An Empirical Study of Stochastic DEA and Financial Performance: the Case of the Turkish Commercial Banking Industry[1]

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Abstract

This study breaks important new ground in the analysis of financial institutions. It is one of the first empirical uses of Stochastic Data Envelopment Analysis (SDEA) in the efficiency literature. The pattern of efficiency is examined for the year 1999. The purpose of stochastic setting of DEA is two-fold: to accommodate both the inefficiency and the presence of measurement errors; and to convert the resulting stochastic linear programmes for DEA into deterministic non-linear DEA programmes. The results show that there are wide variations in the DEA efficiency scores and SDEA results suggest that these are due to measurement errors or other stochastic factors in the raw data, probably attributable to macroeconomic shocks and issues of changes in banking regulations.

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1. Introduction

The changes in regulatory frameworks, advancements in technology and market enlargements impose increasing pressures and therefore, aggravate concerns for competition and efficiency within a deregulatory industry. In recent years, the Turkish commercial banking industry is undergoing numerous changes in laws and regulations. The aim is to bring the banking sector operations in line with the European Union standards. The Turkish financial authorities have now minimal policy constraints on banking operations. Foreign banks are allowed to operate in the domestic market, thus the capital inflows are expected to increase competition and efficiency.

The purpose of this study is to examine the efficiency pattern for the year, 1999. We use the deterministic Data Envelopment Analysis (DEA) and Stochastic DEA (SDEA) to obtain the efficiency of individual commercial banks. The purpose of stochastic setting of DEA is two-fold: to accommodate both the inefficiency and the presence of measurement errors; and to convert the resulting stochastic linear programmes for DEA into deterministic non-linear DEA programmes. We use the Land, Lovell and Thore (1993) or LLT (1993) model incorporating information on the covariance structure of inputs and outputs to study efficiency across a panel of 36 commercial banks.

The purpose of this SDEA model can be expressed simply. Compared to deterministic DEA, the constraints representing the relationship between an individual decision-making unit (DMU) and the reference technology are made more difficult to satisfy by amending the right hand side to incorporate terms in the variance of the weighted outputs and inputs. This has the effect of raising the measured technical efficiency of every DMU relative to the deterministic model. In the case of a single realisation, some DMUs will demonstrate super efficiency.

The paper proceeds as follows. The following section overviews the Turkish banking. The DEA applications in Turkish banking are reviewed in Section 3. Section 4 presents the SDEA methodology. The data and specification of the relevant variables are discussed in Section 5. Section 6 summarises the efficiency results of the deterministic DEA and SDEA realisation for the year 1999 and SDEA mean performance for 1992-1999. Section 7 concludes.

2. Overview of Turkish Banking

The Turkish financial system includes the Central Bank, commercial banks, investment, and development banks. The commercial banks can be grouped as state-owned, privately-owned and foreign-owned banks. They operate as universal banks. In other words, they engage in financial activities from providing traditional depository and lending services, financing foreign trade activities and maintaining capital market transactions as well as investment banking activities. As of 1999, there were 81 banks operating in the Turkish banking industry. Of these, 62 were commercial banks, and 19 were development and investment banks. Of the commercial banks, 4 were state-owned, 31 were privately-owned banks, 19 were foreign banks, and 8 were banks in the Fund (Banks in Turkey, 1999).

Until the 1980s, the Turkish financial system was highly regulated and the economic policies in Turkey were inward looking and having extensive protection against foreign competition. Because there were strict barriers to entry, the commercial banks were operating in an oligopolistic environment. As a result, interest rates on both credits and deposits were determined in a monopolistic manner. Low interest rates applied to credits provided great incentives for firms, but minor incentives for depositors. The main difference between the interest rates set for deposits and credits provided high profits for the banking sector and thus gave overconfidence to the commercial banks, which, in turn, may have prevented a careful analysis of bank performance and the managerial ability of their executives (Yolalan, 1990).

In 1980, with the announcement of the economic stabilisation and structural adjustment program, the macroeconomic situation in Turkey changed dramatically. The program aimed to introduce the spirit of a free market economy and competition. It adopted policies giving priority to economic growth based on export promotion and to structural reforms including deregulation and liberalisation of financial markets. The financial reforms in Turkey were mainly designed to decrease the role the of state and increase the role of market forces in the operation of the financial system. The reforms included the elimination of interest rate ceilings, reductions in both the reserve and liquidity requirements and financial taxes. In addition, together with the newly established Turkish banks, foreign banks were allowed to operate in Turkey and foreign exchange trading and capital movements were significantly relaxed (Zaim, 1995).

However, high inflation rates were still a major problem in the economy. There was a decline during the early 1980s but after that, there followed an upward trend which threatened the economic stability, and in turn, exerted a negative impact on the growth of financial markets. Chronic inflation coupled with the political instabilities made financial reforms incomplete and caused public sector borrowing to increase. In addition, macroeconomic instabilities accelerated currency substitution. This decreased the demand for TL, increased interest rates, and shortened the maturity structure. Government’s initiation to lower interest rates led to a financial crisis at the beginning of 1994. TL depreciated by 170 percent and the inflation rate reached to 121 percent on average (Keskin and Alparslan, 2001).

Indeed, the 1994 crisis hit the banking system severely. The sharp depreciation of TL created a confidence crisis which led to the withdrawal of deposits from banks. The government intervened in the operation of three banks and took them to the Savings Deposit Insurance Fund. This attempted to provide state insurance to protect all savings deposits. Despite all efforts shown, the banks continued to operate in a highly risky environment. The existence of negative effects of macroeconomic imbalances was one of the most important reasons for high risk conditions. The continuos increase in inflation and interest rates reduced demand for loans and the cash flow and liquidity of the banks became more deteriorated.

When the coalition government took over in June 1999, rehabilitation of the banking sector was given priority and Parliament approved a long awaited new Banking Law. The changes in the Banking Law designated supervision and operation of the banking sector in line with international standards. Soon after the change in Law, the management of five privately-owned commercial banks was taken by the Fund. As a result, the number of banks in Fund increased to eight. Such action made these banks’ financial statements more transparent and comforted the auditing issues. The Turkish banking industry now has minimal policy constraints on domestic and financial market intermediation as Turkish financial authorities have allowed foreign banks to operate in the domestic market with the expectation of capital inflows, increasing competition and efficiency, and gaining international and domestic banking experience. The enlargement of the financial system was expected to expedite an increase in funds and loans of the banking sector.

Table 1. Market Shares of groups in the Turkish banking industry

	% share of total assets		% share of total deposits		% share of total loans	
Bank Group	**1990**	**1999**	**1990**	**1999**	**1990**	**1999**
Commercial	91	95	100	100	88	90
State-owned	45	35	49	40	45	28
Privately-owned	44	49	49	46	40	55
Banks in the Fund	_	6	_	11	_	4
Foreign banks	3	5	2	3	3	3
Development and investment banks	9	5	_	_	12	10

Source: Banks Association of Turkey (1990, 1999)

Table 1 presents the market shares of groups for the years 1990 and 1999. A close inspection of this table provides a good indication that the Turkish banking system grew between 1990 and 1999. The shares of total assets and total loans of commercial banks rose to 95% and 90% respectively in 1999 from 91% and 88% respectively in 1990. However, there has been a significant decrease in the share of state-owned commercial banks in total assets, deposits and loans. The sector share of privately-owned commercial banks changed because of the banks taken to the Fund. The share of banks in the Fund was 6% in total assets, 11% in total deposits, and 4% in total loans. The share of foreign banks increased in both total assets and total deposits, but no change was observed in loan shares.

3. Literature Survey: DEA Applications in Turkish Banking

A number of studies have applied DEA and DEA based Malmquist indices to question the efficiency and productivity change respectively in the Turkish commercial banking industry. Mercan and Yolalan (2000) provide an excellent survey of studies of the efficiency of Turkish banks. Zaim (1995) analyses the efficiency of Turkish commercial banks to investigate the effects of post-1980 financial liberalisation policies. This study uses the intermediation approach to select bank inputs and outputs and include i) total number of employees, ii) total interest expenditures, iii) depreciation expenditures, and iv) expenditures on materials as inputs. The outputs are i) total balance of demand deposits, ii) total balance of time deposits, iii) total balance of short-term loans, and iv) total balance of long-term loans. The years 1981 and 1990 are selected as representative years for pre and post liberalisation eras respectively. The results show that the financial reforms have a positive effect on both technical and allocative efficiencies, and that state owned banks appear more efficient than their private counterparts.

While there have been considerable DEA applications in banking using physical units and monetary terms, few studies have been published using financial ratios. The analysis by Yeh (1996) is one of the first applications. Yolalan (1996) uses financial ratios to analyse the performance of Turkish commercial banks over the period 1988-1995. This study uses two ratios as inputs: i) non-performing loans/total assets, and ii) non-interest expenses/total assets, and three outputs as: i) (shareholders' equity + net income)/total assets, ii) net fees and commissions/total assets, iii) liquid assets/total assets. The relative performances of banks are ranked under different ownership groups, and the results indicate that while foreign-owned banks are the most efficient group, followed by the private banks, the state owned banks are the least efficient.

Jackson, Fethi and Inal (1998) measure the efficiency and productivity growth in Turkish commercial banking using the DEA based Malmquist Index. They investigate the efficiency and productivity changes of each bank over the 1992-1996 period. The value added method is used to model the bank operations. They use two inputs: i) the number of employees and ii) total non-labour operating expenses. The three outputs used are i) total loans ii) total demand deposits, and iii) total time deposits. The empirical results show that except during the financial crisis period of 1993-94, foreign and private banks are more efficient than their state counterparts owing to the developments in competition and technological advancements.

Yildirim (1999) analyses policy and performance in the Turkish commercial banks in response to the financial liberalisation after 1980 and to the macroeconomic instability. The study covers the period of 1988 and 1996. This study utilises four inputs: i) demand deposits, ii) time deposits, iii) interest expenses, and iv) non-interest expenses. The three outputs are: i) loans, ii) interest income, and iii) non-interest income. The results indicate that the sector did not achieve any sustained efficiency gains in the liberalised era with continuing scale inefficiency. The efficient banks are noted as less profitable. In particular, the less profitable state owned banks seem to be more efficient than others. Other findings also show that there is a relationship between the scale and technical efficiency and bank sizes.

Jackson and Fethi (2000) evaluate the technical efficiency of individual Turkish banks using the DEA and investigate the determinants of efficiency using the Tobit model for the year, 1998. The variable selection procedure was similar to Jackson, Fethi and Inal (1998). The Tobit analysis aims to explain the variation in calculated efficiencies by a set of explanatory variables, i.e. bank size, number of branches, profitability, ownership, and capital adequacy ratio. The results show that larger and more profitable banks are more likely to operate at higher levels of technical efficiency. Moreover 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.

Cingi and Tarim (2000) examine the efficiency and productivity change in Turkish commercial banking using the DEA and DEA-Malmquist Total Factor Productivity Index. The study covers the period 1989-1996. They use a different procedure to select the inputs and outputs in their study and thus, name it “mixed approach”. Two inputs are used: i) total assets and ii) total expenses. The four outputs used are: i) total income, ii) total loans, iii) total deposits, and iv) total non-performing loans/total loans. The results reveal that whereas the four state owned banks in the sample are not efficient, the three private holding banks maintain high efficiency scores over the study period. Another finding is that the efficiency differences in banks generally arise from the differences in scale economies.

Denizer, Dinc and Tarimcilar (2000) assess the banking efficiency in both pre and post-liberalisation environments and examine the scale effects on efficiency for different ownership groups. The study covers the period between 1970 and 1994. This study utilises the production and intermediation approaches and assumes that the banking operations in Turkey occur in a two-stage framework. Three inputs are selected for the production stage: i) total own resources of the bank, ii) total personnel expenses and iii) the interests and fees paid by the bank. At this stage a bank produces two outputs: i) total deposits, and ii) income from charges and commissions collected. Next, the intermediation process comes into play and uses the previous stage's outputs as inputs. The other input is non-labour operating expenditure. The outputs at this stage are i) total loans and ii) banking related income. The results suggest a decrease in efficiency in the post-liberalisation era. Another finding reveals that Turkish banking suffers from a serious scale problem.

Table 2. Input-output measures

Authors	Inputs	Outputs	Approach
Zaim (1995)	Number of employees Interest expenditure Depreciation expenditures Expenditures on materials	Demand deposits Time deposits Short-term loans Long-term Loans	IA
Yolalan (1996)	Non-performing loans/Total assets Non-interest expenses/Total assets	Shareholders' equity + net income)/ total assets Net fees and commissions/ Total assets Liquid assets/Total assets	FR
Jackson, Fethi and Inal (1998)	Number of employees Non-labour operating expenses	Loans Demand deposits Time deposits	VA
Yildirim (1999)	Demand deposits Time deposits Interest expenses	Loans Interest income Non-interest income	IA
Jackson and Fethi (2000)	Number of employees Non-labour operating expenses	Loans Demand deposits Time deposits	VA
Cingi and Tarim (2000)	Total assets Total expenses	Income Loans Deposits Non-performing loans/total loans	MA
Denizer, Dinc and Tarimcilar (2000)	Total own resources of the bank Personnel expenses Interest and fees paid	Deposits Income from charges and commissions	PA
	Deposits Non-labour operating expenditure	Loans Income	IA

PA: Production Approach, IA: Intermediation Approach, VA: Value Added Approach, MA: Mixed Approach and FR: Financial Ratios

4. **Stochastic DEA (SDEA) Theory and Model**

The procedure for DEA measurement of input based technical efficiency is well known. We take each firm in turn and compare it with the reference set of the whole industry. This is represented by the input requirements set for a given level of outputs, which is bounded below by the isoquant. The object here is to find the largest reduction in the firm's actual input usage which will allow it to remain in the input requirements set, i.e. achieve a position on the efficient frontier isoquant determined by the observations on the industry as a whole.

Doing this for each firm in turn we identify the firm's θ value. This is the firm's Farrell efficiency: $0 \le \theta \le 1$. Values of $\theta = 1$ indicate that the firm is already one of those which defines the frontier and is 100 per cent efficient. The firm's inefficiency is $(1-\theta)\times 100\%$. In what follows it is necessary to examine particular output and input constraints which can be written in terms of s outputs: $y_{rj}, r = 1\ldots s, j = 1\ldots n$ and m inputs: $x_{ij}, i = 1\ldots m, j = 1\ldots n$ for the n different producing units (banks). The input requirement set is defined by the following inequalities for each producing unit in turn. The producing unit under observation is subscripted '0' to distinguish it from all of the producing units together: $j = 1\ldots n$

r$^{\text{th}}$ typical output constraint:

$$\mathbf{y}_r{}'\lambda - y_{r0} \ge 0 \quad i.e. \quad \sum_{j=1}^{j=n} y_{rj}\lambda_j - y_{r0} \ge 0 \quad r = 1,\ldots,s$$

i$^{\text{th}}$ typical input constraint:

$$\mathbf{x}_i{}'\lambda - x_{i0}\theta \le 0 \quad i.e. \quad \sum_{j=1}^{j=n} x_{ij}\lambda_j - x_{i0}\theta \le 0 \quad i = 1,\ldots,m$$

We measure the producing unit's technical efficiency by calculating the following linear programme for the firm in question (now subscripted 0):

$$\begin{aligned} &\min \theta \quad s.t \\ &\quad \mathbf{y}_r{}'\lambda - y_{r0} \ge 0 \\ &\quad \mathbf{x}_i{}'\lambda - x_{i0}\theta \le 0 \end{aligned}$$

We now turn to the chance constrained DEA problem described by LLT (1993). This allows the constraints to hold with probability level $\alpha \in (0,1)$ i.e. with less than certainty:

$$\begin{aligned}
&\min \theta \\
&s.t. \\
&\Pr\left(\mathbf{y}_r{}' \lambda - y_{ro} \geq 0\right) \geq \alpha \qquad r = 1 \ldots s \\
&\Pr\left(\mathbf{x}_i{}' \lambda - x_{io}\theta \leq 0\right) \geq \alpha \qquad i = 1 \ldots m
\end{aligned}$$

Charnes and Cooper (1963) show how to use the idea of a modified certainty equivalent to transform this stochastic linear programming problem into a deterministic non-linear programming problem. The difference between the firm's output and the reference weighted outputs of all the firms are treated as a random variable. The difference between the firm's input adjusted for its efficiency and the reference weighted inputs of all the firms in the industry is also treated as a random variable.

We begin with the constraints relating to the outputs, and re-write them as below. In these steps we assume that the random variable has a finite positive variance so that the standard deviation: $\left(\operatorname{var}\left(\mathbf{y}_r{}' \lambda - y_{ro}\right)\right)^{\frac{1}{2}}$ can be used as a divisor.

Now assume the random variable representing the output shortfall is normally distributed:

$$\left(\mathbf{y}_r{}' \lambda - y_{ro}\right) \sim N\left[E\left(\mathbf{y}_r{}' \lambda - y_{ro}\right), \operatorname{var}\left(\mathbf{y}_r{}' \lambda - y_{ro}\right)\right]$$

Using $\Phi(z)$ to represent the cumulative distribution function of the standard normal variable we write the standard normal deviate as $z = \Phi^{-1}(\alpha)$ for given α. Consequently the probability statement for this typical output constraint can be written as:

$$\Phi\left(\frac{E\left(\mathbf{y}_r{}'\lambda - y_{ro}\right)}{\left(\mathrm{var}\left(\mathbf{y}_r{}'\lambda - y_{ro}\right)\right)^{\frac{1}{2}}}\right) \geq \alpha$$

and so

$$\frac{E\left(\mathbf{y}_r{}'\lambda - y_{ro}\right)}{\left(\mathrm{var}\left(\mathbf{y}_r{}'\lambda - y_{ro}\right)\right)^{\frac{1}{2}}} \geq \Phi^{-1}(\alpha)$$

giving:

$$E\left(\mathbf{y}_r{}'\lambda - y_{ro}\right) \geq z\left(\mathrm{var}\left(\mathbf{y}_r{}'\lambda - y_{ro}\right)\right)^{\frac{1}{2}}$$

This completes the transformation of the probabilistic version of the linear output constraint into a deterministic non-linear form using what Charnes and Cooper (1963) refer to as a modified certainty equivalent. It is useful to write it in a slightly more general form as follows.

$$\mathbf{y}_r{}'\lambda + (\mathbf{E}\mathbf{y}_r - \mathbf{y}_r)'\lambda - z\left(\mathrm{var}\left(\mathbf{y}_r{}'\lambda - y_{ro}\right)\right)^{\frac{1}{2}} \geq Ey_{ro}$$

Turning now to the input constraints, these are initially expressed as:

$$\Pr\left(\mathbf{x}_i{}'\lambda - x_{io}\theta \leq 0\right) \geq \alpha$$

together with the normality assumption:

$$\left(\mathbf{x}_i{}'\lambda - x_{io}\theta\right) \sim N\left[E\left(\mathbf{x}_i{}'\lambda - x_{io}\theta\right), \mathrm{var}\left(\mathbf{x}_i{}'\lambda - x_{io}\theta\right)\right]$$

Proceeding as before we therefore write:

$$\frac{E\left(\mathbf{x}_i{}'\lambda - x_{io}\theta\right)}{\left(\operatorname{var}\left(\mathbf{x}_i{}'\lambda - x_{io}\theta\right)\right)^{\frac{1}{2}}} \leq -\Phi^{-1}(\alpha)$$

and

$$E\left(\mathbf{x}_i{}'\lambda - x_{io}\theta\right) \leq -\Phi^{-1}(\alpha)\left(\operatorname{var}\left(\mathbf{x}_i{}'\lambda - x_{io}\theta\right)\right)^{\frac{1}{2}}$$

This completes the transformation as in the output case, but again we can write the transformed non-linear constraint in a slightly more general form:

$$\mathbf{x}_i{}'\lambda + (\mathbf{E}\mathbf{x}_i - \mathbf{x}_i)'\lambda + z\left(\operatorname{var}\left(\mathbf{x}_i{}'\lambda - x_{i0}\theta\right)\right)^{\frac{1}{2}} - Ex_{i0}\theta \leq 0$$

We are now in a position to implement stochastic DEA as a deterministic non-linear programming problem.

For clarity of setting up the model, LLT (1993) suggest that the problem can be restated in non-matrix terms. Using $Z_{1-\alpha}$ to denote the critical value of z from the standard normal tables, we have for the mean performance case:

$$\min \theta$$

$$s.t.$$

$$\sum_{j=1}^{j=n} y_{rj}\lambda_j + \sum_{j=1}^{j=n}\left(Ey_{rj} - y_{rj}\right)\lambda_j - Z_{1-\alpha}\left[\sum_{j=1}^{j=n}\sum_{k=1}^{k=n}\mu_j\mu_k\left(\operatorname{cov}\left(y_{rk}y_{rj}\right)\right)\right]^{\frac{1}{2}} \geq Ey_{r0}$$

$$r = 1\ldots s$$

$$\sum_{j=1}^{j=n} x_{ij}\lambda_j + \sum_{j=1}^{j=n}\left(Ex_{ij} - x_{ij}\right)\lambda_j + Z_{1-\alpha}\left[\sum_{j=1}^{j=n}\sum_{k=1}^{k=n}v_j v_k\left(\operatorname{cov}\left(x_{ik}x_{ij}\right)\right)\right]^{\frac{1}{2}} - Ex_{i0}\theta \leq 0$$

$$i = 1\ldots m$$

In this restatement:

$\mu_j = \lambda_j$, for $j = 1\ldots n, j \neq 0$ and $\mu_j = \lambda_j - 1$, for $j = 0$

and

$v_j = \lambda_j$, for $j = 1\ldots n, j \neq 0$ and $v_j = \lambda_j - \theta$, for $j = 0$

This is a non-linear programming problem in the variables: θ, λ_j, μ_j and ν_j. Specifically it has a linear objective and (s + m) quadratic inequality constraints with additional restrictions on the variables to ensure positive variance terms. This statement of the problem applies to the evaluation of the mean efficiency of performance across both the time and spatial dimensions of a panel. This is a similar statement for the evaluation of the efficiency of a single realisation in which $\mu_{0=}\lambda_j$ and $\nu_0=\lambda_j$ (see Lovell 1993, p. 34-5).

To implement this programme we have used the algorithm of Lasdon et al (1978) which is widely available in many spreadsheet and symbolic programming applications, see Kendrick (1996).

What is the intuition behind SDEA? LLT provide one form of insight using the density function of the random error, but we can also borrow another diagrammatic intuition from the paper by Olsen and Petersen (1995). This is shown in figure 1 below.

In this diagram we illustrate observations on a panel of producing or decision making units (DMUs 1 –3) for the case of two inputs and one output. The boundary of the input requirements set is defined by the isoquant. In deterministic DEA the individually most efficient realisations define the frontier shown by the solid line. However, in implementing SDEA we are in effect looking for confidence regions around each producing unit's observations within the panel. These are shown as grouped within the ellipses shown around sets of observations. Olesen and Petersen describe the SDEA frontier as being evaluated relative to the centre of these confidence regions. As a consequence, the SDEA frontier associates extreme outliers with the stochastic error term and this has the effect of moving the frontier closer to the bulk of the producing units. Some realisations will then lie above the frontier and in evaluating the realisation model these observations will have a super-efficiency larger than unity.

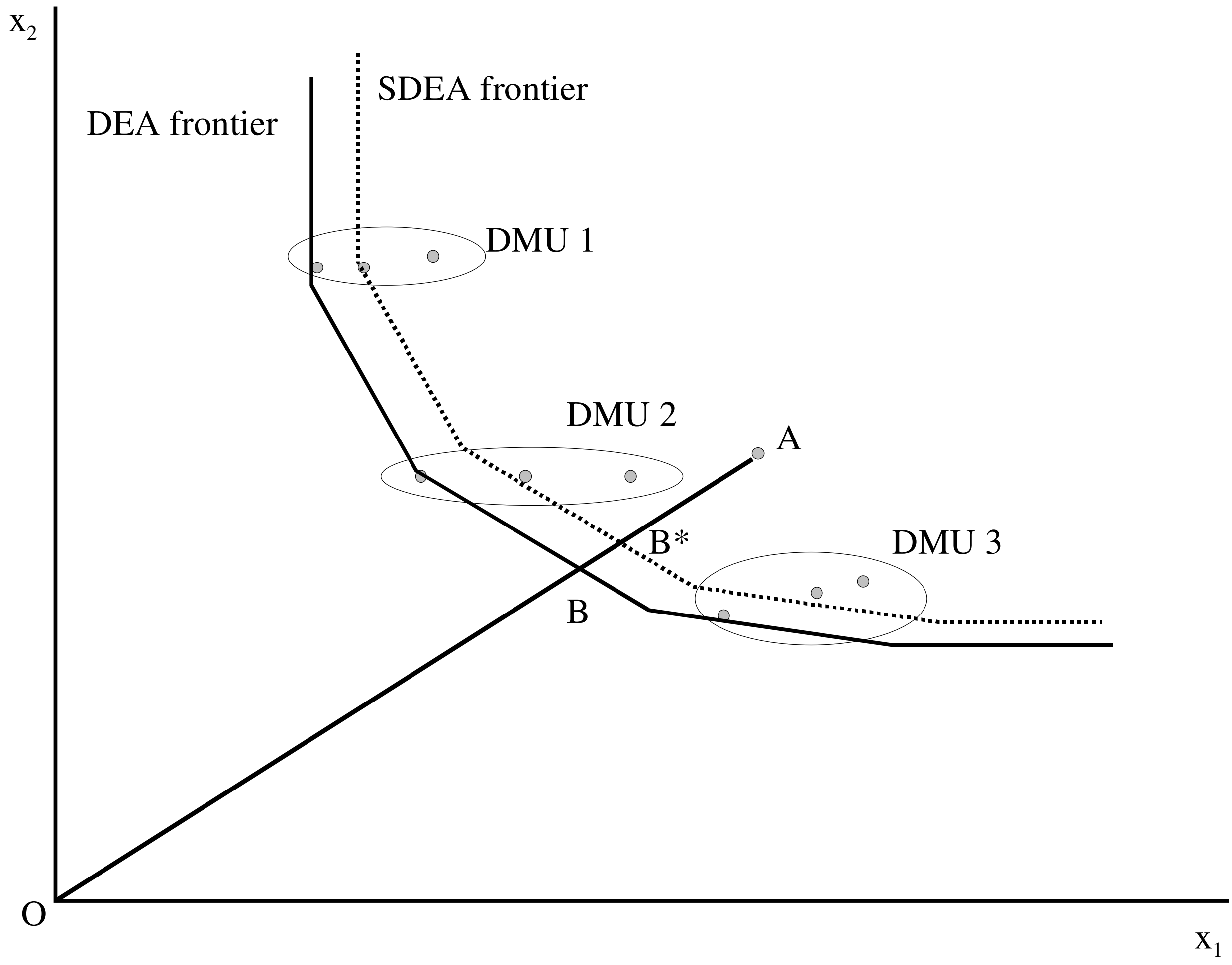

Figure 1. SDEA and DEA frontiers

In the diagram the DEA frontier passes through the most extreme observations of the three DMUs 1, 2, and 3, while the SDEA frontier passes through the centre of the confidence regions around the observations for these DMUs. We can see that particular observations will have a SDEA efficiency larger than unity. The observation at A has two efficiency scores: OB/OA for the DEA frontier and OB*/OA for the SDEA frontier. The SDEA score will usually be greater but never lower than the DEA efficiency score. The distance between the two frontiers represents the role of the stochastic error term in accounting for the variation in production performance. The larger is the variance of the sample, the larger will be the confidence ranges for the data and therefore the greater will be the distance between DEA and SDEA frontiers. In other words, a sample with a wide variation in inputs and outputs observed for each unit will ascribe more of the variation in performance to the stochastic error than a sample with a narrow variation over the panel. In some cases we may find that a widely varying panel has two properties:

The *mean performance* of the units clusters around unity (100 percent efficiency) because the SDEA frontier has shifted so far towards the units which lie below the DEA frontier, and the *extreme performance* or individual realisation of some of the most successful observations lies well in excess of 100 percent. Such results would indicate that the sample contained a very large degree of measurement error and other stochastic influences, and consequently only the mean performance frontier is of relevance in using the results for such purposes as yardstick competition.

5. Data

As Berger and Humphrey (1997) note there is no consensus on modelling bank operations. Three different approaches - production, intermediation and value added - are used to model bank behaviour, thus to specify bank inputs and outputs. In the production approach, banks produce services to depositors and borrowers, thus banks use traditional factors of production (land, labour and capital) to produce outputs (number of accounts or the dollar amounts). The intermediation approach assumes that banks act as financial intermediaries to collect deposits from depositors and lend to borrowers. In this approach, inputs are measured by the volume of loans and deposits collected and funds borrowed from financial markets whereas outputs are the loans and investments.

However, the value-added approach assumes banks as service providers, thus deposits and loans are treated as outputs since these services are providing the vast majority of value added. In this approach, inputs are measured by labour and capital. As Griffel-Tatje and Lovell (1997) emphasizes value added approach is used when the study focus is on bank production whilst other approaches are used when the concern is on bank profitability.

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 also corresponds to the 'value added' approach to bank modelling suggested by Berger and Humphrey (1992), Berg *et al* (1991, 1992) and Grifell-Tatje and Lovell (1997).

We specify two inputs and three outputs; the number of employees (*NEMP*), and the sum of non-labour operating expense, direct expenditure on buildings and amortisation expenses (*NONLOP*), are specified as the two inputs whereas the outputs are loans (*LOANS*), demand deposits (*DEMDEP*), and time deposits (*TIMDEP*). All output variables and non-labour operating expenses are measured in billions of US dollars and they are deflated by 1995 price deflator. The data set is constructed from the 1999 annual publications of the Banks Association of Turkey. The banks with missing data were dropped. The total number of commercial banks used in this study is 36 and we include 4 state-owned banks , 23 privately-owned banks, 2 foreign-owned banks and 7 banks under the Deposit Insurance. Table 3 presents the sample statistics for the 36 banks used in our sample. 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, they dominate the sample period with respect to input and output variables.

Table 3. Summary statistics

	INPUTS		**OUTPUTS**		
1999	NEMP	NONLOP	LOAN	DEMDEP	TIMDEP
Mean	4493	91.2	802.07	379.71	1846.34
St Dev.	6953	88.3	994.64	587.60	2672.21
Minimum	49	0.94	6.5543	1.87	13.11
Maximum	37705	301.50	3367.98	3044.01	13574.91

Note: NEMP; number of employees, NONLOP; non-labour operating expenses, LOAN; total loans DEMDEP; total demand deposits, TIMDEP; total time deposits. All variables except NEMP, are measured in billions of US dollars.

6. Emprical results

We examined the Turkish commercial banking performance in terms of their ability to provide outputs with minimum input consumption. The analysis produced three sets of results: DEA CRS and SDEA realisation for the year 1999 and SDEA mean performance for 1992-1999. They are the total efficiency scores, which are reported for the individual banks under constant returns to scale (CRS) assumption. Table 4 details these results.

The DEA efficiency scores can 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 a bank has an efficiency score of 85%, this implies that that particular bank needs to reduce its inputs by 15% in order to achieve 100% efficiency. We solve the linear programs described in Section 4 to measure the technical efficiency of each observation. The deterministic DEA computations were conducted by the OnFront Software.

The DEA results show that the Turkish commercial banking features high variability in efficiency. The geometric mean of the initial analysis amounts to 0.57, indicating that, on average, banks could produce outputs with approximately 43 per cent fewer inputs. The standard deviation of this analysis is 0.257. The efficiency scores of the banks in the sample ranged from 16 per cent to 100 per cent. The two state banks appear efficient whereas there are no efficient foreign banks in the sample. Among those banks under the Fund, only 2 appear efficient. The private banks are the least efficient group. Among the 23 private banks, only 4 banks are fully efficient.

We now return to the results obtained by solving the chance constrained DEA problem described in Section 4. These are the results which reveal the SDEA realisation for the year 1999 and the SDEA mean performance for 1992-1999. It seems from the SDEA realisation results that every bank's efficiency improves compared to the DEA CRS analysis. Even the inefficient banks have higher efficiency scores. A great number of banks now show $\theta > 1$ as we expect with the realisations compared to SDEA frontier. These banks represent what LLT (1993) call super-efficient or elite companies The results suggest however, that there are a lot of measurement errors or other stochastic factors in the raw data. Such factors could be associated with the existence of macroeconomic shocks and issues of regulatory changes. It is apparent that the Turkish banking system has been severely affected by the macroeconomic imbalances since the 1990s. With the new Banking Law, the system is experiencing many changes in the regulations. Indeed, frequent changes directly or indirectly related to the banking industry along with the macroeconomic imbalances have considerable impact on the performance and growth of the industry and the system.

Another issue is related with the accuracy of the reported data. Banks in Turkey (1999: 35) emphasizes that financial statements of those banks under the Fund became more transparent changing their balance sheet size, asset quality and profitability performance dramatically. This raises serious concerns whether the data are accurately reported, thus an issue of incentive compatible (truth telling) regulation arises. It seems that the regulatory rules applying to bank disclosures and auditing are not offering sufficient reward to banks to reveal theirs true balance sheets.

In addition, when we look at the SDEA results for the 1999 realisation, we find many banks are super-efficient ($\theta > 1$) and some have extremely high relative efficiency scores (e.g. bank 8, (θ^{SDEA} = 5.4). This finding says that the SDEA frontier is extremely far displaced from the 1999 realisation. In other words, the 1999 observations are very extreme outliers. Conceivably this could reflect a genuinely large improvement in efficiency but could equally simply reflect this very great variability in the data. The SDEA model therefore, urges us to be very conservative in drawing policy conclusions.

Suspicion of large stochastic errors in data is confirmed by the SDEA mean performance results for 1992-1999. All banks except two are clustered on frontier. They have mean performance equal to 1 or very close to one. Only Bank 10 and Bank 36 have performance very different from average efficiency over the 1992-1999 period. Bank 10 is a bank under the Fund whereas Bank 36 is a private bank.

Table 4. Results: DEA-CRS, SDEA mean and SDEA 1999

	DEA CRS	**SDEA 1999**	**SDEA mean**
	θ	θ	θ
Bank 1	1	2.73606	1.00000
Bank 2	0.39	0.75108	1.00000
Bank 3	1	2.92050	1.00000
Bank 4	0.68	1.26260	1.00000
Bank 5	0.61	1.05515	1.00000
Bank 6	0.66	1.90757	1.00000
Bank 7	1	2.42942	1.00000
Bank 8	1	5.41956	1.00000
Bank 9	0.57	1.15157	1.00000
Bank 10	0.17	0.61161	0.97060
Bank 11	0.32	1.22110	1.00000
Bank 12	0.55	1.62097	0.99437
Bank 13	0.45	0.81041	1.00007
Bank 14	1	3.98883	1.00000
Bank 15	0.47	0.86427	1.00000
Bank 16	0.48	0.87267	1.00000
Bank 17	0.46	0.93629	1.03571
Bank 18	0.54	2.20991	1.00000
Bank 19	0.16	0.37106	1.01231
Bank 20	1	2.74756	1.00000
Bank 21	0.19	0.72482	1.00000
Bank 22	0.49	0.96059	1.00080
Bank 23	0.48	1.06604	1.00000
Bank 24	0.73	2.38943	1.00065
Bank 25	0.72	1.67403	1.00001
Bank 26	0.46	1.09878	1.00000
Bank 27	0.41	1.17378	1.00000
Bank 28	0.78	1.76837	1.00000
Bank 29	0.86	2.52637	1.00000
Bank 30	0.57	1.06680	1.00000
Bank 31	0.69	1.83638	1.00000
Bank 32	0.84	1.51309	1.00000
Bank 33	0.7	2.19037	1.00014
Bank 34	0.43	1.09401	1.00001
Bank 35	1	3.50539	1.00003
Bank 36	1	1.82390	0.86787
Geometric Mean	0.57458	1.47238	0.99645
Standard deviation	0.25715	1.06001	0.02354

7. Conclusion and interpretations

The objective of this paper was to use SDEA to study the efficiency performance of 36 Turkish commercial banks in 1999. Stochastic DEA constructs production frontiers that incorporate both inefficiency and stochastic error. This results in a closer envelopment of the mean performance of the companies in the sample and diminishes the effect of extreme outliers. We have used Land, Lovell and Thore (1993) model incorporating information on the covariance structure of inputs and outputs to study efficiency. The lack of empirical studies, which focus on the SDEA analysis of the Turkish commercial bank efficiency, motivated this study.

Initially we have derived the relative technical efficiencies in the TR banking sector by implementing non-parametric DEA on a cross-section of 36 banks taken in 1999. This analysis reveals quite wide variation in efficiency. Further analyses was conducted for the SDEA realisation for the year 1999 and the SDEA mean performance for 1992-1999. SDEA suggests huge variability attributable to stochastic error in the sample with measurement errors, macroeconomic shocks and issues of changes in banking regulations.

The purpose of SDEA is to reduce the effect of extreme outliers in the data when the efficiency frontier is constructed. By allowing the reference technology constraints to be violated with a low probability, the model permits outliers to be treated as super-efficient. This means the efficient frontier is displaced closer to the bulk of the observations, making each appear relatively more efficient. The effect of this allowance for the volatility of the banks' performance over a number of years is that a single year's observations are set in context of the undulying variability of the panel over many years. Where this variability is very large, as appears to be the case in this sample, the consequence is that much use of the performance variation in a particular year can be attributable to inefficiency.

A policy implication is that one year's DEA efficiency scores may be a very poor guide to designing regulatory policy. This particular sample is probably very extreme in the amount of stochastic error and variability observed. The Turkish banking system is undergoing large regulatory changes after a period of prolonged exogenous shocks. The incentives to reveal consistent balance sheet information may have been absent. In these circumstances it could be dangerous for regulators to allow the current year's efficiency performance based on input and output levels to have a major policy role.

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