Evaluating the technical efficiency of Turkish commercial banks: An Application of DEA and Tobit Analysis

Professor Peter M. Jackson
Director of Management Centre
University of Leicester, Leicester, LE1 7RH United Kingdom
am56@le.ac.uk

Dr. Meryem Duygun Fethi
Research Associate, Management Centre
University of Leicester, Leicester, LE1 7RH United Kingdom
mdf2@le.ac.uk

Abstract

The purpose of this paper is to investigate the performance of Turkish (TR) commercial banking sector. We evaluate the technical efficiency of individual TR banks using the non-parametric frontier methodology, the Data Envelopment Analysis (DEA). To investigate the determinants of efficiency, we use the Tobit model. This analysis aims to explain the variation in calculated efficiencies to a set of explanatory variables, i.e. banks size, number of branches, profitability, ownership, and capital adequacy ratio. The analysis covers the year, 1998. We find that larger and profitable banks are more likely to operate at higher levels of technical efficiency. Also another finding reveals that the capital adequacy ratio has a statistically significant adverse impact on the performance of banks, which may reflect a risk-return tradeoff in the sector.

Keywords: Efficiency; Data Envelopment Analysis; Tobit model; Turkish commercial banks

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1. Introduction

In recent years the performance measurement concerns for financial institutions have attracted a great deal of attention. Given that the structures of financial service industries are changing rapidly, it is of considerable interest to measure the efficiency of evolving institutions, and explain measured variation in, the (in)efficiency of institutions. Many studies have attempted to analyse efficiency issues by using non-parametric techniques. Recent examples of this type of research include Sherman and Gold (1985), Parkan (1987), Ferrier and Lovell (1990), Charnes et al (1990), Oral and Yolalan (1990), Berg et al (1991), Berg et al (1993), Drake and Weyman-Jones (1992), Fukuyama (1993), Grabowski et al (1994), Zaim (1995), Grifell-Tatje and Lovell (1996, 1997) and Jackson et al (1998).

Evidence suggests that relatively little empirical investigations have been made into the determinants of (in)efficiency using censored regression techniques. Some studies use regression analysis of the efficiency measures to explore the variation in calculated efficiencies. Rangan et al (1988) report a negative relationship between product diversity, and efficiency and positive relationship between efficiency and bank size. A similar study conducted by Aly et al (1990) confirms Rangan et al.’s findings. Moreover, they report positive links between urbanisation and efficiency. Favero and Papi (1995) investigate the determinants of efficiency and find that efficiency is explained by productive specialisation, bank size and to a lesser extent, by location. Miller and Noulas (1996) perform regressions to find the effects of bank size, profitability, market power, and location on efficiency. They report a significant positive relation between efficiency and bank size, profitability, and one location dummy. A recent study by Bhattacharyya et al (1997) use stochastic frontier analysis to examine the varying efficiency patterns across ownership groups and through time. They report that foreign–owned banks improved their efficiency in time whereas the opposite occurred for the public sector banks. According to this study, the efficiency decline for the foreign banks at the beginning of the period is related to the adverse effects of capital adequacy requirement, however the efficiency increase at the end is due to the increase in the number of branches and significant temporal effects.
In the background of these different approaches to finding the determinants of (in)efficiency, this paper seeks to investigate the determinants of efficiency in the Turkish (TR) commercial banks using censored regression techniques. First, we evaluate the technical efficiency of individual TR banks in 1998 using the non-parametric frontier methodology, the Data Envelopment Analysis (DEA). Then, the determinants of efficiency of TR commercial banks are investigated using the censored regression technique, the Tobit model. This aims to explain the variation in calculated efficiencies to a set of explanatory variables. The paper proceeds as follows. The following section is the methodology which presents the DEA and Tobit models. The data and specification of the relevant variables are discussed in Section 3. Section 4 summarises the efficiency results of the DEA for two samples; one sample consisting of the entire population of TR commercial banks and the other one excluding the very large state-owned banks. This aims to detect any effect that may occur in the efficiency measures owing to the outliers in the sample. The determinants of efficiencies are explained in Section 5. Section 6 concludes.

2. Methodology

The theoretical development of DEA was initiated by Farrell (1957), but the model was proposed by Charnes, Cooper and Rhodes (1978), henceforth the CCR model. DEA is a non-parametric technique used to construct empirical production frontiers and it provides a comprehensive evaluation of the homogenous organisations, processes or decision-making units (DMUs). DMUs or in this case, banks, typically perform the same function by consuming multiple inputs to produce multiple outputs. One of the most important features of DEA is its ability to manage the multiple characteristics of a bank, which use several inputs and outputs.

The DEA or CCR model allows each bank to adopt its own set of weights, thus maximises its own best possible efficiency in comparison to the other banks. Under these circumstances, the efficiency for a bank is determined as a maximum of a ratio of outputs to weighted inputs. The algebraic model for the CCR (input based) ratio form is as follows:
The CCR Model

\[ \max \quad h_c = \frac{\sum_{r=1}^{s} u_r y_{rc}}{\sum_{i=1}^{m} v_i x_{ic}} \]

subject to \[ \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \] (1)

\[ u_r, v_i \geq 0 \]

\[ r = 1, \ldots, s; \quad i = 1, \ldots, m \] and \[ j = 1, \ldots, n \]

where

c = a specific bank to be evaluated

\( y_{rj} \) = the amount of output \( r \) from bank \( j \)

\( x_{ij} \) = the amount of input \( i \) to bank \( j \)

\( u_r \) = weight chosen for output \( r \)

\( v_i \) = weight chosen for input \( i \)

\( n \) = number of banks

\( s \) = the number of outputs

\( m \) = the number of inputs

The objective function defined by \( h_c \) aims to maximise the ratio of weighted outputs to weighted inputs of the bank under scrutiny. This is subject to the constraint that any other bank in the sample cannot exceed unit efficiency by using the same weights. It is important to note that these weights are assumed to be unknown, but obtained through optimisation.
Such optimisation is performed separately for each unit in order to compute the weights and the efficiency measure $h_c$.

The problem setting in (1) is a fractional program. This can be converted into linear program (LP) form by restricting the denominator of the objective function $h_c$ to unity, and adding this as a constraint to the problem. The LP version of the fractional setting is shown in model (2):

Primal

$$\text{max} \quad h_c = \sum_{r=1}^{s} u_r y_{rc}$$

subject to $\sum_{i=1}^{m} v_i x_{ic} = 1$

$$\sum_{i=1}^{m} u_{rc} y_{ij} - \sum_{i=1}^{m} v_{rc} x_{ij} \leq 0$$

$$u_r, v_i \geq 0$$

$r = 1, \ldots, s; i = 1, \ldots, m$ and $j = 1, \ldots, n$

The maximising LP setting in (2) assumes constant returns to scale technologies. When the formulation constrains the weighted sum of the inputs to unity as in (2), and maximises the outputs, this becomes an input-based efficiency measurement. That means, given outputs, banks minimise the use of inputs.

One possible solution to the LP (the primal) in (2) is to formulate a dual companion. By denoting the input weights of bank $c$ by $\theta_c$ and the input and output weights of other banks in the sample by $\lambda_j$ the dual form of the maximising problem is formalised as follows:

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$^1$ An alternative formulation constrains the sum of the weighted output to unity, and minimises the inputs. This is an output-based efficiency measurement.
Dual

\[
\min h_c = \theta_c
\]

subject to \( \sum_{j=1}^{n} \lambda_j y_{ij} - s_i^+ = y_{rc} \) \quad (3)

\[
\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_c x_{rc}
\]

\[\lambda_j, s_i^-, s_i^+ \geq 0\]

\[j=1,\ldots,n.\]

The bank \( c \) is regarded as efficient if the \( \theta_c \) is equal to one and the slacks \((s_i^- \text{ and } s_i^+)\) are zero. That is, if and only if,

\[ h_c^* = 1 \text{ with } s_i^* = s_i^{*+} = 0, \text{ for all } c \text{ and } j, \]

where the asterisk denotes optimal values of the variables in the dual. It is important to note that these conditions are also the conditions for Pareto efficiency. When the bank is fully efficient, it is impossible to improve its observed values of input or output without worsening other input or output values. The bank is regarded as inefficient if the \( \theta_c \) is less than one and/or positive slack variables. For these inefficient banks, the optimal values of \( \lambda_j \) construct a hypothetical bank, which is formed by the subset of the efficient banks.

It is important to note that the inclusion of \( \sum_{j=1}^{n} \lambda_j = 1 \) as an extra constraint to the model (3) considers the variable returns to scale (VRS) in the production (Banker, Chames, and Cooper, 1984). DEA efficiency scores are used as performance indicators to determine whether the banks are operating in a technically efficient way.

Hence, it is also of considerable interest to explain DEA efficiency scores by investigating the determinants of technical efficiency. As defined in equations (1) to (3)
the DEA score falls between the interval 0 and 1 (0<h*≤1), making the dependent variable a limited dependent variable. A commonly held view in previous studies is that the use of Tobit model can handle the characteristics of the distribution of efficiency measures and thus provide results that can guide policies to improve performance. DEA efficiency measures obtained in the first stage are the dependent variables in the second stage Tobit model. Tobit model was first suggested in econometrics literature by Tobin (1958). These models are also known as truncated or censored regression models\(^2\) where expected errors are not equal zero. Therefore, estimation with an Ordinary Least Squares (OLS) regression of h* would lead to a biased parameter estimate since OLS assumes a normal and homoscedastic distribution of the disturbance and the dependent variable (Maddala, 1983).

In recent years, many DEA applications employ a two-stage procedure involving both DEA and Tobit. For example, Luoma et al. (1996) and Chilingerian (1995) conduct both DEA and Tobit analyses in health sector applications to estimate both inefficiency and the determinants of inefficiencies. Viitala and Hanninen (1998) apply DEA with Tobit models for the public forestry organisations in Finland. The study by Bjurek et al uses a similar approach to measure the performance of public day care centres in Sweden. Another recent study by Kirjavainen and Loikkanen (1998) applies both DEA and Tobit for the Finnish senior secondary schools.

The standard Tobit model can be defined as follows for observation (bank) \(i\):

\[
y_i^* = \beta' x_i + \epsilon_i
\]

\[
y_i = y_i^* \quad \text{if} \quad y_i^* > 0, \quad \text{and}
\]

\[
y_i = 0, \quad \text{otherwise},
\]

\(^2\) “The model is truncated if the observations outside a specified range are totally lost and censored if one can at least observe the exogenous variables” (Amemiya, 1984:3).
where $\varepsilon_i \sim N(0, \sigma^2)$, $x_i$ and $\beta$ are vectors of explanatory variables and unknown parameters, respectively. The $y_i^*$ is a latent variable and $y_i$ is the DEA score.

The likelihood function (L) is maximised to solve $\beta$ and $\sigma$ based on 48 observations (banks) of $y_i$ and $x_i$ is

$$L = \prod_{y_i=0} (1 - F_i) \prod_{y_i>0} \frac{1}{(2\pi\sigma^2)^{1/2}} \times e^{-\frac{1}{2\sigma^2}(y_i - \beta'x_i)^2}$$

where

$$F_i = \int_{-\infty}^{\beta'x_i/\sigma} \frac{1}{(2\pi)^{1/2}} e^{-t^2/2} \, dt$$

The first product is over the observations for which the banks are 100% efficient ($y = 0$) and the second product is over the observations for which banks are inefficient ($y > 0$). $F_i$ is the distribution function of the standard normal evaluated at $\beta'x_i/\sigma$.

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3. $u_{it}$ are unobserved firm-specific effect and $\varepsilon_{it}$ are residuals that are independently and normally distributed, with mean equals to zero and common variance, $\sigma^2$. 

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3. **Data and the specification of variables**

The Turkish financial system consists of the Central Bank, commercial banks, investment and development banks. Commercial banks dominate the system. In terms of total assets, the total share of commercial banks was 95.2% in 1998. With regard to ownership, commercial banks can be grouped as state, private and foreign banks. State owned banks controlled 34.9% of total assets and privately owned banks and investment and development banks controlled 55.9% and 4.4% of total assets respectively (Banks Association of Turkey, 1998). It is important to note that amongst the largest 10 banks in TR commercial banking sector, there are 5 state-owned banks, one of which is an investment and development bank. Investment and development banks are established to extend medium and long-term loans to certain industries in Turkey and they are funded by the government or other international organisations, e.g. World Bank.

Given that the aim and structure of these banks are different, our focus is on TR commercial banks. Our data set is compiled from the 1998 annual publication of the Banks Association of Turkey. This publication contains income statements and balance sheets for every bank. In 1998, there were 60 commercial banks in total. We included the entire population of state, private and foreign banks founded in TR. Data is not available from 12 foreign banks having branches in TR and thus were excluded from the analysis. Hence, we have usable data for 48 commercial banks for the year, 1998.

In the banking literature, there is considerable disagreement on the specification of bank outputs. For example, there is no consensus on whether deposits should be treated as inputs or outputs. Our selection of variables in this study is mainly guided by the objectives of the Turkish banking system. In Turkey, commercial banks act as intermediaries with the objective of collecting deposits and achieving such objectives is output. Thus, we treat deposits as outputs since they are regarded as ‘resource-consuming activity’, and therefore contain a significant portion of the value added in the Turkish banking system. This was also significant in the pre-liberalisation period where there was no price competition⁴. The role of deposits as the traditional main source of funds is still

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⁴ The ‘1980 Stabilisation Program’ significantly liberalised interest and foreign exchange rates and allowed new entries from both domestic and foreign banks.

This study adopts Grifell-Tatje and Lovell’s (1997) value added approach to specify the inputs and outputs that will be used in the empirical applications. The number of employees ($X_1$), and the sum of non-labour operating expense, direct expenditure on buildings and amortisation expenses ($X_2$), are specified as the two inputs whereas the outputs are loans ($Y_1$), demand deposits ($Y_2$), and time deposits ($Y_3$). All output variables and non-labour operating expenses are measured in billions of US dollars. Table 1 presents the sample statistics for two samples: the sample consisting of 48 banks and the sample excluding 4 state-owned banks. An important feature of the data is that there are enormous variations among banks in the sample. This is evidenced by the large standard deviations of the variables. Even though state owned banks are only four, it appears that they dominate the sample period with respect to input and output variables. DEA, as a deterministic technique, is sensitive to outliers. Hence, in the next step, it is fundamental to check that efficiency scores are stable and do not change dramatically when very large banks are excluded from the sample.

### Table 1. Sample Statistics

<table>
<thead>
<tr>
<th></th>
<th>All Banks (n= 48)</th>
<th>State-owned banks excluded (n= 44)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>$X_1$</td>
<td>3336.7</td>
<td>6073.1</td>
</tr>
<tr>
<td>$X_2$</td>
<td>66.5</td>
<td>81.9</td>
</tr>
<tr>
<td>$Y_1$</td>
<td>847.0</td>
<td>1262.0</td>
</tr>
<tr>
<td>$Y_2$</td>
<td>300.3</td>
<td>586.8</td>
</tr>
<tr>
<td>$Y_3$</td>
<td>1297.5</td>
<td>2111.4</td>
</tr>
</tbody>
</table>

Note: All variables except $X_1$ are measured in billion of US dollars. $X_1$ is measured in terms of number of employees.
4. Empirical findings

The TR commercial banking performance is examined in terms of their ability to provide outputs with minimum input consumption. The DEA efficiency scores can then be interpreted to show how much each bank could reduce its input usage without reducing output if it were as technical efficient as the best practice banks. For example, if bank A has an efficiency score of 75%, this implies that that particular bank needs to reduce its inputs by 25% in order to achieve 100% efficiency. We solve the linear programs described in Section 2 to measure the technical efficiency of each observation. The computations were conducted by the OnFront Software.

Table 2 summarises the efficiency scores under different scale assumptions. The results are reported for the two samples. In the initial analysis of 48 banks based on two inputs and three outputs amounts to 0.67, indicating that, on average, banks could produce outputs with approximately 33 per cent fewer inputs. In the first sample, where all banks are included, the efficiency scores ranged from 14 per cent to 100 per cent when CRS is assumed. In the second sample, the efficiency varies from 17 to 100 per cent. When VRS is assumed, the minimum values and the average efficiencies are higher in both sets, and as expected a greater number of banks appear efficient under the VRS technology. The results of this exercise show that there is slight variation between the efficiencies in each sample.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Minimum value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=48 banks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRS</td>
<td>0.67</td>
<td>0.24</td>
<td>0.14</td>
<td>1.00</td>
</tr>
<tr>
<td>VRS</td>
<td>0.77</td>
<td>0.21</td>
<td>0.37</td>
<td>1.00</td>
</tr>
<tr>
<td>n=44 banks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRS</td>
<td>0.69</td>
<td>0.24</td>
<td>0.17</td>
<td>1.00</td>
</tr>
<tr>
<td>VRS</td>
<td>0.78</td>
<td>0.21</td>
<td>0.39</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Having derived the measures of efficiency, we now concentrate on the CRS measures of efficiency in order to investigate the determinants of efficiency for the TR banks. The CRS assumption allows comparing large banks with smaller ones. Zaim
(1995) reports that Turkish banking operates at the CRS in both pre- and post-liberalisation periods. In that study, only 2 representative years (1981 and 1990) are selected to distinguish the pre- and post-liberalisation eras and the efficiency scores of different organisation forms and their scale adjustments are compared accordingly. There are contrary results in other countries. Bhattacharyya et al. (1997) for Indian commercial banks, and Drake and Weyman-Jones (1992) for UK building societies report that most banks in their samples operate at DRS.

5. Explaining differences in efficiency

This section reports on our attempt to explain differences in the calculated technical efficiency of TR commercial banks after implementing Tobit model. First, we suggest a number of potential determinants and then continue to discuss the empirical results.

We consider the effects of bank size, profitability, ownership and capital adequacy ratio on technical efficiency. Size is measured in two ways: the total assets measured in billions of US dollars and the number of branches a bank operates. Bank profitability is net operating income to total assets. We employ a dummy variable to incorporate the ownership effect. The four state-owned banks in the sample are represented by a unity value and zero otherwise. The capital adequacy ratio indicates the coverage of banks’ assets by owners’ funds. This variable is computed as the ratio of shareholders’ equity and net income to total deposits and non-deposit funds. The data source is the Banks Association of Turkey, 1998.
Table 3. *Estimation results: Tobit model (n=48)*

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t-ratio</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.701</td>
<td>0.05337</td>
<td>13.1366</td>
<td>2.89E-15</td>
</tr>
<tr>
<td>Number of branches</td>
<td>-0.0003</td>
<td>0.00033</td>
<td>-0.9450</td>
<td>0.344647</td>
</tr>
<tr>
<td>Total assets</td>
<td>4.95E-05</td>
<td>2.45E-05</td>
<td>2.02353</td>
<td>0.043019</td>
</tr>
<tr>
<td>Profitability</td>
<td>0.00973</td>
<td>0.00311</td>
<td>3.12715</td>
<td>0.001765</td>
</tr>
<tr>
<td>Ownership</td>
<td>-0.08055</td>
<td>0.14534</td>
<td>-0.5542</td>
<td>0.579423</td>
</tr>
<tr>
<td>Capital adequacy ratio</td>
<td>-0.00796</td>
<td>0.00308</td>
<td>-2.58146</td>
<td>0.009838</td>
</tr>
<tr>
<td>Sigma</td>
<td>0.1985</td>
<td>0.0203</td>
<td>9.7980</td>
<td>2.89E-15</td>
</tr>
</tbody>
</table>

Table 3 reports the results for the Tobit estimation. It is important to note that the dependent variable in the model is the DEA efficiency score. A positive coefficient implies an efficiency increase whereas a negative coefficient means an association with an efficiency decline. The results of the regression are significant at 95% level or higher. The computations were conducted by LIMDEP.

Both bank size and bank profitability have significant positive effects on efficiency, indicating that the larger and more profitable banks have higher technical efficiency. On the other hand, the capital adequacy variable is significantly negatively related to the technical efficiency. This adverse effect on performance may reflect a risk-return trade-off in the sector. Banks with low-risk portfolios, as measured by a higher capital adequacy ratio are likely to be less efficient. This may be because they rather prefer safer and lower-earning portfolios over riskier but higher-earning portfolios. Interestingly, the number of branches, the second proxy for bank size, yields a negative and insignificant coefficient. The expansion of branch networks to direct services to rural as well as to metropolitan areas may have increased costs and thus, affected efficiency negatively. Another insignificant coefficient with negative sign is the ownership dummy. The negative coefficient on the state ownership binary variable confirms that state ownership worsens efficiency. However, the effect is not statistically significant. We can speculate on the reasons for this. Firstly, state owned banks may have goals other than cost minimisation e.g. encouraging employment of
skilled workers. Secondly, managers in state owned banks may have a different loans policy, e.g. a more conservative supply of loans depending on their perceptions of the objectives that a state bank should pursue. Certainly the variability of loan totals is smaller for the sample excluding state owned banks.

6. Conclusion

The objective of this paper was to apply a two-step methodology to investigate the recent performance record and assess the determinants of performance in the TR commercial banking sector. The lack of empirical studies, which focus on the analysis of the determinants of TR commercial bank efficiency, motivated this study.

Initially we have derived the relative technical efficiencies in the TR banking sector by implementing non-parametric Data envelopment Analysis on a cross-section of 48 banks taken in 1998. A further analysis was conducted after excluding the four large state owned banks from the data set. This was done to detect any possible outlier effects of these observations on the efficiency measures. All analyses were repeated under different scale assumptions. Having obtained the efficiency measures, we implemented censored regression analysis using Tobit model to explain the variation in calculated efficiencies to a set of explanatory variables. These variables were bank size, bank profitability, capital adequacy ratio, number of branches and ownership.

The explanation of the efficiency scores using Tobit regressions offers useful economic insights. We interpret the significance of bank size as an indication of higher efficiency of large banks. Also, more profitable banks achieved higher technical efficiency. The significance of capital adequacy ratio in explaining efficiency implies that banks with higher capital adequacy ratio, are less efficient since they are risk-averse and prefer safer and lower-earning portfolios. The ownership and the number of branches variables have negative sign, but they are insignificant. The state ownership and the branch expansion policies may be an impediment for being efficient in the Turkish commercial banking sector.
It is apparent that when the banking system in newly liberalised countries such as the former East Germany entered the EU banking system large differences in efficiency showed up. Knowing the determinants of efficiency may assist Turkish banks and further directions for research could relate to the way Turkish banking system can prepare for EU entry and Single Market.

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