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Productivity and Efficiency Analysis of Iranian Banking Sector (2000-2011) Using Data Envelopment Analysis

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ABSTRACT

This paper explains the process of measuring and analyzing Bank's total productivity (BTP) and the productivity changes in bank branches using Slack Based Measure (SBM) of DEA and Malmquist Productivity Index (MPI). in Export Development Bank of Iran (EDBI). For this purpose, we have measured and analyzed the productivity growth in EDBI branches using MPI in the period of 2000-2011. The trend of efficiency scores' moving averages confirms improvement in BTP over the period of study. Moreover, the results show %1 and %2 on average improvement in the productivity of EDBI branches in period 2000 and 2011, respectively.

Introduction

Managerial accounting systems provide useful information to support managers' decision making and organizational performance evaluation. One of the most important information that this system provides is about organizational productivity. In reality, measuring the productivity regards as the most important and difficult step in productivity cycle.

One of the most famous non-parametric techniques in measuring the productivity of similar Decision Making Units (DMUs) is Data Envelopment Analysis (DEA). DEA is a mathematical programming that generates production function or efficient frontier using observed or available data. In addition to DEA, one can apply Malmquist Productivity Index (MPI) to measure productivity growth for a firm.

This paper is to explain the process of measuring and analyzing Bank's total productivity (BTP) and Productivity Growth (PG) using DEA, Slack Based Measure (SBM) and Malmquiest Productivity Index (MPI). For this purpose, results of an empirical study (case of Export Development Bank of Iran: EDBI) is provided.

This paper is organized as follows. In the next section, we explain review of the literature. Section 3 introduces two main research hypotheses. Research methodology is explained in section 4. Section 5 provides results of hypotheses tests. Finally, the paper ends with conclusions and final remarks.

Literature Review

Berger and Humphrey (1992) measure the efficiency in commercial banking. In the other study, they study on measuring efficiency of financial institutions. Berger and Mester (2003) in their paper titled as "Inside the black box: What explains differences in the efficiencies of financial institutions?" profound the literature on financial institution efficiency. Rogers (2004) focuses on the nontraditional activities and the efficiency of US commercial banks. Golany and Storbeck (2005) applied a multiperiod DEA to measure the efficiencies of selected branches of a large US bank over second quarter of 1992 to the third quarter of 1993. They developed budgeting and target-setting modules, within a DEA framework. Altunbas, Liu, Molyneux, and Seth (2006) measure the efficiency and risk in Japanese banking. Mukherjee, Ray and Miller (2007) measure the productivity growth for 201 large US commercial banks in the period of 1984 to 1990 using DEA, MPI. They attempt to distinct the contributions of technical change, technical efficiency change, and scale change to productivity growth. Isik and Hassan (2009) study total factor productivity change in Turkish commercial bank. They utilize a DEA-type Malmquist total factor productivity change index and examine productivity growth, efficiency change, and technical progress in Turkish commercial banks during the deregulation of financial markets in Turkey. Laeven, and Majnoni (2009) study on the loan loss provisioning and economic slowdowns. Halkos and Salamouris (2010) apply DEA in measuring the performance of the Greek banking sector. They study on the efficiency of Greek banks and use a number of financial efficiency ratios for the time period 2003–2005. The ratios were return difference of interest bearing assets, return on average equity, profit/loss per employee, efficiency ratio, and net interest margin. Their model helps bank to compare the inefficient banks with the efficient ones. They suggest DEA as either an alternative or complement to ratio analysis for the evaluation of an organization's performance and find a positive relation between the size of total assets and the efficiency. Their study shows that reducing the number of small banks due to mergers and acquisitions leads to increasing in efficiency. They cannot find systematic significant relationship

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between transfer of ownership and last period's performance. Grosskopf and Weber (2010) study the effect of risk-based capital requirements on profit efficiency in banking. Drakea, Hallb and Simper (2006) evaluate the relative technical efficiency of institutions operating in a market that has been significantly affected by environmental and market factors in recent years. They incorporate environmental factors into the efficiency analysis using SBM, incorporate the operating environment into a nonparametric measure of technical efficiency, employ SBM in DEA. In Iran ,Nafar (1991) applies DEA to measure technical efficiency in banking industry .Fattahpour (2007) attempts to measuring efficiency in the biggest bank of Iran (Bank Melli Iran) using DEA .Moreover ,Zarepour (2009) desigs a combined model of measuring efficiency using DEA and Goal Programming (GP) techniques in Basijian Financial Funds.

As mentioned in introduction, this research is aimed to explain the process of measuring and analyzing total productivity in a bank and the productivity changes in its branches using DEA and SBM and MPI. Next section introduces research hypotheses. The research methodology that we used to measure and analyze bank total factor efficiency and its changes over the time explained in section 4.

Research Hypotheses

Change in productivity is a well-known indicator of a unit/firm's performance over the time. Productivity regards as comparison of efficiency over the time or to other similar units/firms. When one compares a unit/firm's performances in two periods or when he compares two firms, he uses Total Productivity Index (TPI).

This research aims to assess the total productivity of the bank over between 1994 - 2011 and its branches' productivity growth in 2009-2011 using DEA model. Finally, it aims to provide a simple model to categorize branches in terms of their productivity growth.

Two main hypotheses of this research are as followings:

H1: Bank Total Productivity improved over the periods of study.

H2: The Average Productivity Growth of the branches improved over the periods of study.

To compare bank total productivity in 1994-2011, SBM, and in order to compare branches efficiency and analyze their efficiency growth over the period of study DEA model are applied.

Research Methodology

Statistical population of this research included EDBI and its all 28 benches. Each branch of bank provides both foreign currency and regular banking activities. Period of study of bank total productivity was 1994-2011. In order to measure branches productivity, we selected all branches that were active in period 2009-2011. Since two branches were established in the middle of 2010, then totally 26 of 28 branches were empirically examined. The data and information for bank total productivity extracted from bank's audited financial statements and for the analyzes of branches productivity, bank's documents, statistical reports and bank's branches' monthly balance reports in 2009 to 2011 were used.

To measure and assess bank total productivity, supposing variable return to scale, full ranking model of SBM of super-efficiency was applied. SBM is a DEA model that directly uses slack variables (input surplus and output slack variables) and focuses on both inputs and outputs at the same time so that provides a Scalar for efficiency score (Tone, 2007). We used SBM and variable rate of return to scale assumption because it was not possible for the bank to increase its productivity just by decreasing its inputs or increasing outputs.

Suppose $X=(x_{ij})\in R^{m\times n}$ and $Y=(y_{rj})\in R^{s\times n}$ denote input and output matrix for n Decision Making Units (DMUs), respectively. In this case, the Production Possibility Set (PPS) for these DMUs can be defined as $P=\{(x,y)|\ x\geq X\lambda,\ y\leq Y\lambda,\ \lambda\geq 0\}$ where λ is a non-negative vector in R^n and for each $DMU(x_o,y_o)$ we will have $x_o=X\lambda+s^-$, $y_o=Y\lambda-s^+$, and $s^+\geq 0$ ، $s^-\geq 0$ ، $\lambda\geq 0$ where s^- and s^+ are slack variables imply to output shortfall and input surplus vectors, respectively. Using slack variables vectors and supposing $\Lambda=t\lambda,\ S^-=ts^-,\ S^+=ts^+$, a linear programming SBM with variable rate of return to scale can be formulated as follows:

$$\begin{aligned}
&Minimize: && \rho=t-(1/m)\textstyle\sum_{i=1}^{m} S_i^-/x_{io}\\
&subject\ to: && 1=t+(1/s)\textstyle\sum_{r=1}^{s} S_r^+/y_{ro}\\
& && t\,x_o=X\Lambda+S^-\\
& && t\,y_o=Y\Lambda-S^+\\
& && \textstyle\sum_{j=1}^{n}\Lambda_j=1\\
& && \Lambda\geq 0,\ S^-\geq 0,\quad S^+\geq 0,\quad t>0
\end{aligned}$$

In SBM, $DMU(x_o,y_o)$ is efficient if $\rho^*=1$. Also for full ranking of all DMUs in SBM, we have to including DMUs with efficiency scores 1 (Tone, 2008). Accordingly, full ranking linear programming model with variable rate of return to scale is as:

$$\begin{aligned}
&\tau^*=\min\tau=\frac{1}{m}\sum_{i=1}^{m}\tilde{x}_i/x_{io}\\
&subject\ to\quad 1=\frac{1}{s}\sum_{r=1}^{s}\tilde{y}_r/y_{ro}\\
&\qquad \tilde{x}\geq\sum_{j=1,\neq o}^{n}\Lambda_j x_j\\
&\qquad \tilde{y}\leq\sum_{j=1,\neq o}^{n}\Lambda_j y_j\\
&\qquad \sum\Lambda_j=1\\
&\qquad \tilde{x}\geq t\,x_o,\ \tilde{y}\leq t y_o,\ \tilde{y}\geq 0,\ \lambda\geq 0
\end{aligned}$$

Where $\tau^*\geq 1$.

In order to assess bank total productivity using SBM, we considered performance of bank in each year (between 1994-2011) as a distinct DMU. We solved SBM for each DMU (each financial period) by Lindo software. Then, for DMUs with efficiency score 1, a full ranking linear programming model formulated and solved. We also measured scale inefficiency and compared SBM results under variable and constant rate of return to scale assumptions. To test H1 (first research hypothesis), we used the results of SBM under variable rate of return to scale.

To measure bank's branches' efficiency scores, we measured MPI. This index measures DMUs efficiency changes over the years and calculates a yearly efficiency of a DMU based on the data of that year respect to previous year production technology. MPI does not suppose that a DMU behavior optimized behavior. Moreover, it use of non-parametric method of DEA (Rezitis and Anthony, 2006).

If a DMU in period t (t=2،1، ... ،T), can produce M of y^t outputs using x^t inputs, in each period *t*, production technology and distance functions can be defined as $S^t = \left(x^t, y^t\right)$ and $D_O^t(x^t, y^t) = \inf\{\theta : (y^t/\theta) \in S^t\}, t = 1,...,T$, respectively. This equations show the maximum outputs that can be obtained with the technology of period *t*. If outputs vector locates on the technology frontier, the value of distance function for outputs, θ, will be one. MPI, using distance function for outputs, measures the changes in productivity between *t* and *t+1* as follows:

$$M_O(x^{t+1}, y^{t+1} x^t, y^t) =$$

$$[M_O^t(x^{t+1}, y^{t+1} x^t, y^t) \times M_O^{t+1}(x^{t+1}, y^{t+1} x^t, y^t)]^{1/2} =$$

$$\left[\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)} \times \frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^t, y^t)}\right]^{1/2}$$

The productivity increased when $M_0 > 1$. To estimate function, MPI uses Data Envelopment Analysis, DEA. Solving four linear programming problem, we can generate the functions $D_O^t(x^{t+1}, y^{t+1})$ ، $D_O^{t+1}(x^{t+1}, y^{t+1})$ ، $D_O^t(x^{t+1}, y^{t+1})$ and $D_O^{t+1}(x^t, y^t)$. For example, distance function for the K_{th} DMUs (k=1,2,…, K) under constant rate of return to scale calculates as following:

$$Max\,\theta^P = \left(D_O^t(x^{p,t}, y^{p,t})\right)^{-1}$$

subject to

$$\theta^P y_m^{p,t} \le \sum_{k=1}^{K} z^{k,t} y_m^{k,t} \qquad m = 1, \ldots, M$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \le x_n^{p,t} \qquad n = 1, \ldots, N$$

$$z^{k,t} \ge 0 \qquad k = 1, \ldots, K$$

In order to measure MPI, first we solved the $D_O^t(x^{t+1}, y^{t+1})$, $D_O^{t+1}(x^{t+1}, y^{t+1})$ ، $D_O^t(x^{t+1}, y^{t+1})$ and $D_O^{t+1}(x^t, y^t)$ using EMS software and then the index was calculated for each period.

For selecting the inputs and outputs variables, the literature is reviewed. Some researchers suggested correlation technique (Farzipour Saen, Memariani and Hosseinzadeh Lotfi (2009) Considering the literature suggestions, the following inputs and outputs variables were selected.

- In SBM, number of employee, cost of doubtful liabilities and main financing resources considered as input variables and facilities amounts as output variable.
- In MPI, number of employees, administrative & salary costs, profit and fees paid considered as input variables and fees received, facility donated, no cost deposits, and regular (with cost) deposits as output variables.

Results of Hypotheses Tests

Tables 1 and 2 shows the descriptive statistical results of this research.

Table 1. Descriptive statistics of selected variables in SBM (*In Million Rials)

Outputs	Inputs			
Facilities *Amounts	Cost of doubtful *Liabilities	Number of Employees	Main Financing *Resources	
10,128	**175**	**895**	**11,888**	Maximum
164	**3**	**156**	**325**	Minimum
2,823	**40**	**578**	**3,655**	Mean
3,294	**51**	**234**	**3,827**	Standard deviation

Table 2: Descriptive statistics of three years average of selected variables in SBM (*In Million Rials)

Outputs				Inputs			
Cost Consuming Deposits *	Without Cost Deposits *	Facility *Donation	Fees *Received	Prof and *Fees paid	Administrative & *Salary Costs	Number of Employees	
352,503	**1,726,815**	**3,484,583**	**38,479**	**27,584**	**6,783**	**85**	Maximum
1,142	**2,270**	**6,911**	**105**	**114**	**767**	**6**	Minimum
27,420	**99,589**	**239,892**	**3,070**	**2,140**	**1,513**	**14**	Mean
68,073	**333,355**	**684,385**	**7,648**	**5,334**	**1,167**	**15**	Standard Deviation

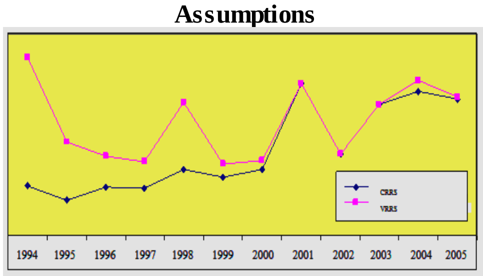
Using inputs and outputs data in Figure 1, regular linear programming model of SBM and full ranking SBM for efficient DMUs under constant and variable rate of returns to scale assumptions for each financial period formulated. Table 3 presents the solutions of two models over the period of study.

Table 3: Solution of SBM using linear programming

Years	Variable Return to Scale		Instant Return to Scale	
	τ^*	ρ^*	τ^*	ρ^*
2006		**0.40**	**1.42**	**1.00**
2007		**0.28**		**0.75**
2008		**0.38**		**0.63**
2009		**0.38**		**0.59**
2010		**0.53**	**1.05**	**1.00**
2011		**0.47**		**0.56**
2006		**0.52**		**0.60**
2007	**1.21**	**1.00**	**1.21**	**1.00**
2008		**0.65**		**0.69**
2009	**1.04**	**1.00**	**1.04**	**1.00**
2010	**1.15**	**1.00**	**1.23**	**1.00**
2011	**1.08**	**1.00**	**1.10**	**1.00**

Figure 1 shows bank total productivity trends under variable and constant rate of return to scale (VRRS and CRRS) assumptions over the period of study.

Figure 1. Comparing Bank Total Productivity Trend under Variable And Constant Return to Scale (VRRS and CRRS) Assumptions

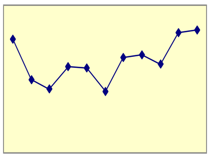
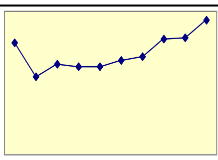
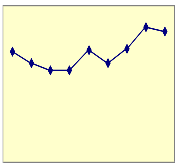
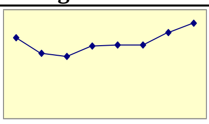
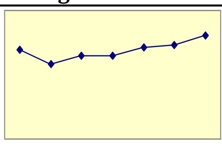
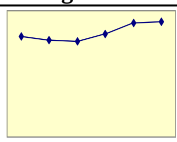
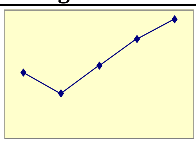
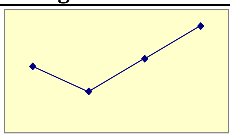
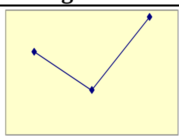


As shown in Figure 1, there is a considerable difference between two trends. This difference is called as scale inefficiency. Remind that first research hypothesis (H1) states that bank total productivity improved over the periods of study. Also Figure 1 confirms H1, to have a better conclusion, moving averages calculated. Table 4 and Figure 2 provide results of calculations and the trends.

Table 4. Moving average of efficiency scores for different durations

Periods / Duration of Moving Averages	1	2	3	4	5	6	7	8	9	10	11
2 Years	1.08	0.69	0.61	0.82	0.81	0.58	0.90	0.93	0.85	1.14	1.17
3 Years	0.93	0.66	0.76	0.74	0.74	0.79	0.82	0.97	0.97	1.13	
4 Years	0.85	0.76	0.71	0.70	0.86	0.75	0.87	1.03	1.01		
5 Years	0.89	0.72	0.69	0.80	0.81	0.81	0.95	1.05			
6 Years	0.83	0.70	0.77	0.78	0.85	0.88	0.97				
7 Years	0.80	0.77	0.76	0.81	0.91	0.91					
8 Years	0.83	0.79	0.84	0.89	0.93						
9 Years	0.83	0.79	0.84	0.89							
10 Years	0.85	0.83	0.87								
11 Years	0.88	0.86									

Figure 2. Moving average trends of efficiency scores for different durations

		
2 Years Moving Average	**3 Years Moving Averag**	**4 Year Moving Average**
		
5 Years Moving Average	**6 Years Moving Average**	**7Years Moving Average**
		
8 Years Moving Average	9 Years Moving Average	10 Years Moving Average

Second research hypothesis (H2) indicates that the average productivity growth of the branches improved over the past three periods. To examine this research hypothesis, we calculated MPI for the years 2009, 2010, and 2011. In other words, once we measured this index and compared change in productivity between 2009 and 2010 and again it has been calculated for the years 2010 and 2011, respectively. Table 5 presents results of calculating MPI and rank of each branch. According the data, average productivity growth of the branches in 2010 and 2011 were 1% and 2%, respectively.

Table 5. Results of MPI moving and grouping branches in terms of their productivity growth

2011 Comparing to 2010			2010 Comparing to 2009			Branches
Rank of Branch in Terms of Its Productivity Growth	Productivity Situation	MPI	Rank of Branch in Terms of Its Productivity Growth	Productivity Situation	MPI	
2	Stable	**1.00**	**2**	Stable	**1.00**	DMU1
1	Increased	**2.30**	**3**	Decreased	**0.35**	DMU2
2	Decreased	**0.85**	**2**	Decreased	**0.97**	DMU3
2	Increased	**1.01**	**3**	Decreased	**0.77**	DMU4
2	Decreased	**0.92**	**2**	Increased	**1.16**	DMU5
3	Decreased	**0.79**	**2**	Decreased	**0.88**	DMU6
2	Stable	**1.00**	**2**	Decreased	**0.91**	DMU7
2	Decreased	**0.91**	**2**	Decreased	**0.96**	DMU8
2	Stable	**1.00**	**2**	Stable	**1.00**	DMU9
2	Decreased	**0.94**	**2**	Decreased	**0.86**	DMU10
2	Increased	**1.20**	**2**	Increased	**1.14**	DMU11
3	Decreased	**0.61**	**2**	Increased	**1.12**	DMU12
2	Decreased	**0.96**	**2**	Increased	**1.03**	DMU13
1	Increased	**1.46**	**2**	Decreased	**0.91**	DMU14
2	Stable	**1.00**	**2**	Stable	**1.00**	DMU15
2	Decreased	**0.94**	**2**	Increased	**1.06**	DMU16
2	Increased	**1.10**	**2**	Increased	**1.02**	DMU17
2	Stable	**1.00**	**2**	Stable	**1.00**	DMU18
3	Decreased	**0.89**	**1**	Increased	**1.75**	DMU19
2	Decreased	**0.97**	**2**	Increased	**1.03**	DMU20
2	Decreased	**0.84**	**2**	Decreased	**0.98**	DMU21
2	Decreased	**0.83**	**2**	Decreased	**0.87**	DMU22
2	Stable	**1.00**	**2**	Increased	**1.13**	DMU23
2	Increased	**1.07**	**2**	Stable	**1.00**	DMU24
3	Decreased	**0.61**	**2**	Decreased	**0.87**	DMU25
1	Increased	**1.32**	**2**	Decreased	**0.88**	DMU26
-	Increased	**1.02**	**-**	Increased	**1.01**	**Average**

Table 6 shows lower level and upper level of productivity growth in 2010 and 2011. To define the categories, we divided the range of maximum and minimum productivity growth to 3. Then, using this method of partitioning, we put all branches in their proper groups.

Table 6. Basic data for grouping branches based on productivity growth (MPI)

Years / Group Rank	2011		2010	
	Upper Level	Lower Level	Upper Level	Lower Level
Group 1	**2.30**	**1.73**	**1.75**	**1.28**
Group 2	**1.73**	**1.17**	**1.28**	**0.82**
Group 3	**1.17**	**0.61**	**0.82**	**0.35**

Conclusions and Final Remarks

This paper explained the process of measuring bank total productivity and analyzing its branches productivity growth over the time using DEA, SBM and MPI. To explain the process more simply, evidence from EDBI was provided. We tested two main research hypotheses. These hypotheses stated that “bank total productivty and its branches average productivity improved over the periods of study. Results of empirical tests confirms both of research hypothesis because in addition to increasing bank total productivity index, its branches productivity improved on average %1 and %2 in 2010 and 2011, respectively. Moreover, we provided a simple method of categorizing all branches in three categories based on their productivity growth rates. The authors believe that more researches need to be conducted in the future in order to compare bank productivity improvements to the domestic and international benchmarks.

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