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Efficiency measurement of the Greek commercial banks with the use of financial ratios: a data envelopment analysis approach

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Abstract

This study offers an application of a non-parametric analytic technique (data envelopment analysis, DEA) in measuring the performance of the Greek banking sector. It explores the efficiency of Greek banks with the use of a number of suggested financial efficiency ratios for the time period 1997–1999. In this way the proposed model offers an empirical reference set for comparing the inefficient banks with the efficient ones. It departs from most frontier studies of bank performance, by using these suggested ratios as output measures and with no use of input measures. The proposed model is compared to the conventionally used input–output analysis as well as to the simple ratio analysis. It is shown that data envelopment analysis can be used as either an alternative or complement to ratio analysis for the evaluation of an organization's performance. We find that the higher the size of total assets the higher the efficiency. We also find a wide variation in performance and we show that the increase in efficiency is accompanied with a reduction in the number of small banks due to mergers and acquisitions. Finally, from the efficiency results it seems that there is a non-systematic relationship between transfer of ownership and last period's performance.

Keywords: Banking; Financial ratios; Data envelopment analysis

1. Introduction

In the Greek financial system, the commercial banks play an important role and contribute substantially to the finance of the national economy. The Greek banking industry has undergone a substantial development over the last years. Since the end of 1980s it has entered a new stage with several changes, which started with the Report of the Karatza's Committee in 1987. These changes are on going and are expected to continue into the future as well.

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The main changes in the banking system after 1992 include among others the liberalization of interest rate determination,[1] the abolition of various credit rules, the free movement of capital and the increased competition from banks of the European Union (Noulas, 1999). As a result, banks have been free to determine their interest policy for deposits and loans since 1993. In the same year, banks were allowed to follow their own investment policy without the restriction of investing a certain percentage in government bonds. These two measures towards further liberalization have driven increased competition in both price and quality levels of the offered services by the banking sector. The competition among banks has increased mainly due to this market liberalization, technological improvements and the entrance of non-banking institutions for the provision of banking services in the form of non-intermediation (Staikouras and Steliarou, 1999). The competition has strengthened with the emergence of banking institutes from the EU but also from the competition from other credit institutes such as insurance companies and cooperative banks.

Although till recently the main choice of banks to achieve their targets for development was by growing the components of their assets, today this choice has moved to increasing profitability. All of the above require the determination and management of several factors, which play an important role in the profitability of banks in the new environment.

The task of this study is to examine the efficiency of the commercial banking system during the period 1997–1999 and the relative efficiency of each bank. We intend to show that financial accounting ratios and non-parametric techniques can be used as a complement to each other for the evaluation of bank performance (Rouse et al., 2002). For this reason we employ both ratio analysis and data envelopment analysis techniques (hereafter DEA) for the measurement of efficiency with the use of financial ratios which are frequently applied in the banking sector.[2] It is also generally accepted among analysts of the banking sector, that the efficiency of a bank is multidimensional from its nature. Specifically the efficiency of a bank is measured by using ratios such as return on equity (ROE), return on total assets, the difference of interest bearing elements of assets and liabilities, profit/loss per employee, the efficiency ratio and the net interest margin ratio.

Before we proceed with the presentation of the method used, we have to emphasize that the derivation of reasonable conclusions related to the comparative performance of a subset of banks pre-supposes that this comparison is carried out among banks operating in homogeneous markets. That is, we should compare banks with the maximum feasible homogeneity in their offered services.

This study offers an application of DEA to the Greek banking system. In contrast to most frontier studies of bank performance, which use bank inputs and outputs, we rely on standard ratio measures of bank financial performance as output measures in the DEA model. In this way we evaluate the performance of the Greek banks over the period of 1997–1999. This modeling follows that of Lovell (1995), who took standard measures of macroeconomic performance and used a modified DEA model to derive a composite index of performance.

There are some innovative features in this study. It is the first time that financial-banking efficiency ratios are used as variables to evaluate efficiency, instead of the typically used input–output variables in almost all banking applications based on input quantity, output quantity and prices.

Another interesting feature is the absence of inputs in the model which while not innovative is relatively underutilized. In this study performance is measured with an output vector consisting of five

[1] For the consequences in banks' efficiency from the reduction in interest rates in the zone of EURO see Thanos (2000).

[2] See Vasiliou (1993), Mathioudaki (1995) and Siafakas (1980).

financial-banking ratios and no inputs. This modeling constitutes an interesting alternative for efficiency evaluation and a complement to the simple ratio analysis employed by financial analysts in the banking sector.

Finally, this study concentrates on 3 years where significant changes occurred in the banking system due to the transfer of publicly owned banks to the private sector, and mergers and acquisitions. This enables us to draw some conclusions over the efficiency of changes in the banking system in the short run. Moreover, a comparative efficiency analysis between large and small banks is also attempted.

We show that the proposed DEA model can be used as a complement/substitute to simple ratio analysis. We also find that the higher the size of total assets the higher the efficiency. Moreover, we find a wide variation in performance and we show that the increase in efficiency is accompanied by a reduction in the number of small banks due to mergers and acquisitions. Finally, we conclude that there is a non-systematic relationship between the transfer of ownership and last period's performance.

The remainder of the paper is organized as follows. In the next section a literature review of similar studies is presented. Then the suggested non-parametric technique is described. The methodology and the financial ratios employed are analyzed and the banks included in our sample are presented next. The empirical results and a comparison among input–output and the ratio model follow. Finally, the last section presents the conclusions and policy implications from the results obtained.

2. Literature review

In the literature interest in the measurement of comparative efficiency of banks has grown. There are a number of papers that use non-parametric methods for determining the efficient banks (Berg et al., 1991; Berg et al., 1993; Ferrier and Lovell, 1990; Fucuyama, 1993). There are a few studies that measure bank performance by observing the change in earnings-based financial ratios including the value of return on assets (ROA) and return on equity (ROE). Also the simple expense to revenue ratio is used to approximate efficiency.

The use of financial ratios helps the evaluation of bank performance. Accounting ratios may be used in order to interpret financial accounts or management accounting data. Two main reasons for using ratios as a tool of analysis are to allow comparison among different sized bank and to control for sector characteristics permitting the comparison of individual bank's ratios with some benchmark for the sector.

The use of these accounting-based financial ratios to measure bank performance has been criticized. For instance, accounting data ignores the current market value of the bank and does not represent economic value-maximizing behavior (Kohers et al., 2000). Additionally, these financial ratios do not consider the input price and the output mix (Berger and Humphrey, 1992) while the selection of the weights of financial ratios is subjective.

Due to these difficulties, Berger and Humphrey (1997) conclude that efficient frontier approaches seem to be superior compared to traditional financial ratios analysis in terms of measuring performance. They claim that the frontier approach offers an overall objective numerical score and ranking, and an efficiency proxy together with the economic optimization mechanism. It is worth mentioning that the frontier analysis suffers from the same drawback we mentioned for the financial ratios. Namely, they rely on accounting data and not on market values. But it is believed that the efficiency proxies of the frontier approach are better measures of bank performance.

Many DEA studies analyze bank branch performance (Athanassopoulos, 1997; Berger et al., 1997; Schaffnit et al., 1997; Sherman and Ladino, 1995; Drake and Howcroft, 1994; Al-Faraj et al., 1993; Oral et al., 1992; Oral and Yolalan, 1990; Sherman and Gold, 1990; Haag and Jaska, 1995). Although there is not an accepted model for the technology of providing bank services and products, Dekker and Post (2001) claim that the technology may be represented by certain outputs in the form of loans, mortgages and insurance which are produced by certain inputs such as personnel, computers, etc.

Concerning the Greek commercial banks we have a number of studies. Giokas (1991, 1993) and Vassiloglou and Giokas (1990) evaluated the relative effectiveness of the branches of some commercial banks while Noulas (1994) presents a comparison of efficiency for the Greek banking institutions.

Other studies examine the scale and scope efficiencies in banking markets. Clark (1998) reviews 13 such studies including those of Berger et al. (1987), Kolari and Zardkoohi (1987), and Gilligan et al. (1984). In these studies economies of scale were measured using the Cobb–Douglas production form and assuming no interdependence among outputs. Some other studies used a more flexible functional form with the translog cost function (Hunter and Timme, 1986; Lawrence and Shay, 1986; Benston et al., 1982).

Another set of studies investigates the technical and allocative efficiencies using Farrell's (1957) approach for analyzing efficiency (Berg et al., 1991; Drake and Weyman Jones, 1992; Vassiloglou and Giokas, 1990; Parkan, 1987; Greenberg and Nunamaker, 1987; Nunamaker, 1985). Berger and Humphrey (1997) provide a comprehensive review of efficiency studies of financial institutions in 21 countries.

Finally, a number of studies try to explain the market's reaction to bank mergers and some of these studies examine the relationship between bank performance and abnormal returns around the merger announcement date. Cornett and Tehranian (1992), Bishop and Thomson (1992), Haskel and Szymanski (1993), and Brook et al. (1998) found a significant correlation between abnormal returns and bank performance but Pilloff (1996) did not find a relationship like this, while Boussofiane et al. (1995) reported mixed results. Knaw and Wilcox (1999), Berger et al. (1999), and DeYoung and Hasan (1998) provide evidence in support of the assertion that bank mergers lead to efficiency gains.

3. The technique

In our study a non-parametric analytic technique for the evaluation of corporate performance is applied. Specifically, we employ DEA, which is a non-statistical method using linear programming. It provides a measure of relative technical efficiency of different decision-making units (hereafter DMUs) operating and performing the same or similar tasks. The technique's main advantage is that it can deal with the case of multiple inputs and outputs as well as factors, which are not controlled by individual management.

Another important advantage of this non-parametric technique, and in general of all the non-parametric techniques, is that we skip most of the usual difficulties, which arise by the use of parametric methods in the analysis of financial ratios. That is, we skip problems like the necessity to determine the functional form[3] or to determine the statistical distribution of the ratios. Additionally, when we refer to the analysis of financial ratios, problems arise if the numerator or the denominator take negative values,[4] while the manipulation of outliers is not clear.

[3] It is usually assumed that the relationship between the variables is linear.

[4] This is a problem of DEA as well.

The application of this technique facilitates the comparison of efficiency for a large sample of banks with the simultaneous use of multiple criteria, which determine efficiency for each bank. The comparative advantage of this model in comparison to the broadly employed simple ratio analysis, is that it forms a rounded judgment on firms' efficiency, taking into consideration a variety of ratios simultaneously and combining them into a single measure of efficiency. Thus, the comparison of relative efficiency of the sample banks is carried out, relying on the derived efficiency ratio for every bank, as the solution of the mathematical model. The higher a bank's efficiency ratio in relation to the corresponding ratio of another bank the higher is the efficiency of this bank.

We may think of DEA as measuring the technical efficiency of a given bank by calculating an efficiency ratio equal to a weighted sum of outputs over a weighted sum of inputs. For each DMU these weights are derived by solving an optimization problem which involves the maximization of the efficiency ratio for that DMU subject to the constraint that the equivalent ratios for every DMU in the set is less than or equal to 1.

That is, DEA seeks to determine which of the N DMUs determine an envelopment surface or efficient frontier. DMUs lying on the surface are deemed efficient, while DMUs that do not lie on the frontier are termed inefficient, and the analysis provides a measure of their relative efficiency. As mentioned, the solution of the model dictates the solution of (N) linear programming problems, one for each DMU. It provides us with an efficiency measure for each DMU and shows by how much each of a DMU's ratios should be improved if it were to perform at the same level as the best performing banks in the sample. In this way we extract an efficiency ratio for each bank, which shows us by how much the ratios of each bank could be improved so as to reach the same level of efficiency with that of the most efficient banks in the sample.

The fundamental feature of DEA is that the technical efficiency score of each DMU depends on the performance of the sample of which it forms a part. This means that DEA produces relative, rather than absolute, measures of technical efficiency for each DMU under consideration. DEA evaluates a DMU as technically efficient if it has the best ratio of any output to any input and this shows the significance of the outputs–inputs taken under consideration.

Let us now consider the problem diagrammatically. Assume that we examine the efficiency of eight commercial banks (T_1, T_2,...,T_8). To simplify things, we use two efficiency ratios: (a) return on equity and (b) the return difference of the interest bearing assets (RDIBA). Suppose that banks, which achieve the optimal efficiency are T_1, T_2, T_3, and T_4. The efficient frontier is determined from the segments that pass through points T_1, T_2, T_3, and T_4. Bank T_5 not on the frontier is considered either as less efficient or not efficient. Point T_μ determines the optimal level of efficiency and represents the combination of the two ratios R_1 and R_2 in the same proportion as bank T_5 and thus, it is considered as the reference point, which is used for the measurement of relative efficiency of bank T_5. T_μ is a linear combination of T_2 and T_3. That is the reference subset for bank T_5 contains banks T_2 and T_3. The portion by which T_μ exceeds T_5 shows us the size of inefficiency. The degree of efficiency for bank T_5 is found by the ratio of the distances $\mathrm{OT}_5/\mathrm{OT}_\mu$ (as shown in Fig. 1).

Let us now consider the problem from a mathematical point of view. In contrast with the original model suggested by Charnes et al. (1978) in our suggested model we do not take inputs directly into consideration. The main hypothesis behind this is that, inputs are considered similar and equal for all banks as they operate in the same markets for money and services. Thus, we focus attention on output in the form of financial efficiency ratios. The N banks under consideration produce a vector of outputs R_i in the form of the mentioned financial ratios. The matrix of outputs R_i (with $i = 1, 2, 3, \dots, m$) is

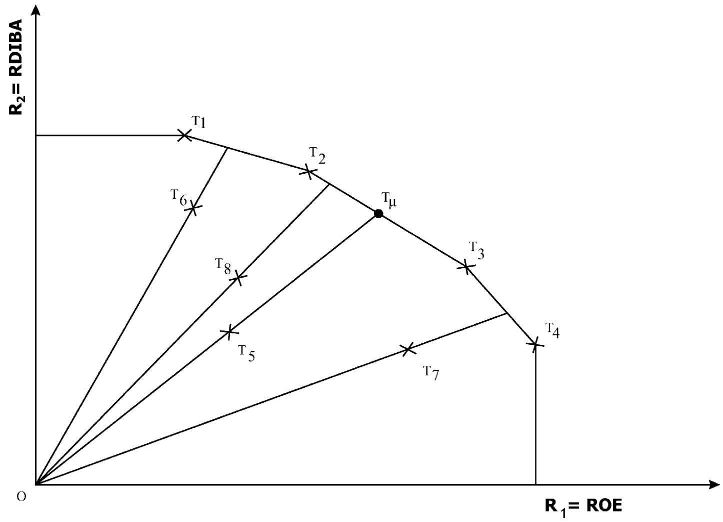

Fig. 1. Diagrammatic presentation of the model.

known for each bank n (with $n = 1, 2, \ldots, N$). The n variables to be determined are a set of weights (λ),[5] ($\lambda = \lambda_1, \lambda_2, \ldots., \lambda_\kappa)^\ell$ placed on each of the banks in forming the efficiency frontier for firm (ℓ) and an efficiency measure Θ^ℓ.

Then the linear program for each bank can be written as:

$$\max \vartheta_\ell$$

subject to

$$\begin{aligned} &\sum_{n=1}^{N} \lambda_n R_{\text{in}} \geq \vartheta_\ell R_{i\ell} \quad (i = 1, 2, \ldots\ldots, m) \\ &\sum_{n=1}^{N} \lambda_n = 1 \\ &\vartheta_\ell \geq 0 \\ &\lambda_n \geq 0 \quad (n = 1, 2, \ldots\ldots, N) \end{aligned} \tag{1}$$

The efficiency score for each bank is given by $\Theta_\ell^* = 1/\vartheta_\ell$, and it is positive and less than or equal to 1. DMUs with Θ^* value of unity and all slacks zero are deemed efficient while DMUs with a Θ^* score of less than one are considered as inefficient. Also, if we obtain an efficiency score of 1 but a slack value is positive then the model has identified a point on the efficient frontier but still has excess on an output, which corresponds to the positive slack. This implies that this DMU is not Pareto-efficient, as its outputs cannot be expanded jointly.

[5] If a bank wishes to improve its score it would be best to concentrate on those outputs with the highest weight, as the efficiency score is most sensitive to those outputs.

The optimal weights $(\lambda_1^*, \ldots, \lambda_n^*)^\ell$ of the reference group in the solution, set a feasible target for improvement in each ratio (R_i) for bank ℓ. That is,

$$\hat{Y}_{i\ell} = \sum_{n=1}^{N} \lambda_n^* R_{\text{in}} \quad \text{or} \quad \hat{Y}_{i\ell} = R_{i\ell} \frac{1}{\Theta_\ell^*} + s_{i\ell} \tag{2}$$

where ($s_{i\ell}$) is the slack on ratio (i) and reflects the non-proportional residual output slack, while $(1/\Theta_\ell^*)$ reflects the proportional output augmentation.

A potential problem arises because some of the ratios may take negative values. This compromises the inequalities in Eq. (1) because unaltered the program would allow the reference group of efficient banks to assume a negative ratio even lower than that of the bank with the negative value. As a result, in a few cases where negative ratios are exhibited (e.g. banks 9818 and 9819 where the first two digits represent the year and the second two the code of the bank), we adopted the expedient of setting that ratio as a fixed output. This is along the lines suggested by Banker and Morey (1986). So in these cases we amended the constraint associated with the negative ratio to the following:

$$\sum_{n=1}^{N} \lambda_n R_{\text{in}} \geq R_{i\ell} \tag{3}$$

ensuring that the reference group banks exhibit performance not worse than a bank on the ratio on which this bank has negative performance (the same treatment of the negative ratios we can see in Smith (1990)).

Before we proceed to the analysis of the suggested model we note that the 3 years are merged into a single sample of 50 observations for comparison of the efficiency scores over time.

4. Methodological approach

In our analysis we take under consideration all the Greek commercial banks members of the Union of Greek banks.[6] Our analysis includes 15 banks for the year 1999, 17 banks for the year 1998 and 18 banks for the year 1997. We excluded from our analysis five Banking institutes (Agricultural Bank of Greece, Aspis Housing Bank, National Housing Bank of Greece, ETEBA, ETBA) since these institutes are concentrating their activities in agricultural, housing credit and investment banking, respectively. Consequently, we focused only on commercial banking where all the products and services are similar for all banks. This is done to ensure maximum feasible comparability among banks. Knowing that all banks considered in our sample offer approximately the same services, any observed difference in efficiency should be explained by differences in technical efficiency and not in lack of comparability. The data used in this study were extracted and analyzed from the balance sheets and profit and loss accounts of the banks under consideration.

Multiple criteria are used in our effort to explore the efficiency of banks. A variety of financial ratios are applied for this evaluation with each ratio to provide indications for a bank's technical efficiency.

[6] Banks which are included in our sample for the years 1997, 1998, 1999 are the following: ALPHA Bank (T_2), Bank of Attica (T_4), General Bank (T_5), Egnatia Bank (T_6), National Bank of Greece (T_7), Commercial Bank of Greece (T_8), Ergasias Bank (T_9), EFG Eurobank (EFG Eurobank Ergasias, (T_{10})), Ionian and Popular Bank of Greece (T_{11}), Popular Bank Hellas (former European and Popular Bank, (T_{12})), Macedonia-Thrace Bank (T_{13}), Piraeus Bank (T_{14}), Prime Bank (T_{15}), Telesis Investment Bank (former Doriki, (T_{16})), Xiosbank (T_{17}), Bank of Central Greece (T_{18}), Bank of Crete (T_{19}), Bank of Athens (T_{20}).

However, it is worth mentioning, that no one of these ratios on its own provides an adequate indication of a bank's efficiency. Thus, in this study we select six financial ratios which reflect the most important dimensions of their performance. The financial ratios used as outputs of a commercial bank's activities are presented next.[7]

(i) Return difference of interest bearing assets (RDIBA):

This measure is calculated as the return difference of the interest bearing assets and the interest rate cost of the liabilities. Specifically,

$$\mathrm{RDIBA} = \frac{\mathrm{IRSI}_t}{(\mathrm{IBA}_t + \mathrm{IBA}_{t-1})/2} - \frac{\mathrm{IPSC}_t}{(\mathrm{IBL}_t + \mathrm{IBL}_{t-1})/2} \tag{4}$$

where IRSI is the interest receivable and similar income; IPSC, interest payable and similar charges; IBA, interest bearing assets;[8] IBL, interest bearing liabilities[9] and t the time. This measure is derived as the difference between the interest income divided by the assets that yield interest and the interest cost divided by the liabilities that yield this cost. The larger this difference is, the more efficient is the management of the bank's capital.

(ii) Return on equity (ROE, average)

$$\mathrm{ROE} = \frac{\mathrm{PBT}_t}{(E_t + E_{t-1})/2} \tag{5}$$

where PBT is the profit (loss) before tax; E, equity[10] and t, time. This ratio shows the profitable capability of the bank and estimates the efficiency with which the bank exploits its equity.

(iii) Return on total assets (ROA, average)

$$\mathrm{ROA} = \frac{\mathrm{PBT}_t}{(\mathrm{TA}_t + \mathrm{TA}_{t-1})/2} \tag{6}$$

where PBT is the profit (loss) before tax; TA, total assets and t, the time. This ratio calculates the yield of the total assets of a bank and, therefore, it can be a criterion for evaluating the management goals achieved; i.e. with this index we estimate the efficiency of the invested capital (equity and foreign capital) of a credit institution. As shown later on in our study, there is a very high correlation between ROA and ROE and thus we excluded this ratio from our analysis.

(iv) Profit/loss per employee (P/L)

$$(P/L) = \frac{\mathrm{PBT}_t}{L_t + L_{t-1}/2} \tag{7}$$

where PBT is the profit (loss) before tax; L, number of employees and t, time. This ratio shows us the productivity of the bank's labor. A rise in the index number shows a rise in productivity and vice versa.

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[7] The choice of ratios used in our study of efficiency, rely on what is most commonly used by bankers and financial analysts. It must be clarified that the ratios chosen could have been more or different depending on the subject of research.

[8] Interest bearing assets = cash in hand + balances with central banks + loans and advances to credit institutions + loans and advances to customers.

[9] Interest bearing liabilities = amount owned to credit institutions + amounts owned to customers + subordinated liabilities.

[10] Equity = shareholders capital + reserves + fixed assets (revaluation) reserve + fixed asset investment subsidy + retained earnings.

(v) Efficiency ratio (EFF)

$$\mathrm{EFF} = \frac{\mathrm{OE}_t}{\mathrm{GOP}_t} \tag{8}$$

where OE is the operational expenses,[11] GOP, gross operating profit (loss) and t the time. This ratio expresses the percentage of gross income absorbed by the operational costs (management, appropriation, depreciation, etc.). The smaller the index is, the more efficient the bank is, because the percentage of the bank's profits and losses is sufficient to cover its financial and other expenses.

We should mention here, that, since the specific ratio is derived as the ratio of the operational expenses to the gross operating profit and loss, the smaller this ratio is, the more efficient this bank is. For reasons of convenience with the other indices, the efficiency variable (EFF) was used in our application as 1/EFF.

(vi) Net interest margin (NIM)

$$\mathrm{NIM} = \frac{\mathrm{NI}_t}{(\mathrm{TA}_t + \mathrm{TA}_{t-1})/2} \tag{9}$$

where NI the net income, TA the total assets and t the time. This ratio shows the assets' efficiency. Thus, taking as granted the fact that all the other factors, which influence a bank's yield, are fixed, we calculate a bank's efficiency with the use of the above-mentioned indices, which reflect different efficiency aspects.

5. Empirical results

Fig. 2a–e present the ratios for all the banks included in the analysis for the years 1997–1999.

From the RDIBA ratio and especially from the ROE and P/L we can see that there is a significant improvement of performance of most of the Greek banks. In particular P/L is higher for all banks in 1999. The reasons for the improved profitability for the time period 1997–1999 are mainly attributed to (a) the significant gains from bonds and participating interest realization, which were 27% higher in 1998 in comparison to 1997 and 182% higher in 1999 in relation to 1998 due to the favorable conditions in the Stock market. (b) The increase in interest income by 11% in 1998 in comparison with 1997 and 23% in 1999 in relation to 1998, which reflects the increase in loans and interest income from fixed income securities and (c) the increase in revenues from income from shares and other variable yield securities in 1999.

The above mentioned reasons show that the profitability of banks is to a less extent due to the increase of traditional banking works and more to the activation of banking institutes in the Athens Stock Exchange Market. Also, there is a significant improvement of the EFF for almost all the banks (with the exception of bank no. 10) in the sample contributing this way to the improved performance of the banking system. However, it should be noted that the improvement in the efficiency ratio is attributed more to the significant increase in revenues and to a less extent to the reduction in the operating expenses, which appear to be increased for all the years of our study. It is important to stress that from Fig. 2 we can see some of the DMUs that will form the efficiency frontier for the other non-efficient DMUs in the sample. In particular,

[11] Operating expenses = commissions payable + staff costs and other administrative expenses + fixed assets depreciation + other operating charges + extraordinary charges.

the highest, RDIBA ratios for bank 7 in 1998, ROE for bank 8 in 1999, *P*/*L* for bank 14 in 1999, EFF for bank 9 in 1999 and NIM for bank 4 in 1998, suggest that at least these DMUS will be efficient.

Descriptive statistics of the variables are presented in Table 1. Using a correlation coefficient of about 0.80 as a cut off (this rule of thumb may vary depending on the study or discipline) we exclude the ROA variable from the analysis due to higher correlation coefficients compared to ROE. Turning next to the DEA model, Table 2 lists the results showing that efficiency ratios of the commercial banks under consideration range from 0.41 to 1. Four banks are considered to be efficient for the year 1999, three for the year 1998 and two for the year 1997. Specifically, as it can be seen in Table 2, efficient banks are considered to be those with efficiency ratio equal to one ($\Theta^* = 1$). The banks that appear to have a rather good performance in the year 1999 are banks 08, 09, 14, and 16, for the year 1998 are 04, 07, and 16 whereas for the year 1997 are banks 05, and 09, which form the reference set or the comparison group for the inefficient banks.

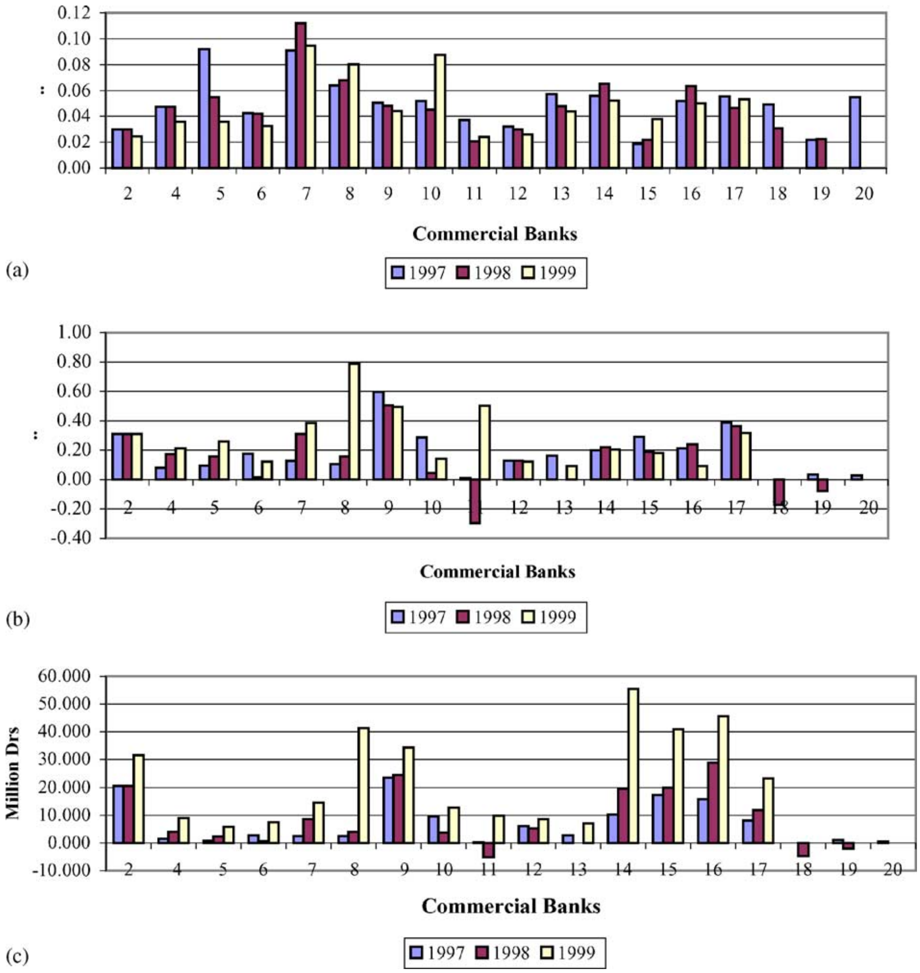
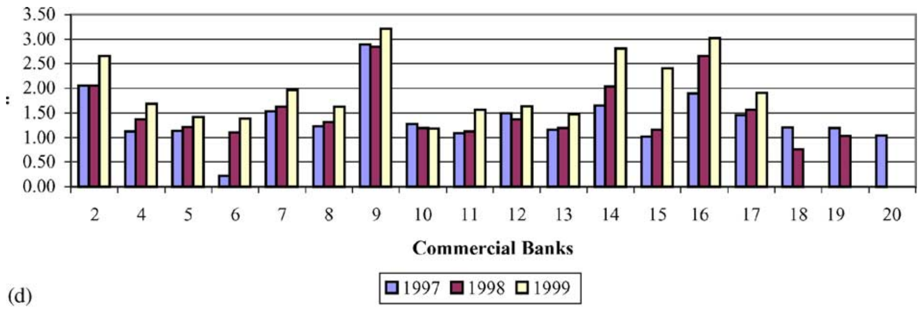
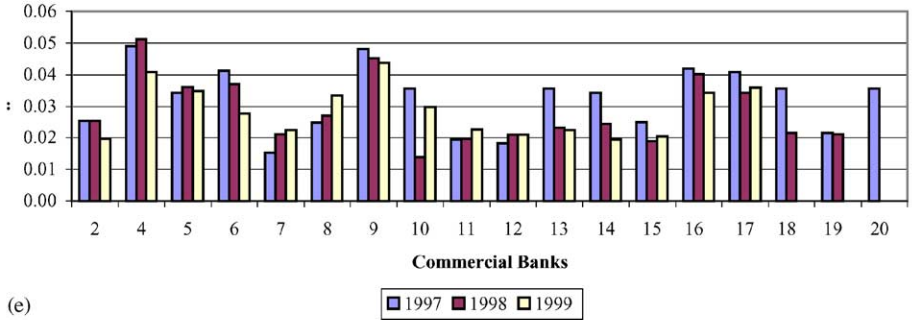


Fig. 2. (a) Return difference of interest bearing assets; (b) return on equity; (c) profit/loss per employee; (d) 1/efficiency ratio; (e) net interest margin.



(d)



(e)

Fig. 2. (*Continued*).

The first, fourth and seventh columns in Table 2 represent the banks (where the first two digits represent the year and the second two the code of the bank), the second, fifth and eighth columns the efficiency scores and the third, sixth and ninth columns show the rank of banks according to their efficiency. The same columns show us how many times the efficient banks constitute a reference and comparison criterion for the inefficient banks (the numbers in parentheses). That is, how many times the specific bank appears to be a member of the reference set.

Table 3 gives us a clear and complete picture of relative efficiency for our sample's banks during the time period 1997–1999. As it can be seen, banks T_{20} in 1998 and banks T_{18} and T_{19} in 1999 were

Table 1
Descriptive statistics and correlation coefficients of the ratio model

	RDIBA	ROE	*P*/*L*	EFF	NIM
Descriptive statistics					
Maximum	0.112	0.790	55328.000	3.209	0.051
Minimum	0.019	−0.298	−5302.000	0.22	0.014
Average	0.048	0.194	10545.340	1.605	0.030
Standard deviation	0.021	0.187	12789.090	0.629	0.010
Correlation coefficients					
RDIBA	1				
ROE	0.240	1			
P/*L*	0.055	0.522	1		
EFF	0.068	0.519	0.664	1	
NIM	0.134	0.338	0.051	0.154	1

Table 2
Efficiency scores and rank for 1997–1999 of the ratio model

1999	Θ^*	Rank	1998	Θ^*	Rank	1997	Θ^*	Rank
9908	1	1 (6)	9804	1	1 (18)	9705	1	1 (23)
9909	1	1 (12)	9807	1	1 (14)	9709	1	1 (35)
9914	1	1 (1)	9816	1	1 (0)	9704	0.97	12
9916	1	1 (11)	9809	0.97	11	9717	0.91	14
9907	0.99	10	9814	0.84	19	9716	0.91	15
9910	0.95	13	9805	0.83	22	9707	0.86	17
9902	0.90	16	9808	0.78	28	9713	0.84	20
9917	0.85	18	9806	0.77	30	9706	0.83	21
9904	0.83	24	9817	0.76	31	9720	0.83	23
9915	0.78	29	9802	0.70	35	9710	0.82	25
9905	0.71	33	9813	0.61	37	9714	0.81	26
9911	0.71	34	9810	0.53	43	9718	0.80	27
9913	0.60	38	9815	0.51	44	9708	0.73	32
9906	0.60	39	9812	0.50	45	9702	0.70	35
9912	0.53	41	9818	0.48	47	9715	0.57	40
			9819	0.43	49	9712	0.53	42
			9811	0.41	50	9711	0.49	46
						9719	0.45	48

Table 3
Average efficiency scores and total rank for the years 1997–1999 of the ratio model

Bank	1999	1998	1997	Average	Rank
09	(Pr) 1	(Pr) 0.97	(Pr) 1	0.99	1
16	(Pr) 1	(Pr) 1	(Pr) 0.91	0.97	2
07	(P) 0.99	(P) 1	(P) 0.86	0.95	3
04	(Pr) 0.83	(Pr) 1	(P) 0.97	0.93	4
14	(Pr) 1	(Pr) 0.84	(P) 0.81	0.88	5
05	(P) 0.71	(P) 0.83	(P) 1	0.85	6
17	(Pr) 0.85	(Pr) 0.76	(Pr) 0.91	0.84	7
08	(P) 1	(P) 0.78	(P) 0.73	0.84	8
20	–	–	(P) 0.83	0.83	9
02	(Pr) 0.9	(Pr) 0.7	(Pr) 0.7	0.77	10
10	(Pr) 0.95	(Pr) 0.53	(Pr) 0.82	0.77	11
06	(Pr) 0.6	(Pr) 0.77	(Pr) 0.83	0.73	12
13	(Pr) 0.6	(P) 0.61	(P) 0.84	0.68	13
18	–	(P) 0.48	(P) 0.8	0.64	14
15	(Pr) 0.78	(Pr) 0.51	(Pr) 0.57	0.62	15
11	(Pr) 0.71	(P) 0.41	(P) 0.49	0.54	16
12	(Pr) 0.53	(Pr) 0.5	(Pr) 0.53	0.52	17
19	–	(P) 0.43	(P) 0.45	0.44	18
Mean efficiency	0.83	0.71	0.78	0.77	
Median efficiency	0.85	0.76	0.83	0.80	
Maximum efficiency	1	1	1	0.99	
Minimum efficiency	0.53	0.41	0.45	0.44	
Mean efficiency (Pr)	0.81	0.76	0.78		
Mean efficiency (P)	0.90	0.65	0.78		

absorbed or acquired by other sample banks. If we compare the efficiency of these banks with the median efficiency we realize that it is equal or lower than our sample banks. This is a possible indication that inferior efficiency makes banks vulnerable leading to mergers and acquisitions.[12]

The efficiency of the banking sector in total shows an unstable improvement during the period 1997–1999. As it can be seen in Table 3 the average banks' efficiency increased from 78% in 1997 to 83% in 1999 with a remarkable decrease in 1998 to 71%. During the time period 1997–1999 six banks appear at least once to be efficient. In Table 3, a banks' efficiency, for the examined time period, is presented in the fifth column while the corresponding rank of the banks is shown in the last column.

In Table 3 next to the efficiency score for each bank there is an indication whether this bank is private (Pr) or Public (P). In 1997 there were ten public and eight private banks, in 1998 there were ten private and seven public banks while in 1999 there were twelve private banks and only three public ones. From the efficiency point of view public banks are performing better on average in comparison to the private banks during the third year (1999) while private banks are performing better in the second year (1998) of the study. In 1997 private and publicly controlled banks appear to have equal efficiency. However, we should stress that in 1999 public banks exhibit higher efficiency on average than private banks (but they are only three in a total of 15 banks). The current trend towards mergers and acquisitions in combination with privatization policies for the publicly owned-controlled banking institutes establish new conditions in the banking sector.

Eurobank (10) absorbed the Bank of Athens in 1997 and the bank of Crete in 1998. Its efficiency fluctuated from 0.82 in 1997 to 0.53 in 1998 and 0.95 in 1999. So in the short run the effect in performance from the absorption of these two banks seems to be uncertain. Another important issue to be addressed is whether the privatization of public owned banks lead to higher efficiency levels. From our study we derive mixed results. Specifically, the banks that experienced change in ownership are Bank of Attica (04), Piraeus Bank (14), Macedonia Thrace Bank (13) and the Ionian and Popular Bank of Greece (11). From Table 3, after their privatization Banks (14) and (11) show an increase in efficiency. Macedonian Thrace Bank present the same approximately level of efficiency, while in the case of Attica Bank we can not say something with certainty since the initial increase in efficiency from 0.97 to 1 in 1998 follows a considerable decrease in performance from 1 to 0.83 in 1999. So in the last two cases efficiency does not seem to have increased significantly after privatization.

In the international literature there are mixed results regarding the productivity growth—increased efficiency of the firms—organizations for the period before their privatization. In this study as it can be observed from Table 3 there is no systematic relationship between transfer of ownership and last period increased performance. The main task is the increase in efficiency and competitiveness of the banking system through the increase of the average size (as we will see later on) of Greek banks and the exploitation of economies of scale.

At this point it is worth mentioning that a bank, which appears to be most times in the efficient frontier for the less efficient banks is considered to be the Global leader. By counting how many times each bank appears to be in the reference set (Table 2), we notice that bank 09 in 1997 is the most efficient. This bank appears 35 times (more than all the other efficient banks in all years) to be part of the reference set during the time period considered. This means that its performance is greater on average in all dimensions of efficiencies as they are described in our model compared to the other efficient sample banks.

[12] The reasons that lead to a merger or acquisition are more than one and do not relate to the specific study; the economic state, however, plays an important role.

As it can be seen from the mathematical formulation, the feasible target for the improvement of every ratio is achieved by summing up the products of the weights (λ_i) and the respective ratios (R_i). The financial ratios that are used for each bank's efficiency as well as the feasible target for improving any ratio are shown in Table 4. We notice that for the banks that form the efficient frontier, there is no difference between the actual ratios and the feasible targets. On the other hand, there is a possibility of improvement for all banks whose efficiency, according to Table 2, is less than 1.

It is worth mentioning that Table 4 must be used together with the derived lambdas (not presented here). This means that 9804 and 9709 define the feasible improvement target for all 9904s ratios. This means that 9804 defines by 0.55 and 9709 by 0.45 the feasible improvement targets of all 9904s ratios. That is, using the following expression:

$$\hat{Y}_{i2} = \sum_{n=1}^{N} \lambda_n^* R_i \tag{10}$$

the feasible target for 9904 can be calculated as:[13]

$$\hat{Y}_{9904} = 0.55 \begin{bmatrix} 0.05 \\ 0.17 \\ 338 \\ 1.37 \\ 0.05 \end{bmatrix} + 0.45 \begin{bmatrix} 0.050 \\ 0.60 \\ 23413 \\ 2.89 \\ 0.05 \end{bmatrix} = \begin{bmatrix} 0.05 \\ 0.36 \\ 10744 \\ 2.05 \\ 0.05 \end{bmatrix}$$

where 0.55 and 0.45 are the λ-values for 9804 and 9709, respectively. In a similar way, for each bank the rest of the feasible efficient target ratios can be calculated for every year.

Table 5 ranks all the banks according to the size of their total assets in two categories, large and small for all the years of our study. We observe that the average size of total assets shows a continuous increase where from 1,302,380 in 1997 reached 1,678,975 in 1998 and 2,353,679 in 1999. At the same time the larger banks appear to be more efficient than the smaller ones during the years 1998, 1999 while the opposite holds for 1997.

However, it is important to stress that the continuous increasing size of the Greek banks from 1997 has driven the difference in average efficiency between the large and small banks to take its maximum value. Analytically, the average efficiency of large banks in 1997 is lower than the corresponding for the small banks by −3%. Conversely in 1998, the difference in efficiency between large and small banks takes the value of +6%, while in 1999 the difference in efficiency of these two categories appears to take its maximum value of +13%. This drives us to the conclusion that there is a strong positive correlation of the large size and efficiency. Moreover, more mergers and acquisitions will be expected in the near future with main purpose the size increase and the exploitation of the potential scale economies in the increasing competitive banking sector. For the year 2000 the number of the banks is going to be reduced compared to 1999 since one merger and two acquisitions have been already announced. More specifically Piraeus Bank (14) absorbs Macedonia-Trace Bank (13), Xiosbank (17) and Prime Bank (15), while Ergasias Bank (09) merged with Eurobank (10).

[13] We should mention that the feasible targets for each of 9904 Bank ratios contain both radial and non-radial slack.

Table 4
Financial ratios per bank and feasible targets (1999–1997)

Banks	RDIBA	ROE	*P*/*L*	EFF	NIM
9902 (0.90)	0.02 (0.05)	0.31 (0.34)	31505.00 (34955.42)	2.66 (2.95)	0.02 (0.04)
9904 (0.83)	0.04 (0.05)	0.21 (0.36)	8872.00 (10743.93)	1.68 (2.05)	0.04 (0.05)
9905 (0.71)	0.04 (0.05)	0.26 (0.36)	5725.00 (11036.83)	1.42 (2.06)	0.04 (0.05)
9906 (0.60)	0.03 (0.06)	0.12 (0.43)	7355.00 (15112.51)	1.38 (2.31)	0.03 (0.05)
9907 (0.99)	0.09 (0.09)	0.38 (0.39)	1444.00 (12344.79)	1.96 (1.98)	0.02 (0.03)
9908 (1.00)	0.08 (0.08)	0.79 (0.79)	41208.00 (41208.00)	1.63 (1.63)	0.03 (0.03)
9909 (1.00)	0.04 (0.04)	0.49 (0.49)	3424.00 (3424.00)	3.21 (3.21)	0.04 (0.04)
9910 (0.95)	0.09 (0.09)	0.14 (0.32)	12737.00 (13437.14)	1.19 (1.35)	0.03 (0.03)
9911 (0.71)	0.02 (0.07)	0.50 (0.70)	9808.00 (33157.41)	1.57 (2.20)	0.02 (0.04)
9912 (0.53)	0.03 (0.05)	0.12 (0.36)	8587.00 (16146.72)	1.64 (3.08)	0.02 (0.04)
9913 (0.60)	0.04 (0.07)	0.09 (0.49)	6986.00 (17344.75)	1.47 (2.44)	0.02 (0.04)
9914 (1.00)	0.05 (0.05)	0.21 (0.21)	55328.00 (55328.00)	2.81 (2.81)	0.02 (0.02)
9915 (0.78)	0.04 (0.05)	0.18 (0.47)	4084.00 (5228.50)	2.42 (3.90)	0.02 (0.04)
9916 (1.00)	0.05 (0.05)	0.09 (0.09)	45636.00 (45636.00)	3.03 (3.03)	0.03 (0.03)
9917 (0.85)	0.05 (0.06)	0.32 (0.62)	23149.00 (27326.96)	1.91 (2.39)	0.04 (0.04)
9802 (0.70)	0.03 (0.05)	0.31 (0.44)	20434.00 (29161.95)	2.06 (2.94)	0.03 (0.04)
9804 (1.00)	0.05 (0.05)	0.17 (0.17)	388.00 (388.00)	1.37 (1.37)	0.05 (0.05)
9805 (0.83)	0.06 (0.07)	0.16 (0.19)	2277.00 (3459.22)	1.21 (1.46)	0.04 (0.04)
9806 (0.77)	0.04 (0.05)	0.02 (0.18)	664.00 (1873.06)	1.10 (1.42)	0.04 (0.05)
9807 (1.00)	0.11 (0.11)	0.31 (0.31)	8535.00 (8535.00)	1.62 (1.62)	0.02 (0.02)
9808 (0.78)	0.07 (0.09)	0.16 (0.26)	3951.00 (7952.86)	1.31 (1.67)	0.03 (0.03)
9809 (0.97)	0.05 (0.05)	0.51 (0.53)	24557.00 (25212.88)	2.84 (2.92)	0.05 (0.05)
9810 (0.53)	0.05 (0.08)	0.05 (0.38)	3644.00 (6862.95)	1.20 (2.26)	0.01 (0.03)
9811 (0.41)	0.02 (0.05)	−0.30 (0.55)	−5302.00 (20890.55)	1.13 (2.72)	0.02 (0.05)
9812 (0.50)	0.03 (0.06)	0.13 (0.51)	5245.00 (15031.09)	1.38 (2.75)	0.02 (0.04)
9813 (0.61)	0.05 (0.08)	0.00 (0.34)	0.00 (11483.65)	1.19 (1.95)	0.02 (0.04)
9814 (0.84)	0.07 (0.08)	0.22 (0.26)	19522.00 (23130.96)	2.04 (2.41)	0.02 (0.03)
9815 (0.51)	0.02 (0.06)	0.19 (0.37)	19823.00 (39000.99)	1.16 (2.69)	0.02 (0.04)
9816 (1.00)	0.06 (0.06)	0.24 (0.24)	28802.00 (28802.00)	2.65 (2.65)	0.04 (0.04)
9817 (0.76)	0.05 (0.06)	0.37 (0.48)	11823.00 (18256.12)	1.57 (2.48)	0.03 (0.04)
9818 (0.48)	0.03 (0.06)	−0.17 (0.23)	−4884.00 (5068.19)	0.76 (1.58)	0.02 (0.04)
9819 (0.43)	0.02 (0.05)	−0.08 (0.45)	−2166.00 (15841.81)	1.03 (2.38)	0.02 (0.05)
9702 (0.70)	0.03 (0.05)	0.31 (0.44)	20434.00 (29161.95)	2.06 (2.94)	0.03 (0.04)
9704 (0.97)	0.05 (0.05)	0.08 (0.19)	1353.00 (1392.23)	1.13 (1.43)	0.05 (0.05)
9705 (1.00)	0.09 (0.09)	0.09 (0.09)	732.00 (732.00)	1.14 (1.14)	0.03 (0.03)
9706 (0.83)	0.04 (0.05)	0.18 (0.22)	2729.00 (3268.98)	0.22 (1.53)	0.04 (0.05)
9707 (0.86)	0.09 (0.11)	0.12 (0.33)	2433.00 (8045.80)	1.53 (1.77)	0.02 (0.02)
9708 (0.73)	0.06 (0.09)	0.10 (0.27)	2535.00 (8162.53)	1.23 (1.68)	0.03 (0.03)
9709 (1.00)	0.05 (0.05)	0.60 (0.60)	23413.00 (23413.00)	2.89 (2.89)	0.05 (0.05)
9710 (0.82)	0.05 (0.06)	0.29 (0.35)	9533.00 (11655.61)	1.28 (2.03)	0.04 (0.04)
9711 (0.49)	0.04 (0.07)	0.01 (0.41)	18.00 (14743.34)	1.08 (2.19)	0.02 (0.04)
9712 (0.53)	0.03 (0.06)	0.13 (0.39)	5909.00 (11117.81)	1.50 (2.82)	0.02 (0.04)
9713 (0.84)	0.06 (0.07)	0.16 (0.19)	2771.00 (3595.72)	1.15 (1.46)	0.04 (0.04)
9714 (0.81)	0.06 (0.07)	0.20 (0.36)	10252.00 (12634.52)	1.66 (2.06)	0.03 (0.04)
9715 (0.57)	0.02 (0.05)	0.29 (0.51)	17115.00 (29831.76)	1.02 (2.79)	0.03 (0.04)
9716 (0.91)	0.05 (0.06)	0.21 (0.47)	15848.00 (17394.36)	1.90 (2.45)	0.04 (0.05)
9717 (0.91)	0.06 (0.06)	0.39 (0.43)	7975.00 (15321.18)	1.45 (2.29)	0.04 (0.04)
9718 (0.80)	0.05 (0.06)	0.00 (0.21)	5.00 (3918.03)	1.21 (1.52)	0.04 (0.05)
9719 (0.45)	0.02 (0.05)	0.04 (0.52)	1017.00 (19426.16)	1.19 (2.62)	0.02 (0.05)
9720 (0.83)	0.06 (0.07)	0.03 (0.14)	34.00 (572.91)	1.05 (1.27)	0.04 (0.04)

The feasible targets for each ratio appears in parentheses.

Table 5
Comparative bank efficiency according to the size of total assets (in million Greek drachmas)

Banks	1999	Θ^*	Banks	1998	Θ^*	Banks	1997	Θ^*
7	12,978,476	0.99	7	12,092,565	1	7	9,802,976	0.86
2	5,904,191	0.9	2	4,274,130	0.7	2	3,447,019	0.7
8	4,543,799	1	8	3,396,175	0.78	8	3,087,548	0.73
10	2,575,014	0.95	11	1,879,707	0.41	11	2,209,380	0.49
9	2,186,263	1	9	1,729,332	0.97	9	1,403,402	1
11	1,990,697	0.71	10	1,290,418	0.53	10	685,257	0.82
14	1,525,060	1	14	670,421	0.84	13	489,949	0.84
13	830,278	0.6	13	642,747	0.61	5	394,880	1
17	676,432	0.85	5	523,025	0.83	19	394,234	0.45
5	654,991	0.71	17	508,595	0.76	17	332,617	0.91
6	525,035	0.6	6	418,184	0.77	14	319,294	0.81
4	341,798	0.83	19	401,396	0.43	12	181,698	0.53
12	294,911	0.53	12	206,710	0.5	18	165,889	0.8
16	186,863	1	4	197,498	1	4	140,262	0.97
15	91,384	0.78	18	178,131	0.48	6	128,726	0.83
			16	85,040	1	20	119,520	0.83
			15	48,497	0.51	15	75,679	0.57
						16	64,509	0.91
Total assets	35,305,192			28,542,571			23,442,839	
Mean assets	2,353,679			1,678,975			1,302,380	
Median assets	830,278			523,025			363,426	
Average efficiency	0.83			0.71				0.78
Average efficiency of large banks	0.89			0.74				0.77
Average efficiency of small banks	0.76			0.68				0.80

6. Ratio and input–output DEA models: a comparison

In the previous sections of the paper, ratio analysis and the proposed DEA ratio model were analytically presented. However, it is quite interesting to comparatively examine also the conventional input–output (I/O) DEA models[14] under both the assumptions of constant and variable returns to scale with the ratio model in order to see whether it provides similar results or not. The variables employed for the output oriented CRS/VRS models and super efficiency CRS/VRS models are drawn from the balance sheets and income statements of the banks under examination for the years 1997–1999. We use interest expenditure (IntExp), total assets (Tassets), number of employees (Labour), operating expenditures (OE) as inputs, and, interest income (IntInc), net profit (Netprofit) as outputs.

At the stage of designing the model, if highly correlated variables are identified among inputs and outputs and these highly correlated variables appear in the same input or output group then they are omitted from the model in order to keep the model's discrimination power high (Avkiran, 1999). On the other hand, Rhodes and Southwick (1993) and Charnes et al. (1994), argue that highly correlated inputs or outputs can remain in the DEA models without distorting the efficiency scores at the expense of lower discrimination power. Therefore, high correlation coefficients do not prevent us from running a DEA

[14] Details on the formulation of the models can be found in Coelli et al. (2001) Chapter 6.

Table 6
Descriptive statistics and correlation coefficients on input–output data

	Tassets	Labour	OE	IntExp	IntInc	NetProfit
Descriptive statistics						
Maximum	12,978,476	15,984	765,743	1,043,485	1,321,355	311,574
Minimum	48,497	52	1,637	2,935	4,366	−22,123
Average	1,745,812	2685.16	64216.42	115180.9	154062,8	30072.34
Standard deviation	2,839,525	3765.016	118565.2	222101.7	276054.4	60085.59
Correlation coefficients						
Tassets	1					
Labour	0.967	1				
OE	0.435	0.442	1			
IntExp	0.978	0.958	0.435	1		
IntInc	0.986	0.964	0.438	0.997	1	
NetProfit	0.703	0.636	0.306	0.610	0.655	1

model because of the non-parametric nature of DEA, which is supposed to mitigate this effect. Table 6 presents the descriptive statistics and correlation coefficients of the variables included in the I/O models.

The efficiency scores derived from these models as well as the mean efficiencies for private—public and large—small banks are presented in Table 7. In the first column of Table 7 the sample banks are presented. In the columns four to seven the efficiency scores for each bank are presented for each model. In the eight column each bank's returns to scale follow while last column presents the scale efficiency scores. In the third column the efficiency scores of the ratio model are included to facilitate the comparison among the models.

As it appears in Table 7 the ratio model has the highest discrimination power among the DEA models since only nine DMUs appear to be efficient for all the years of the study. The average efficiency of the banking sector as derived from the CRS and VRS models shows a decrease from the year 1997 to the year 1998 while from 1998 to 1999 the mean efficiency scores remain almost the same. Conversely ratio model results show an increase in the efficiency from 1997 to 1999 with a considerable decrease in 1998.

Comparing the efficiency of public and private banks similar results are derived from all the models for the time period considered. Specifically private banks appear to perform better than the public ones for the years 1997 and 1998 while public banks are performing better than private in 1999.

Finally all models indicate that the mean efficiencies of small banks are higher than the corresponding mean efficiencies of large banks for the year 1997. In 1999 the opposite result is derived. All models results suggest that the average efficiency of large banks is higher than the average efficiency of small banks. For the year 1998, the ratio model indicates higher efficiency on average for the large banks while all the I/O models results indicate the opposite. An overall view from the comparison of the results is that all models provide us with similar results, and therefore, all could be used for efficiency evaluations.

Now turning to the returns to scale, as identified by the output oriented VRS model and displayed in Table 8 it can be seen that for the evaluation of returns to scale we adopted the approach suggested by Fare et al. (1985, 1994). This approach is based to the following relations, $\theta^*_{\mathrm{CRS}} \leq \theta^*_{\mathrm{NIRS}} \leq \theta^*_{\mathrm{VRS}}$, where θ^*_{CRS} and θ^*_{VRS} are optimal for the CRS and VRS models, respectively, and θ^*_{NIRS} is optimal when the constraint $\sum \lambda \leq 1$ is adjoined to the CRS model (or alternatively altering the variable return to scale

Table 7
Efficiency scores, returns to scale, scale scores

Banks	OS	Ratio model efficiency	CRS efficiency	VRS output efficiency	CRS super efficiency	VRS output super efficiency	Returns to scale	Scale Score
1999								
9902	(Pr)	0.9	0.87	1	87.2	107.84	Decreasing	0.87
9904	(Pr)	0.83	0.89	0.89	88.52	89.02	Increasing	0.99
9905	(P)	0.71	0.89	0.91	89.19	91.32	Decreasing	0.98
9906	(Pr)	0.6	0.82	0.83	82.39	83.04	Decreasing	0.99
9907	(P)	0.99	1	1	101.49	110	Constant	1.00
9908	(P)	1	1	1	110	110	Constant	1.00
9909	(Pr)	1	1	1	109.46	110	Constant	1.00
9910	(Pr)	0.95	0.86	0.92	86.37	91.86	Decreasing	0.94
9911	(Pr)	0.71	0.86	0.92	85.76	91.57	Decreasing	0.94
9912	(Pr)	0.53	0.86	0.86	85.83	83.05	Constant	1.00
9913	(Pr)	0.6	0.78	0.79	78.12	79.28	Constant	0.99
9914	(Pr)	1	1	1	108.92	110	Constant	1.00
9915	(Pr)	0.78	0.86	1	86.45	110	Increasing	0.86
9916	(Pr)	1	1	1	110	110	Constant	1.00
9917	(Pr)	0.85	0.95	1	95.34	100.47	Decreasing	0.95
1999 Mean efficiency		0.83	0.91	0.94	93.67	98.50		0.97
Mean efficiency (Pr)		0.81	0.90	0.93	92.03	97.18		0.96
Mean efficiency (P)		0.90	0.96	0.97	100.23	103.77		0.99
Mean efficiency (L)		0.89	0.92	0.95	95.92	101.32		0.97
Mean efficiency (S)		0.76	0.90	0.93	91.10	95.27		0.97
1998								
9802	(Pr)	0.7	0.84	0.96	84.09	96.46	Constant	0.87
9804	(Pr)	1	1	1	102.3	103.31	Constant	1.00
9805	(P)	0.83	0.89	0.93	89.44	92.63	Decreasing	0.97
9806	(Pr)	0.77	0.87	0.90	86.74	89.97	Constant	0.96
9807	(P)	1	1	1	104.65	104.66	Constant	1.00
9808	(P)	0.78	0.86	0.95	86.26	95.35	Constant	0.90
9809	(Pr)	0.97	1	1	101.65	101.84	Constant	1.00
9810	(Pr)	0.53	0.90	0.90	89.52	89.65	Constant	1.00
9811	(P)	0.41	0.91	0.97	90.76	94.4	Decreasing	0.93
9812	(Pr)	0.5	0.94	0.94	93.76	94.49	Constant	0.99
9813	(P)	0.61	0.82	0.85	82.06	81.68	Decreasing	0.97
9814	(Pr)	0.84	0.78	0.82	78.4	81.55	Decreasing	0.96
9815	(Pr)	0.51	1	1	110	110	Constant	1.00
9816	(Pr)	1	1	1	110	110	Constant	1.00
9817	(Pr)	0.76	0.91	0.95	90.98	94.89	Constant	0.96
9818	(P)	0.48	0.81	0.81	80.93	81.33	Constant	1.00
9819	(P)	0.43	0.96	1	95.98	100.53	Decreasing	0.96
1998 Mean efficiency		0.71	0.91	0.94	92.80	95.46		0.97
Mean efficiency (Pr)		0.76	0.92	0.95	94.74	97.22		0.97
Mean efficiency (P)		0.65	0.89	0.93	90.01	92.94		0.96
Mean efficiency (L)		0.74	0.89	0.93	89.65	93.14		0.96
Mean efficiency (S)		0.68	0.94	0.95	96.34	98.07		0.98

Table 7 (*Continued*)

Banks	OS	Ratio model efficiency	CRS efficiency	VRS output efficiency	CRS super efficiency	VRS output super efficiency	Returns to scale	Scale Score
1997								
9702	(Pr)	0.7	0.81	0.89	81.07	89.41	Constant	0.91
9704	(P)	0.97	1	1	100.36	101.72	Constant	1.00
9705	(P)	1	1	1	99.68	104.74	Decreasing	1.00
9706	(Pr)	0.83	0.99	0.99	98.57	98.61	Decreasing	1.00
9707	(P)	0.86	0.89	0.92	89.06	91.52	Constant	0.97
9708	(P)	0.73	0.87	0.95	86.84	94.64	Constant	0.92
9709	(Pr)	1	1	1	105.15	107.03	Constant	1.00
9710	(Pr)	0.82	0.88	0.93	88.2	92.91	Constant	0.95
9711	(P)	0.49	0.76	0.81	76.48	81.32	Constant	0.94
9712	(Pr)	0.53	0.97	1	96.6	102.97	Increasing	0.97
9713	(P)	0.84	0.94	0.97	93.75	96.58	Constant	0.97
9714	(P)	0.81	0.84	0.84	83.67	84.45	Increasing	0.99
9715	(Pr)	0.57	1	1	110	110	Constant	1.00
9716	(Pr)	0.91	0.99	1	99.37	110	Increasing	0.99
9717	(Pr)	0.91	0.96	0.99	96.49	99.32	Constant	0.97
9718	(P)	0.8	0.90	0.90	89.56	90.26	Increasing	0.99
9719	(P)	0.45	0.91	0.93	90.53	93.4	Decreasing	0.97
9720	(P)	0.83	0.99	0.99	98.85	99.97	Decreasing	1.00
1997 Mean efficiency		0.78	0.93	0.95	93.57	97.16		0.97
Mean efficiency (Pr)		0.784	0.95	0.98	96.93	101.28		0.97
Mean efficiency (P)		0.778	0.91	0.93	90.88	93.86		0.98
Mean efficiency (L)		0.77	0.90	0.93	90.08	94.62		0.96
Mean efficiency (S)		0.80	0.96	0.97	97.05	99.70		0.99

Notes. OS: ownership structure, (Pr): private bank, (P): public bank, (L): large banks, (S): small banks.

model, by substituting $\sum\lambda = 1$ restriction with $\sum\lambda \leq 1$ of non-increasing returns to scale restriction). These relations determine returns to scale in the following manner:

(a) If $\theta^*_{\text{CRS}} = \theta^*_{\text{VSR}}$ then returns to scale is constant

(b) If $\theta^*_{\text{CRS}} = \theta^*_{\text{VRS}}$ then,

(b$_1$) If $\theta^*_{\text{CRS}} = \theta^*_{\text{NIRS}}$ then scale inefficiency is due to increasing returns to scale

(b$_2$) If $\theta^*_{\text{CRS}} = \theta^*_{\text{NIRS}}$ then scale inefficiency is due to decreasing returns to scale

Our results show that there are 6 banks displaying increasing returns to scale, 29 constant returns to scale and 15 decreasing returns to scale. More detailed presentation can be found in Table 8.

Scale scores are calculated by dividing pure technical efficiency (VRS) by technical efficiency (CRS) as can be found in Coelli et al. (2001). As stated in Thanassoulis (2001), if the technical efficiency (CRS) and pure technical efficiency (VRS) of a DMU are equal then scale efficiency is 1 and whether or not we control for its scale size we reach the same view on the DMU's technical efficiency. We may identify no adverse impact of scale size on its productivity. If, however, the DMU has lower CRS efficiency compared to VRS efficiency ratings then its scale efficiency will be below 1. The lower CRS compared to VRS efficiency scores suggests that the DMU is more productive in the former case and less productive when

Table 8
Returns to scale results

Banks	1999	1998	1997
9702	(Pr) Decreasing	(Pr) Constant	(Pr) Constant
9704	(Pr) Increasing	(Pr) Constant	(P) Constant
9705	(P) Decreasing	(P) Decreasing	(P) Decreasing
9706	(Pr) Decreasing	(Pr) Constant	(Pr) Decreasing
9707	(P) Constant	(P) Constant	(P) Constant
9708	(P) Constant	(P) Constant	(P) Constant
9709	(Pr) Constant	(Pr) Constant	(Pr) Constant
9710	(Pr) Decreasing	(Pr) Constant	(Pr) Constant
9711	(Pr) Decreasing	(P) Decreasing	(P) Constant
9712	(Pr) Constant	(Pr) Constant	(Pr) Increasing
9713	(Pr) Constant	(P) Decreasing	(P) Constant
9714	(Pr) Constant	(Pr) Decreasing	(P) Increasing
9715	(Pr) Increasing	(Pr) Constant	(Pr) Constant
9716	(Pr) Constant	(Pr) Constant	(Pr) Increasing
9717	(Pr) Decreasing	(Pr) Constant	(Pr) Constant
9718		(P) Constant	(P) Increasing
9719		(P) Decreasing	(P) Decreasing
9720			(P) Decreasing
Increasing	2—(2 Pr)	0	4—(2 Pr, 2P)
Constant	7—(6 Pr, 1P)	12—(9 Pr, 3P)	10—(5 Pr, 5P)
Decreasing	6—(5 Pr, 1P)	5—(1 Pr, 4P)	4—(9 Pr, 3P)

we control for scale size. This means that scale operation does impact the productivity of the DMU. Therefore, the larger the divergence between VRS and CRS efficiency scores the lower the value of scale efficiency and the more adverse the impact of scale size on productivity. Scale score results are presented in the last column of Table 7.

As can be seen, 9814 bank has low efficiency VRS score (0.82) and relatively high scale efficiency (0.96). That means that the overall inefficiency of the bank in the CRS model (0.78) is attributed mainly to inefficient operations or management. The same holds also for other banks such as 9805, 9906, 9714. On the other hand, if a bank has a fully efficient VRS score and low scale score that may mean that the global inefficiency of the bank under CRS is attributed to disadvantageous conditions. An example of this case can be bank 9902 which has an optimal VRS score of (1) and a relatively low scale score of (0.87).

7. Conclusions and policy implications

In this study we performed an application of data envelopment analysis to the Greek commercial banking system, by using standard ratio measures of bank financial performance, as output measures in the suggested model and for the time period 1997–1999. From the analysis we obtained the efficiency scores, the optimal output (ratios) levels for inefficient bank for all the 3 years of the study. Results drawn from the broadly used ratio analysis were also compared to the results derived from the DEA model. More specifically the results derived from the two analyses are similar, which implies that we can agree with the Berger and Humphrey (1997) argument that the efficient frontier approaches seem to be superior compared to traditional financial ratio analysis in terms of performance. In particular this study shows that ratio analysis and DEA can be used and it is probably recommended to use them as complements to each other for the evaluation of performance of DMUs.

The advantage of using DEA compared to financial ratios is that DEA provides us with an overall objective numerical score, ranking, and efficiency potential improvement targets for each one of the inefficient units. Specifically, DEA assist in efficiency comparisons with the simultaneous use of multiple criteria, which determine efficiency for each DMU, forming a rounded judgment on DMU efficiency taking into consideration a variety of efficiency dimensions and combining them into a single performance measure.

In the context of the present paper we can conclude that the DEA ratio model seems to be more reliable since correlation among the ratios (used as output variables in the model) was not so high. Conversely, the results drawn from the DEA input–output model due to extremely high correlation coefficient among some of the variables should be treated with caution. Additionally, it is worth mentioning that we should also take into consideration that a drawback of both ratio analysis and DEA technique is that they rely on accounting data and not on market values.

Other significant findings of this study are the following:

(a) A wide variation in performance of the Greek banking system is observed through the period 1997–1999 where a decrease in average efficiency level in 1998 is followed by a significant increase in 1999 which is the maximum attained performance level in the examined period.
(b) There is a positive relationship between size and performance. Mergers and acquisitions lead to a continuous increase of average efficiency of the larger banks while efficiency of the small banks is deteriorating. The higher the size of total assets the higher the efficiency is. This is confirmed from the significant increase in the sum of the total assets employed in the market as well as the increase in the average level of Banks' Assets. It is also worth mentioning that the efficiency difference between large and small banks reaches its maximum value in 1999.
(c) A considerable decrease of public owned or controlled banks from the period of 1997–1999. From ten public banks and eight private in 1997 we end with three public and twelve private in 1999. The varying average efficiencies of public and private banks during the period of the study do not permit us to conclude for the efficiency superiority of the one structure of ownership over the other.
(d) Mergers and acquisitions that materialized during this period provided mixed results on efficiency grounds. In some cases an improved performance is observed while in other cases we obtained the opposite result.
(e) Mixed results are also derived regarding the issue of productivity growth of the banks for the period before their privatization. We can conclude that there is non-systematic relationship between transfer of ownership and last's period performance.

Finally an improvement of the performance of the Greek banking system is observed. The reasons for the improved profitability for the time period 1997–1999 are mainly attributed to the following:[15]

(i) The significant gains from bonds and participating interest realization, which were 27% higher in 1998 in comparison to 1997 and 182% higher in 1999 in relation to 1998 due to the favorable conditions in the Stock market.

[15] See Union of Greek Banks (1999, 2000).

(ii) The increase in interest income by 11% in 1998 in comparison with 1997 and 23% in 1999 in relation to 1998, which reflects the increase in loans and interest income from fixed income securities.
(iii) The increase in revenues due to income from shares and other variable yield securities in 1999.

The above mentioned reasons show that the profitability of banks is to a less extent due to the increase of traditional banking works and more to the activation of banking institutes in the Athens Stock Exchange Market. Moreover, the good performance especially in 1999 is also attributed to the improvement in the efficiency ratio. However, we have to stress that this is due to the significant increase in revenues and not to the reduction in the operating expenses, which appear to be increased for all the years of our study. We believe that the reduction in operating expenses could be considered as the means for improvement of banks' competition in the following years.

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References

Al-Faraj, T.N., Alidi, A.S., Bu-Bshait, K.A., 1993. Evaluation of bank branches by means of data envelopment analysis. Int. J. Operations Prod. Manag. 13 (8), 45–52.

Athanassopoulos, A.D., 1997. Service quality and operating efficiency synergies for management control in the provision of financial services: evidence from Greek bank branches. Eur. J. Operational Res. 98, 301–314.

Avkiran K.N., 1999. Productivity Analysis in the Services Sector. Avkiran.

Banker, R.D., Morey, R.C., 1986. Efficiency analysis for exogenously fixed inputs and outputs. Operations Res. 34, 513–521.

Benston, G.J., Hanweck, G.A., Humphrey, D.B., 1982. Scale economies in banking: a restructuring and reassessment. J. Money Credit Bank. 14, 435–456.

Berg, A., Forsund, F., Jansen, E., 1991. Technical efficiency in Norwegian banks: a non parametric approach to efficiency measurement. J. Prod. Anal. 2, 127–142.

Berg, S.A., Forsund, F.R., Hjalmarsson, L., Souminen, M., 1993. Banking efficiency in the Nordic countries. J. Bank. Finance 17 (2/3), 371–388.

Berger, A.N., Hanweck, G.A., Humphrey, D.B., 1987. Competitive viability in banking: scale, scope and product mix economies. J. Monetary Econ. 20, 501–520.

Berger, A.N., Humphrey, D.B., 1992. Measurement and efficiency issues in commercial banking. In: Griliches, Z. (Ed.), Output Measurement in the Service Sectors. University of Chicago Press, Chicago, pp. 245–279.

Berger, A.N., Leusner, J.H., Mingo, J.J., 1997. The efficiency of bank branches. J. Monetary Econ. 40, 141–162.

Berger, A.N., Humphrey, D.B., 1997. Efficiency of financial institutions: international survey and directions for future research. Eur. J. Operational Res. (special issue), www.http://papers.ssrn.com/paper.taf?ABSTRACT_ID=2140.

Berger, A.N., Demsetz, R.S., Strahan, P.E., 1999. The consolidation of the financial services industry: causes, conseques and implications for the future. J. Bank. Finance 23, 135–194.

Bishop, M., Thomson, D., 1992. Regulatory reform and productivity growth in the UK's public utilities. Appl. Econ. 24, 1181–1190.

Boussofiane, A., Martin, S., Parker, D. 1995. Assessing the Technical Efficiency of UK Privatised Organisation Using Data Envelopment Analysis, Occasional Paper in Industrial Strategy, No. 30. University of Birmingham.

Brook, Y., Hendershott, R., Lee, D., 1998. The gains from takeover deregulation: evidence from the end of interstate banking restrictions. J. Finance 53, 2185–2204.

Charnes, A., Coopers, W., Rhodes, E., 1978. Measuring the efficiency of decision making units. Eur. J. Operational Res. 3, 429–444.
Charnes, A., Cooper, W.W., Lewin A.Y., Seiford, L.M., 1994. Data Envelopment Analysis: Theory, Methodology and Applications. Kluwer Academic Publishers.
Clark, J.A., 1998. Economies of scale and scope at depository financial institutions: a review of the literature. Fed. Reserve Bank Kansas City Econ. Rev. 73, 16–33.
Coelli, T., Prasada Rao, D.S., Battesse, E.G. 2001. An Introduction to Efficiency and Productivity Analysis. Kluwer Academic Publishers.
Cornett, M.M., Tehranian, H., 1992. Changes in corporate performance associated with bank acquisitions. J. Financial Econ. 22, 211–234.
Dekker, D., Post, T., 2001. A quasi-concave DEA model with an application for bank branch performance evaluation. Eur. J. Operational Res. 132, 296–311.
DeYoung, R., Hasan, I., 1998. The performance of de novo commercial banks: a profit efficiency approach. J. Bank. Finance 22, 565–587.
Drake, L., Weyman Jones, T.G., 1992. Technical and scale efficiency in UK building societies. Appl. Financial Econ. 2, 1–9.
Drake, L., Howcroft, D., 1994. Relative efficiency in the branch network of a UK bank: an empirical study. Omega Int. J. Manag. Sci. 22 (1), 83–90.
Fare, R., Gresskopf, S., Lovell, C.A.K. 1985. The Measurement of Productive Efficiency. Kluwer Academic Publishers, Norwel, MA.
Fare, R., Gresskopf, S., Lovell, C.A.K. 1994. Production Frontiers. University of Cambridge Press, Cambridge.
Farrell, M.J., 1957. The measurement of productive efficiency. J. R. Stat. Soc. 120 (Series A), 253–281.
Ferrier, G., Lovell, C., 1990. Measuring cost efficiency in banking: econometric and linear programming evidence. J. Econometrics 46, 229–245.
Fucuyama, H., 1993. Technical and scale efficiency of Japanese commercial banks: a non parametric approach. Appl. Econ. 25, 1101–1112.
Gilligan, T., Smilrock, M., Marshall, W., 1984. Scale and scope economies in the multi-product banking firm. J. Monetary Econ. 13, 393–405.
Giokas, D., 1991. Bank branch operating efficiency: a comparative application of DEA and the log linear model. Omega Int. J. Manag. Sci. 19 (6), 549–557.
Giokas, D., 1993. Methods of productivity measurement: the case of banks. In: Paper Presented in the International Conference of the Hellenic Center for Productivity, Athens, 29 September–1 October.
Greenberg, R., Nunamaker, T., 1987. A generalized multiple criteria model for control and evaluation of non-profit organizations. Financial Account. Manag. 3 (4), 331–342.
Haag, E., Jaska, V., 1995. Interpreting inefficiency ratings: an application of bank branch operating efficiencies. Manag. Decision Econ. 16 (1), 7–14.
Haskel, J., Szymanski, S., 1993. The Effects of Privatization, Restructuring and Competition on Productivity Growth in UK Public Corporations, Working Paper No. 286. Department of Economics, Queen Mary and Westfield College, University of London.
Hunter, W.C., Timme, S.G., 1986. Technical change, organizational form and the structure of bank production. J. Money Credit Bank. 18 (2), 152–166.
Kohers, T., Huang, M., Kohers, N., 2000. Market perception of efficiency in bank holding company mergers: the roles of the DEA and SFA models in capturing merger potential. Rev. Financial Econ. 9, 101–120.
Kolari, J., Zardkoohi, A., 1987. Bank, Cost, Structure and Performance. Lexington Books, Lexington, MA.
Knaw, S.H., Wilcox, J.A., 1999. Hidden Cost Reductions in Bank Mergers: Accounting for More Productive Banks. Federal Reserve Bank of San Francisco, Working Paper 99–10.
Lawrence, C., Shay, R., 1986. Technology and financial intermediation in a multiproduct banking firm: an econometric study of I.S.S. banks, 1979–1982. In: Lawrence, C., Shay, R. (Eds.), Technological Innovation, Regulation and the Monetary Economy. Ballinger, Cambridge, MA.
Lovell, C.A.K., 1995. Measuring the macroeconomic performance of the Taiwanese economy. Int. J. Prod. Econ. 39 (1/2), 165–178.
Mathioudaki, S., 1995. The efficiency of the Greek Banks in the decade 1985–1994. Econ. Rev. (Commercial Bank of Greece) 3, 32–39.

Noulas, A., 1994. Operating efficiency in the Hellenic bank industry: a data envelopment analysis approach. In: Proceedings of 40th International Atlantic Economic Conference in Williamsburg.

Noulas, A., 1999. Profitability and efficiency of the Greek banks (1993–1998). Bull. Union Greek Banks 4, 53–60.

Nunamaker, T.R., 1985. Using data envelopment analysis to measure the efficiency of nonprofit organizations: a critical evaluation. Manag. Decision Econ. 6 (1), 50–58.

Oral, M., Yolalan, R., 1990. An empirical study on measuring operating efficiency and profitability of bank branches. Eur. J. Operational Res. 46, 282–294.

Oral, M., Kettani, O., Yolalan, R., 1992. An empirical study on analyzing the productivity of bank branches. IIE Trans.: Ind. Eng. Res. Dev. 24 (11), 166–176.

Parkan, C., 1987. Measuring the efficiency of service operations: an application to bank branches. Eng. Costs Prod. Econ. 12, 237–242.

Pilloff, S.J., 1996. Performance changes and shareholders wealth creation associated with mergers of publicly traded banking institutions. J. Money Credit Bank. 28, 294–310.

Rouse, P., Putterill, M., Ryan, D., 2002. Integrated performance measurement design: insights from an application in aircraft maintance. Manag. Account. Res. 13, 229–248.

Rhodes, E.L., Southwick, J.L., 1993. Variations in Public and Private University Efficiency. Appl. Manag. Sci. 7, 145–170.

Siafakas, N., 1980. Analyses of balance sheets based on economic and financial components. Issue of the General Bank.

Schaffnit, C., Rosen, D., Paradi, J.C., 1997. Best practice analysis of bank branches: an application of DEA in a large Canadian bank. Operations Res./Manag. Sci. 37, 653–656.

Sherman, D., Gold, F., 1990. Bank branch operating efficiency: evaluation with data envelopment analysis approach. J. Bank. Finance 9, 297–315.

Sherman, H.D., Ladino, G., 1995. Managing bank productivity using data envelopment analysis (DEA). Interfaces 25 (14), 60–73.

Smith, P., 1990. Data envelopment analysis applied to financial statements. Omega Int. J. Manag. Sci. 18, 131–138.

Staikouras, C., Steliarou, M., 1999. Determinants of profitability for the Greek banking institutes. Issue of the Union of Greek Banks. pp. 61–66.

Thanassoulis, E. 2001. Introduction to the Theory and Application of Data Envelopment Analysis. Kluwer Academic Publishers.

Thanos, G., 2000. How falling interest rates but increasing banking output give higher banking profits: a trade off. Arch. Econ. History 11 (1/2), 179–196.

Vasiliou, D., 1993. Exploring the profitability of the Greek banking market. Bull. Union Greek Banks 37/38 (A), 95–98.

Vassiloglou, M., Giokas, D., 1990. A study of the relative efficiency of bank branches: an application of data envelopment analysis. J. Operational Res. Soc. 41, 591–597.

Union of Greek Banks, 1999. The Banks in Greece. Athens.

Union of Greek Banks, 2000. The Banks in Greece. Athens.