.Ş.	1,314	1,308	1,317	1,000	1,314	1,000	1,000
TÜRKİYE HALK BANKASI A.Ş.	1,458	1,314	1,501	1,031	1,415	1,029	1,001
PUBLIC (**)	*1,384*	*1,311*	*1,406*	*1,015*	*1,364*	*1,015*	*1,001*
TÜRKİYE VAKIFLAR BANKASI T.A.O.	1,296	1,225	1,345	1,019	1,271	0,975	1,045
AKBANK T.A.Ş.	1,419	1,355	1,607	1,000	1,419	1,000	1,000
TÜRKİYE GARANTİ BANKASI A.Ş.	1,211	1,147	1,396	1,000	1,211	1,000	1,000
TÜRKİYE İŞ BANKASI A.Ş.	1,318	1,254	1,385	1,082	1,218	1,088	0,994
YAPI VE KREDİ BANKASI A.Ş.	1,087	1,042	1,178	0,891	1,220	0,913	0,976
PRIVATE 1	*1,261*	*1,200*	*1,375*	*0,997*	*1,265*	*0,994*	*1,003*
TÜRK EKONOMİ BANKASI A.Ş.	0,784	0,723	0,855	0,762	1,029	0,770	0,990
FORTİS BANK A.Ş.	0,876	0,836	0,914	0,687	1,275	0,760	0,904
ING BANK A.Ş.	1,414	1,289	1,497	1,347	1,049	1,342	1,004
FİNANSBANK A.Ş.	1,127	1,056	1,222	0,995	1,133	0,972	1,024
HSBC BANK A.Ş.	0,764	0,734	0,824	1,000	0,764	1,000	1,000
DENİZBANK A.Ş.	1,170	0,943	1,262	1,000	1,170	1,000	1,000
PRIVATE 2	*0,996*	*0,910*	*1,068*	*0,943*	*1,057*	*0,956*	*0,986*
ŞEKERBANK T.A.Ş.	1,066	1,012	1,097	0,920	1,159	0,917	1,004
CITIBANK A.Ş.	0,784	0,727	0,830	0,804	0,975	0,800	1,005
TEKSTİL BANKASI A.Ş.	1,100	0,968	1,197	1,000	1,100	1,000	1,000
ALTERNATİFBANK A.Ş.	0,916	0,875	1,057	0,998	0,918	1,000	0,998
ANADOLUBANK A.Ş.	1,078	0,993	1,151	1,000	1,078	1,000	1,000
PRIVATE 3	*0,981*	*0,909*	*1,058*	*0,941*	*1,042*	*0,940*	*1,001*
ARAP TÜRK BANKASI A.Ş.	2,320	2,218	2,550	1,000	2,320	1,000	1,000
TURKISH BANK A.Ş.	1,001	0,736	1,062	1,000	1,001	1,000	1,000
TURKLAND BANK A.Ş.	0,810	0,778	0,901	0,899	0,901	0,907	0,991
EUROBANK TEKFEN A.Ş.	1,126	1,085	1,221	0,677	1,662	0,401	1,690
PRIVATE 4	*1,206*	*1,084*	*1,314*	*0,883*	*1,366*	*0,776*	*1,138*
SECTOR	1,117	1,034	1,202	0,949	1,177	0,930	1,021

Banka Adı (*)	2009-2010 mpi	mpi lb	mpi ub	eff	tech	pure.eff	scale
T.C. ZİRAAT BANKASI A.Ş.	0,882	0,738	0,908	1,000	0,882	1,000	1,000
TÜRKİYE HALK BANKASI A.Ş.	1,052	0,912	1,103	1,000	1,052	1,000	1,000
PUBLIC (**)	*0,963*	*0,820*	*1,001*	*1,000*	*0,963*	*1,000*	*1,000*
TÜRKİYE VAKIFLAR BANKASI T.A.O.	0,972	0,927	1,039	0,844	1,151	0,861	0,981
AKBANK T.A.Ş.	0,996	0,880	1,072	1,000	0,996	1,000	1,000
TÜRKİYE GARANTİ BANKASI A.Ş.	1,000	0,914	1,059	1,000	1,000	1,000	1,000
TÜRKİYE İŞ BANKASI A.Ş.	0,983	0,914	1,039	1,023	0,961	1,020	1,003
YAPI VE KREDİ BANKASI A.Ş.	1,183	0,960	1,262	1,184	0,999	1,150	1,030
PRIVATE 1	*1,024*	*0,919*	*1,091*	*1,005*	*1,020*	*1,002*	*1,003*
TÜRK EKONOMİ BANKASI A.Ş.	1,070	0,881	1,147	1,051	1,018	1,178	0,892
FORTİS BANK A.Ş.	1,244	1,178	1,364	1,045	1,191	1,118	0,935
ING BANK A.Ş.	1,100	1,028	1,177	1,000	1,100	1,000	1,000
FİNANSBANK A.Ş.	1,097	0,991	1,162	1,175	0,934	1,142	1,029
HSBC BANK A.Ş.	0,853	0,736	0,909	0,896	0,952	1,000	0,896
DENİZBANK A.Ş.	0,817	0,736	0,903	1,000	0,817	1,000	1,000
PRIVATE 2	*1,019*	*0,911*	*1,098*	*1,024*	*0,995*	*1,070*	*0,957*
ŞEKERBANK T.A.Ş.	0,984	0,945	1,055	0,945	1,041	0,909	1,039
CITIBANK A.Ş.	1,408	1,321	1,462	1,309	1,075	1,249	1,048
TEKSTİL BANKASI A.Ş.	0,974	0,923	1,050	0,787	1,237	0,913	0,862
ALTERNATİFBANK A.Ş.	0,683	0,610	0,750	0,660	1,036	0,691	0,955
ANADOLUBANK A.Ş.	1,011	0,881	1,033	1,000	1,011	1,000	1,000
PRIVATE 3	*0,986*	*0,909*	*1,046*	*0,915*	*1,077*	*0,935*	*0,978*
ARAP TÜRK BANKASI A.Ş.	0,973	0,969	1,007	1,000	0,973	1,000	1,000
TURKISH BANK A.Ş.	1,038	0,878	1,148	1,000	1,038	1,000	1,000
TURKLAND BANK A.Ş.	0,701	0,652	0,741	0,612	1,145	0,679	0,901
EUROBANK TEKFEN A.Ş.	0,817	0,758	0,885	0,813	1,005	0,865	0,940
PRIVATE 4	*0,872*	*0,805*	*0,933*	*0,840*	*1,038*	*0,876*	*0,959*
SECTOR	0,979	0,884	1,044	0,957	1,024	0,980	0,976

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