Estimating Bank Efficiency using a Bootstrapping Malmquist Indices

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Abstract
We conduct a consistent bootstrap estimation method for Malmquist indices of productivity and their decompositions. We assume constant returns to scale (Fare et al., 1992) and estimate distance functions to construct estimates of efficiency, technology and productivity change. We are therefore able to draw robust conclusions about estimate Malmquist indices that are significantly different from unity at the 0.10 and 0.05 levels.

Keywords: DEA; Bootstrap; Malmquist indices; Resampling; Productivity.

1. Introduction
Within the framework of a dynamic analysis, it is logical to think that the production boundary moves in time. The idea selected is to consider that the productivity modification depends on the effectiveness technical variation and the technology modification through time. The measure of the technical productive efficiency was given by the static method, but there is nothing on the temporal components change.

The calculation of the index-numbers, between the period t and t+1 measures the Malmquist productivity change to determine the movement of the boundary from one period to another and to
analyze by index decomposition the possibilities of banks growth or decline. The theoretical reference work on the Malmquist Productivity Index (MPI) is listed in Malmquist (1953), Solow (1957) and Moorsten (1961).

In fact, the MPI breaks down the productivity evolution into two components: technological change and effectiveness technical modification.

The interest of our research is twofold. We will determine, on the one hand, DEA estimates in the construction of the indices change and to know if the changes in productivity, effectiveness and technology are statistically insignificant. On the other hand, we estimate the Bootstrapping Malmquist Indices developed by Simar and Wilson (1998).

2. Data Envelopment Analysis

Data Envelopment Analysis (DEA), developed by Charnes, Cooper and Rhodes (CCR, 1978)\(^1\) has emerged as an important tool to evaluate the efficiency of a set of “Decision Making Units” (DMUs) using multiple inputs to produce multiple outputs. Then, ‘DEA’ is a non-parametric method which uses the linear programming techniques to determine the boundary of a production frontier. It has been extensively applied in performance evaluation and benchmarking in a wide variety of contexts including educational departments in public schools and universities, health care units, prisons, agricultural production, and banks. Based on the works of Shephard (1953, 1970), Banker, Charnes and Cooper (BCC, 1984), the approach of variable returns to scale emerged. Other DEA models exist and are all extensions of the CCR model (see e.g., Dubois et al., 1988, Meada et al., 1998).

- The Input-Oriented
  To what extent can input quantities be proportionally reduced without changing the output quantities produced?
- The Output-Oriented
  To what extent can output quantities be proportionally expanded without altering the input quantities used?

The CCR formulation to evaluate the technical (input and output) efficiency measure for a DMU target is given by the following linear programming sets:

\[
\begin{align*}
\text{Input-Oriented CCR model} & : \begin{align*}
\text{Min} & \quad \theta - \varepsilon I s^+ - \varepsilon I s^- \\
\text{subject to} & : Y \lambda - s^+ = Y_0 \\
& \theta X_0 - X \lambda - s^- = 0 \\
& \lambda, s^+, s^- \geq 0
\end{align*} \\
\text{Output-Oriented CCR model} & : \begin{align*}
\text{Max} & \quad \phi + \varepsilon I s^+ + \varepsilon I s^- \\
\text{subject to} & : \phi Y_0 - Y \lambda + s^+ = 0 \\
& X \lambda + s^- = X_0 \\
& \lambda, s^+, s^- \geq 0
\end{align*}
\end{align*}
\]

with \( x_{ij} > 0 \) and \( y_{ij} > 0; \forall i = 1, ..., M; \forall r = 1, ..., S \) and \( \forall j = 1, ..., N \).

Additionally, \( I \) is an identity vector, \( s^+ \) and \( s^- \) denote the outputs and inputs slacks vectors respectively. These slacks allow handling reduction and augmentation of inputs or outputs to reach the boundary of a production frontier. \( \varepsilon \) is a non-Archimedean vector of constants.

In the above settings (1) and (2) \( \theta \) (resp. \( \phi \)) represent the efficiency measure in the input (resp. output)-oriented CCR model. It is calculated by running the above linear programming algorithm once for each firm in the sample. If \( \theta = 1 \), firms are considered technically efficient, while if \( \theta < 1 \) firms are regarded as inefficient and in this case \( \theta \) measures how much each input should be used for every firm to be considered technically efficient. For instance, a value of 0.7 means that the DMU is inefficient and would need to employ all inputs by 30%, given its output bundle to be considered efficient.

\(^1\) The CCR model assumes constant returns to scale.
Similarly, if $\phi = 1$, firms are considered efficient, while if $\phi < 1$ firms are considered inefficient and $\phi$ measures how much each output should be expanded for every firm to be considered technically efficient. For example, a value of 0.6 means that the DMU is inefficient and would need to expand all outputs by 40% given its input bundle to be considered efficient.

Indeed, if the DMU$_j$ consumes inputs $X_j = \{x_{ij}\} (i = 1,...,M)$ and produces outputs $Y_j = \{y_{rj}\} (r = 1,...,S)$ we have the following:

- $X_{(M,N)}$: is the inputs matrix used by all firms in the sample,
- $Y_{(S,N)}$: is the outputs matrix produced by all the firms in the sample,
- $X_{0(M,1)}$: is the inputs vector consumed by the DMU$_0$ to produce $Y = Y_{0(S,1)}$.

where $M$, $S$ and $N$ denote respectively the number of inputs, outputs and DMUs in the sample.

3. Presentation of the Tunisian Banking Sector

The banking sector in Tunisia is mainly defined by commercial banks, development banks, investment banks and offshore banks along with specialized financial institutions in the fields of factoring, recovery and leasing. Each of the aforementioned institutions revolves around the Central Bank of Tunisia. Tunisian banks have played a key role in the establishment of the country's infrastructure which made them synonymous to development banks. Pursuant to the Structural Adjustment Plan undertaken by the International Monetary Fund (1986-1987), the essential role of these banks shifted to granting loans and improving the purchasing power of households and thus helped emerge an economy of debt. The Tunisian banking landscape was mainly dominated by commercial banks. The latter hold nearly 89% of total number of loans granted. The remainder is shared both by Development Banks (6%) and leasing corporations (5%). Further to the dynamics of financial liberalization of the banking sector, banks became more competitive and more responsible to take their own credit decisions and most of them turned into private banks. In fact, private banks hold the lion’s share in the Tunisian Banking Sector while public banks stood out in financing the economy. In the Tunisian banking sector, the private sector begins to deal with the big private banks such as Amen Bank (AB) owned by the family Ben Yedder, the Arab International Bank of Tunisia (BIAT) owned by some Tunisian businessmen and international financial institutions, the Union Internationale des Banques (UIB), Union Bancaire du Commerce et de l’Industrie (UBCI) and Attijari Bank which is owned by the following international banks: Societe Generale, BNP Paribas and the Company of Attijari wafa Bank (Morocco) and Stander and Banco Central Hispano (Spain).

The Tunisian banking system is mainly characterized by:

- Free interest rates: the prudential laws and solvency ratios are provided by the Banking Act. The coverage ratio of capital commitments according to which banks should hold at least 8% its risk-weighted assets is in line with the international standards.
- A convertible Tunisian dinar for current account transactions since 1994 and the foreign exchange market ensures operations of buying and selling of foreign currencies.
- Commitments made by Tunisia revolve around three areas: privatization, modernization and improved transparency.
- While taking into account the specificities of Tunisian banks, a program to restructure the banking system was implemented with the subtle purpose of creating a new banking environment marked by rationalizing the number of institutions and increasing their size. This dynamic of restructuring came into effect in July 2001 with the enactment of a banking law on credit institutions. This legislation has set up a more liberal environment for carrying on banking businesses and blurred the distinction between commercial banks and investment banks for the objective of a "Universal Bank" having for main activity the provision of credit.
Further to the new law of 10 July 2001, the banking system mainly consists of the Central Bank, the credit institutions such as the Universal Banks and the financial institutions, the offshore banks, the investment banks and the Associate Members.

Table 1: Overview of banks

<table>
<thead>
<tr>
<th>Banks</th>
<th>Capital (DT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB: Amen bank</td>
<td>100 000 000</td>
</tr>
<tr>
<td>ABC: Arab Bankig Corporation</td>
<td>50 000 000</td>
</tr>
<tr>
<td>ATB: Arab Tunisian Bank</td>
<td>100 000 000</td>
</tr>
<tr>
<td>Attijari Bank: Banque Attijari de Tunisie</td>
<td>168 750 000</td>
</tr>
<tr>
<td>BFPME: Banque de Financement des Petites et Moyennes Entreprises</td>
<td>75 000 000</td>
</tr>
<tr>
<td>BH: Banque de l’Habitat</td>
<td>90 000 000</td>
</tr>
<tr>
<td>BT: Banque de Tunisie</td>
<td>112 500 000</td>
</tr>
<tr>
<td>BTE: Banque de Tunisie et des Emirats</td>
<td>90 000 000</td>
</tr>
<tr>
<td>BFT: Banque Franco-Tunisienne</td>
<td>5 000 000</td>
</tr>
<tr>
<td>BIAT: Banque Internationale Arabe de Tunisie</td>
<td>170 000 000</td>
</tr>
<tr>
<td>BNA: Banque Nationale Agricole</td>
<td>160 000 000</td>
</tr>
<tr>
<td>BTS: Banque Tunisienne de Solidarité</td>
<td>40 000 000</td>
</tr>
<tr>
<td>BTK: Banque Tunisio-Koweitienne</td>
<td>100 000 000</td>
</tr>
<tr>
<td>BTL: Banque Tunisio-Lybienne</td>
<td>70 000 000</td>
</tr>
<tr>
<td>CITIBANK: CITIBANK</td>
<td>25 000 000</td>
</tr>
<tr>
<td>STB: Société Tunisienne de Banque</td>
<td>124 300 000</td>
</tr>
<tr>
<td>STUSID BANK: Société Tunisio-Scoudienne d’Investissement et de Développement</td>
<td>100 000 000</td>
</tr>
<tr>
<td>TQB: Tunisian Qatari Bank</td>
<td>60 000 000</td>
</tr>
<tr>
<td>UBCI: Union Bancaire pour le Commerce et l’Industrie</td>
<td>75 759 000</td>
</tr>
<tr>
<td>UIB: Union Internationale des Banques</td>
<td>196 000 000</td>
</tr>
</tbody>
</table>


4. Malmquist Indices

To define the input Malmquist productivity index, we suppose that at each period $t = 1, ..., T$ the production technology $\psi_t = \{(x_t, y_t) | x_t$ can produce $y_t\}$ indicates the transformation of the inputs $x_t \in R_+^N$, to outputs $y_t \in R_+^N$.

To complete the model characterization, it is necessary to describe the DMU characteristics, in $\psi_t$ relative at the technological border $F_t$. We note, $S_{N,t}$ a sample of $j$th DMU at the date $t$; $S_{N,t} = \{(x_{j,t}, y_{j,t}) \} ; j = 1, ..., N$.

These DMUs are not effective; they all belong to the set $\psi_t$ but not necessarily at the technological border $F_t = \{(x, y) \in \psi_t, / (x, \lambda y) \in \psi_t \forall \lambda > 0 \}$.

A DMU is technically effective (Farell, 1957), if it manages to produce as much as possible for a given input quantity. By supposing known the production whole, the analytical counterpart of the jth DMU efficiency definition is written in the following way,

$$D_j(x_{j,t}, y_{j,t}) = \inf \{\theta | [x_{j,t}, \theta y_{j,t}] \in \psi_t \}$$

We can also give a geometrical definition of the jth DMU efficiency to the date t.

If we note $\|y\|$ the module of $y \in IRS_+$, then the efficiency is given by the ratio of the output standard observed to the output standard that the firm in the event of perfect efficiency would reach.

$$D_j(x_{j,t}, y_{j,t}) = \frac{\|y_{j,t}\|}{\|f_t \cap \psi_t(x_{j,t})\|}$$

(4)

By construction, $\theta_{j,t}^* \equiv D_j(x_{j,t}, y_{j,t}) \leq 1$.

*If $\theta_{j,t}^* = 1$, then the DMU is on the technological border.
*If \( \theta_i < 1 \), the DMU does not exploit ‘the world technology’ effectively, to be effective it should have \( 1/\theta_i \) more significant.

The following assumptions describe how DMUs are distributed under the technological border. They make it possible to show the convergence of these estimators. Briefly we have,

- **H1:** With each date \( \{x_{jt}, y_{jt}\} \) are real random variables i.i.d.

  We note \( \phi_i(x, y) \) the density joined on the support \( \psi_t(x) \);

- **H2:** It exists \( \psi_1 > 0 \) and \( \psi_2 > 0 \), such as for all \( (x, y, \theta) \in IR^N \times \psi_t(x) \times [1 - \psi_2, 1] \) We have \( (x, \theta^{-1}) y \in F_t \) et \( \phi_i(y/x) \geq \psi_i \);

- **H3:** \( D_t(x, y) \) is differentiable compared to its two arguments.

The distribution of efficiencies is not specified. The \( H_2 \) assumption ensures the existence of the points close to the production border which we must estimate. As for standard nonparametric econometric, the studied object should not admit discontinuities (smoothness), the \( H_3 \) assumption ensures this point.

The DEA approach is thus doubly nonparametric. The form of technology is not explicitly specified and the distribution of the DMUs in the production whole is not imposed.

The Malmquist productivity index is defined by,

\[
M_t = \frac{D_j(x, y)}{D_j(x, y)}
\]

We obtain the rate of the factors total productivity like a functional calculus of the distances to the conical envelope \( V \), independently of the scales real nature. This rate between the dates \( t \) and \( t + 1 \), is given by the following indices,

In fact, it is about a ratio of the distance from the DMU in \( t+1 \) at the CCR production border (the conical envelope) and the distance from the DMU in \( t \) at this same border. The DMU productivity progresses since the index is higher than the unit. Therefore, we obtain a Malmquist index independent of the reference date by considering the geometric mean of the two indices given previously,

\[
M_{t,t+1} = (M_{t,t} \times M_{t+1,t})^{\frac{1}{2}}
\]

And thus the Malmquist index of the \( j^\text{th} \) DMU between \( t \) and \( t+1 \) will be,

\[
M_j(t, t+1) = \left( \frac{\theta_t^j \theta_t^{*j}}{\theta_t^{*j+1}} \right)^{\frac{1}{2}}\left( \frac{\theta_t^j \theta_t^{*j}}{\theta_t^{*j+1}} \right)
\]

This index represents the effectiveness estimate for a sample of period \( t+1 \) when the border is that of the period \( t \).

In fact, it is interpreted in the same way that the two other indices and thus the factors total productivity grow when \( M > 1 \). Indeed, the firm \( j \) improved the productivity of \( t \) to \( t+1 \) when \( M_j(t, t+1) \).
$t+1) < 1$, on the contrary, its productivity decreased when the index is largest; and in conclusion, when $M_j(t, t+1) = 1$, the productivity did not change during the time.

5. Estimation

We estimate the production whole by approximating this one with a linear envelope. Fare et al., (1985, 1994) consider the following estimator,

$$\psi_t(S_{N,t}) = \left\{ (x, y) \in IR^Q \times IR^M, \ y_{j,s} \leq \sum_{j=1}^{N} z_{j,t} y_{j,s} \ for \ s=1, \ldots, S, \ x_{m,t} \geq \sum_{j=1}^{N} z_{j,t} x_{m,j} \ for \ m=1, \ldots, M \right\}$$

Where $\{z_{j,t}\}_{j=1}^{N}$ verify the following conditions:

- $z_{j,t} \geq 0$ for $j=1, \ldots, N$, if the technology is CCR type;
- $\sum_{j=1}^{N} z_{j,t} = 1$ and $z_{j,t} \geq 0$ for $j=1, \ldots, N$, if the technology is NIRS type;
- $\sum_{j=1}^{N} z_{j,t} = 1$ and $z_{j,t} \geq 0$ for $j=1, \ldots, N$, if the technology is VRS type.

The variable $z_{j,t}$ describes the $j^{th}$ DMU role in the definition of the production whole at the period $t$. The envelope thus obtained defines ‘the world technology’.

We can show the convergence (and derive the convergence speed) of this estimator (Simar and Wilson (1999)). If the outputs are constant, then $\psi_t^{CRS}(S_{N,t})$; $\psi_t^{NIRS}(S_{N,t})$ et $\psi_t^{VRS}(S_{N,t})$ converge towards the true production whole when DMU number tends towards the infinity.

But, if the technology is the VRS type, then only $\psi_t^{VRS}(S_{N,t})$ converge towards the production true whole. To this estimator of the production whole corresponds a distance estimator to the production frontier. By integrating the definition of the production whole in (4), we obtain the following expression of the boundary distance estimator for the $j^{th}$ DMU,

$$\left(\hat{D}(x_{j,t}, y_{j,t})\right)^{-1} = \max_{\theta_j \in \mathbb{R}_+^N} \theta_j \phi_j y_{j,s,t} \leq \sum_{j=1}^{N} z_{j,t} y_{j,s,t} \ for \ s=1, \ldots, S$$

$$x_{j,m,t} \geq \sum_{j=1}^{N} z_{j,t} x_{j,m,j} \ for \ m=1, \ldots, M$$

For the constraints $\{z_{j,t}\}_{j=1}^{N}$ related to the technology nature. Like this program of linear optimization under constraint, we can compare the DMU situation in space $(x_t, y_t)$ compared to the production whole with a former or future date, i.e. to construct $\hat{D}_{t+1}(x_t, y_t)$, $\hat{D}_{i}(x_t, y_t)$, with $t < t'$ ou $t > t'$. Lastly, we obtain the distance estimate to the conical envelope $V_t$, $\hat{D}(x_t, y_t)$ by estimating the distance to the production frontier with the production whole of CCR model. Therefore, the Malmquist index estimator will be,

$$\hat{M}_j(t, t+1) = \hat{M}_j(x_t, y_t, x_{t+1}, y_{t+1})$$

$$= \left(\frac{\hat{D}_t}{\hat{D}_{t+1}} \right)^{\frac{1}{2}} \left(\frac{\hat{D}_t^{t+1}}{\hat{D}_{t+1}^{t+1}} \right)^{\frac{1}{2}}$$

Fare et al. (1994) showed that it is possible to obtain a decomposition of this index, in order to know the productivity evolution sources. To what extent can an increase in productivity related to closing on towards the production frontier or to the modification of best practice?

The input distance function within the meaning of Shephard (1970) for the $j^{th}$ firm at the date $t$, relating to an existing technology with $t+1$, east defines then,
Thus, we will have,

\[
D_{j,t}^{*+1} = \sup_{\theta \in \Psi_j} \{ \theta \in \theta_j^{t+1} \}
\]

(11)

Thus, we will have,

\[
\hat{\mathcal{M}}_j(t+1) = \frac{D_j^{*+1}}{D_j^{*}} \left( \frac{D_j^{*+1}}{D_j^{*+1}} \right)_{j=1} \]

(12)

\[
\hat{\mathcal{M}}_j(t+1) = \left[ \left( \frac{\hat{\theta}_j^{*+1}}{\hat{\theta}_j^{*}} \right)_{j=1} \right] \left( \frac{\hat{\theta}_j^{*+1}}{\hat{\theta}_j^{*}} \right)_{j=1} \]

(13)

The component \( \hat{EC}_j(t+1) \) shows how productivity changes due to the company effectiveness change. The technology change index \( \hat{TC}_j(t+1) \) provides the productivity change of the boundary shift. The values of the two indices are greater, less or equal to 1, and their interpretations similar to those are given for the productivity change.

6. Bootstrapping DEA Estimates (DEA-MPI)

Some authors employed bootstrapping techniques in order to build confidence intervals for the effectiveness scores and the productivity indices in order to address the principal imperfection of the DEA-MPI approach. The first study is that by Ferrier and Hirschberg (1997), which measured the technical effectiveness of the Italian banks for the year 1986.

In order to solve this disadvantage, and as in the case of the technical effectiveness, Simar and Wilson (1998a, 1999) adapted the Malmquist index bootstrapping. In this case, the algorithm produces the bootstrap effectiveness preserving the temporal correlation of the data by exchanging the function distribution for density estimator of two random variables. In practice, the bootstrap method diverges slightly from the precedent and the principal change is the resample method: we resample in the pairs of effectiveness values during two consecutive years instead of resample in simple effectiveness values.

The empirical distribution of each index for each firm will be,

\[
\left[ \hat{M}_b(t+1)^j, \hat{EC}_b(t+1)^j, \hat{TC}_b(t+1)^j \right]_{j=1}^B
\]

(14)

This is obtained by estimating the effectiveness using Malmquist indices and its decomposed equation (13) during two consecutive years and by repeating this process B time. However, the skewed estimator of each change index can be obtained by,

\[
\hat{\text{bias}} \{ \hat{M}_j(t+1) \} = B^{-1} \sum_{b=1}^B \hat{M}_b(t+1)^j - \hat{M}_j(t+1)
\]

(15)

In the same way, we build the corrected skew \( \hat{M}_j(t+1) \) of the estimator by removing the estimated skew of the equation (15): \( \hat{M}_j(t+1) = \hat{M}_j(t+1) - \hat{\text{bias}} \{ \hat{M}_j(t+1) \} \)

(16)

And we obtain the confidence interval percentile for Mj,

\[
\left( \hat{M}_j(t+1)^{(\alpha)}, \hat{M}_j(t+1)^{(1-\alpha)} \right)\]

(17)

The application of each firm of the confidence interval percentile above provides us with a significant test of \( \hat{M}_j(t+1) \), i.e the presence of the unit in the interval (17) are interpreted as not
significantly different to the unit from $\hat{M}_j (t, t+1)$. However, if the unit is not in the confidence interval, the productivity change value estimated by DEA would be significant.

7. Results

7.2 Data

The data of 20 banks were obtained from the Tunisian Central Bank and the Tunisian Professional Association of Banks and Financial Institutions during the period 1990-2010. The banking inputs\(^2\) used to calculate the efficiency scores are: **Input1**: agencies number; **Input2**: overheads; **Input3**: fixed assets; **Input4**: loans and special resources; **Input5**: other liabilities and **Input6**: number of employees. The banking outputs are: **Output1**: Claims on banks and financial institutions; **Output2**: deposits and assets of banking and financial institutions; **Output3**: commercial and investment portfolios; **Output4**: Other assets.

7.2 Discussion

The table 2 indicates the productivity, the efficiency and the technology variations for the input and output CCR models between all successive pairs of years during the period 1990-2010.

### Table 2: Variation in productivity and technological efficiency (input and output CCR models)

<table>
<thead>
<tr>
<th></th>
<th>M(y,x,C,S)</th>
<th>EC</th>
<th>TC</th>
<th>M_0(y,x,C,S)</th>
<th>EC</th>
<th>TC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990/91</td>
<td>1.5</td>
<td>0.94</td>
<td>1.59</td>
<td>0.79</td>
<td>0.91</td>
<td>0.88</td>
</tr>
<tr>
<td>1991/92</td>
<td>1.9</td>
<td>1.02</td>
<td>1.86</td>
<td>1.04</td>
<td>1.06</td>
<td>1.04</td>
</tr>
<tr>
<td>1992/93</td>
<td>1.31</td>
<td>1.16</td>
<td>1.13</td>
<td>1.07</td>
<td>1.23</td>
<td>0.87</td>
</tr>
<tr>
<td>1993/94</td>
<td>0.87</td>
<td>0.81</td>
<td>1.07</td>
<td>0.82</td>
<td>0.95</td>
<td>0.86</td>
</tr>
<tr>
<td>1994/95</td>
<td>1.12</td>
<td>0.96</td>
<td>1.16</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1995/96</td>
<td>1.06</td>
<td>0.95</td>
<td>1.12</td>
<td>1.02</td>
<td>1.05</td>
<td>1.09</td>
</tr>
<tr>
<td>1996/97</td>
<td>1.09</td>
<td>1.07</td>
<td>1.02</td>
<td>1.14</td>
<td>1.05</td>
<td>1.09</td>
</tr>
<tr>
<td>1997/98</td>
<td>1.22</td>
<td>1.11</td>
<td>1.10</td>
<td>0.93</td>
<td>0.78</td>
<td>1.21</td>
</tr>
<tr>
<td>1998/99</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.86</td>
<td>0.76</td>
<td>1.12</td>
</tr>
<tr>
<td>1999/00</td>
<td>0.95</td>
<td>1.90</td>
<td>0.5</td>
<td>0.91</td>
<td>1.00</td>
<td>0.91</td>
</tr>
<tr>
<td>2000/01</td>
<td>0.51</td>
<td>1.92</td>
<td>0.27</td>
<td>1.23</td>
<td>1.23</td>
<td>1.00</td>
</tr>
<tr>
<td>2001/02</td>
<td>0.57</td>
<td>0.73</td>
<td>0.78</td>
<td>1.01</td>
<td>0.50</td>
<td>2.04</td>
</tr>
<tr>
<td>2002/03</td>
<td>0.82</td>
<td>1.16</td>
<td>0.71</td>
<td>1.14</td>
<td>1.00</td>
<td>1.14</td>
</tr>
<tr>
<td>2003/04</td>
<td>0.96</td>
<td>0.96</td>
<td>1.00</td>
<td>0.32</td>
<td>0.45</td>
<td>0.71</td>
</tr>
<tr>
<td>2004/05</td>
<td>1.33</td>
<td>0.8</td>
<td>1.54</td>
<td>0.80</td>
<td>1.34</td>
<td>0.60</td>
</tr>
<tr>
<td>2005/06</td>
<td>1.09</td>
<td>1.05</td>
<td>1.04</td>
<td>1.01</td>
<td>1.04</td>
<td>0.97</td>
</tr>
<tr>
<td>2006/07</td>
<td>1.02</td>
<td>0.94</td>
<td>1.08</td>
<td>1.84</td>
<td>1.77</td>
<td>1.04</td>
</tr>
<tr>
<td>2007/08</td>
<td>1.25</td>
<td>1.25</td>
<td>1.00</td>
<td>1.02</td>
<td>0.98</td>
<td>1.05</td>
</tr>
<tr>
<td>2008/09</td>
<td>1.23</td>
<td>1.02</td>
<td>1.21</td>
<td>1.57</td>
<td>1.30</td>
<td>1.21</td>
</tr>
<tr>
<td>2009/10</td>
<td>1.20</td>
<td>1.15</td>
<td>1.05</td>
<td>1.57</td>
<td>1.30</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Therefore, $M(y,x,C,S) = EC \times TC$. If $M(y,x,C,S)$; EC and TC are equal to 1, then it leads to no change in the productivity, efficiency and technology respectively.

If $M(y,x,C,S)$; EC and TC are > 1, then there is growth in productivity, efficiency and technology respectively.

If $M(y,x,C,S)$; EC and TC are < 1, then there is decrease of the productivity, efficiency and technology respectively.

In fact, these average levels hide a significant technology and productivity evolution for this period. It is noted that the productivity evolution is above all the resultant of the technology modification, and that the level change of the technical effectiveness is weak width only. We supposed

\(^2\) The definition of each variable is indicated in the appendices.
the total absence of technical effectiveness, the evolution of the productivity would be fixed on that of technology.

In a similar way, if the progress technology is absent (what was previously made when we estimated the production possibilities boundary from the banks whole of our sample on the studied period) the evolution of the productivity would correspond to the effectiveness evolution. As the results show us a weak share of the effectiveness in the explanation of the productivity level, it is easily understood that we find practically the same results with regard to the productivity evolution and the effectiveness evolution when the progress technology is absent.

Concerning periods 2007-08 and 2006-07, the changes in technology remain the same for the input and output CCR models, but banking efficiency decreased. Indeed, over the period 2006-07, although there are a progress technology and productivity improvements, there will be a decrease in the banking efficiency. And thus the technological innovation makes it possible to increase the productivity and not the banking effectiveness. In fact, during this period there was the financial crisis which touched the Tunisian banking structure. For this reason, banking efficiency decreased but it increased again during period 2007-08 and thus productivity improvement by taking into account the stability of technological progress.

In the same way for two years 2004-05, following the change of structure of some Tunisian banks (like the statute change of the development banks for example: STUSID, BTL, TQB and BTK to universal banks) then efficiency is less significant (there is reduction in the technical effectiveness) compared to the first period, in spite of there will be progress technology and productivity growth.

Although no changes were recorded on the level of productivity, efficiency and technology (1998-99), the two periods which followed 1999-00 and 2000-01 knew most of the significant evolution of banking efficiency like EC = 1.90 and 1.92 respectively. Indeed, there was a change of structure of some Tunisian banks such as: the Economic Development bank of Tunisia (BDET) and the National bank of Tourist Development (BNDT) are no more referred to as development banks. Now they belong to the Deposit banks, as from December 2000, the month during which they were absorbed by the Tunisian Company of banks (STB). Lastly, we can say that the studied period is one after financial liberalization; the productivity improvement is due to progress in technology and not to the efficiency increase.

One of the main drawbacks attributable to nonparametric techniques is the inability to disentangle inefficiency from random error, contributing significantly to our understanding of efficiency change, technical change, and productivity growth (or decline) in the Tunisian banking system.

Therefore, these DEA estimator Malmquist indices are unable to provide a statistical accuracy of the estimate and second this approach in not parametric and consequently the efficiency measure distribution measure is unknown and unspecified, rendering thus impossible the assessment of its reliability and usefulness (Simar and Wilson (1998, 2000)). For this reason, we calculate the bootstrapping Malmquist indices.

Table 3: Changes in efficiency ( ), technology ( ) and productivity ( (t, t+1)), 20 Tunisian banks

<table>
<thead>
<tr>
<th>Year</th>
<th>Input orientation</th>
<th>Output orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \hat{M}_j(t, t+1) )</td>
<td>( \hat{EC}_{j}(t, t+1) )</td>
</tr>
<tr>
<td>1990/91</td>
<td>0.906**</td>
<td>1.002</td>
</tr>
<tr>
<td>1991/92</td>
<td>1.052**</td>
<td>1.015</td>
</tr>
<tr>
<td>1992/93</td>
<td>1.090**</td>
<td>1.017</td>
</tr>
<tr>
<td>1993/94</td>
<td>0.982**</td>
<td>1.000</td>
</tr>
<tr>
<td>1994/95</td>
<td>1.078**</td>
<td>1.030</td>
</tr>
<tr>
<td>1995/96</td>
<td>0.961</td>
<td>1.047</td>
</tr>
<tr>
<td>1996/97</td>
<td>1.065**</td>
<td>1.017</td>
</tr>
<tr>
<td>1997/98</td>
<td>1.177*</td>
<td>1.049</td>
</tr>
<tr>
<td>1998/99</td>
<td>1.056**</td>
<td>1.000</td>
</tr>
<tr>
<td>1999/00</td>
<td>0.968</td>
<td>1.008</td>
</tr>
<tr>
<td>2000/01</td>
<td>0.974</td>
<td>0.994</td>
</tr>
</tbody>
</table>
We assume constant returns to scale (Fare et al., 1992) and estimate distance functions using the equation (13) to construct estimates $\hat{EC}_j(t,t+1)$, $\hat{TC}_j(t,t+1)$ and $\hat{M}_j(t,t+1)$. We applied the Bootstrapping DEA estimation outlined in section three to obtain estimates of bias and to test for significant differences from unity, with B=2000 replications. We report the reciprocals of the original estimates (Fare et al., 1992) in table 3. The numbers greater than unity denote progress, while numbers less than unity denote regress. We use single asterisks (*) to indicate cases where the estimate Malmquist indices are significantly different from unity at the 10% level, and double asterisks (**) to indicate cases where the indices are significantly different from unity at the 5% level.

Turning to our results for the technical, efficiency and productivity change index in table 4, we find 9 estimates of productivity change statistically significant at the 0.05 level. Three show significant productivity changes at the 0.10 level but 8 estimates are not significant.

Similarly, our results for the index of efficiency change, we show that four estimates are statistically significant at 0.05 level, one estimate of efficiency change is statistically significant at 0.10 level.

While examining changes in technology, we find 9 estimates statistically significant at 0.05 level and 4 estimates of technology change statistically significant at 0.10 level.

**8. Conclusion**

Since 1997, the Tunisian Central Bank had launched a vast program intended to level the financial institutions in general and the whole of the banking environment in particular, thus favouring the evolution of their productivity. It is also found that this evolution before can be explained by the existing technological progress in the Tunisian banking environment and not by the evolution of their...
technical effectiveness. It is the decomposition of the Malmquist productivity index which made it possible to propose the role of technological progress in the productivity evolution.

The bootstrap methodology provides a correction for inherent bias in nonparametric distance function estimate and hence in estimates of Malmquist indices.

References


Appendices

- The variables
- Overhead costs: are personnel costs and general operating expenses. * Fixed assets: define the net value of assets at year-end which still represents the gross value of assets at the beginning of the year + acquisitions - transfers and regularizations – the amortizations.
• Borrowings and special resources include external resources, budgetary resources, bonds and expenses related to loans and special resources.
• Other liabilities: defined by accruals, diverse creditors and provisions for risks and charges
• Deposits and assets of banks and financial institutions: day-to-day term loans + bank assets, foreign correspondents and specialized financial institutions and accrued interest.
• Deposits and customer assets: include current accounts + savings accounts + term accounts + sight accounts as well as other investment incomes + other amounts due to customers + certificates of deposits (CDs) signed by customers.
• The investment portfolios: These are securities acquired with the intention of holding them for a long span of time. They are recorded at the acquisition date at their cost of acquisition with all fees and expenses included except for the study and consultancy fees committed during the acquisition of investment securities.
• Claims on banks and financial institutions are defined by day-to-day term loans to banks, loans to specialized financial institutions, investments in foreign currency, ordinary receivables of banks in dinars rediscount* interest for loans in the money market as well as rediscount interest for bank accounts and correspondents.
• Other assets are defined by:
  o Current assets: classified as current assets, assets whose realization or full recovery in time seems assured.
  o Monitored assets: these are the commitments whose implementation or full recovery in time is still assured but which are held by companies that are in an industry that is experiencing difficulties or whose financial situation is deteriorating. Delays in payment of interest or principal do not exceed 90 days.
• Loans to customers: consist of the discount portfolio, customer overdrafts, credits on special resources and other loans to customers.
• The commercial portfolios consist of:
  o Trading securities: These are securities which are distinguished by their short holding period (less than 3 months) and their liquidity. - Investment securities held for sale: these are securities that do not meet the criteria of trading securities or investment.

(*Rediscount operation is defined by a negotiable instrument to the Central Bank carried by commercial banks in the case of their liquidity needs. The interest rate is called the discount rate.

**Graph1:** Matrix graph of the data