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PRODUCTIVITY GROWTH IN THE GREEK BANKING INDUSTRY: A NON-PARAMETRIC APPROACH

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This paper investigates productivity growth and technical efficiency in the Greek banking industry for the period 1982-1997. It also compares the 1982-92 and 1993-97 sub-periods, since after 1992 the Greek banking sector experienced substantial changes. The Malmquist productivity index and the DEA method are used to measure and decompose productivity growth and technical efficiency, respectively. Productivity growth is higher after 1992. Recent growth is mainly attributed to technical progress, while until 1992 growth is mainly attributed to improvements in efficiency. Furthermore, after 1992, pure efficiency is higher, and scale efficiency is lower, indicating that although banks achieved higher pure technical efficiency, they moved away from optimal scale. Finally, Tobit results show that size and specialization have positive effects on both pure and scale efficiency.

JEL classification codes: C61, G21, D24
Key words: Greek banking, efficiency, productivity growth, Malmquist index, DEA

I. Introduction

The purpose of this paper is to investigate productivity growth in the Greek banking industry for the period 1982-1997. Furthermore, this paper compares and contrasts productivity growth results between the sub-periods 1982-1992 and 1993-1997, since after 1992, with the enactment of the Second Banking Directive, the process of deregulation and liberalization of the Greek banking sector accelerated. Dramatic and substantial changes have taken place that encouraged competition in the industry by enacting the abolition of credit rationing, deregulating interest rates, eliminating the requirement of banking institutions to invest a significant portion of their reserves in public bonds and permitting free entry to banking institutions from abroad. These factors, together with the

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development and adoption of information technology, and the provision of new products and services are considered to have caused changes in the productivity and efficiency of the Greek banking industry.

Until the mid-1980s, the Greek banking industry operated in an environment heavily controlled and regulated by the Central Bank, which had gradually caused significant distortions and great inefficiency in the Greek financial system. The types of regulation included barriers to the development of new financial products, the regulation of interest rates, specific asset-holding and branching as well as complex credit rules that determined the interest rates on business loans. These financial regulations aimed at achieving economic policy priorities set by the Greek government, such as the financing of state-owned firms, the development of small and medium-sized enterprises, the expansion of exports, etc. The operation of the banking industry was under such complete dominance of the monetary authorities that it caused the absence of competition in the industry. In particular, the Central Bank of Greece and two major state-owned banks, the National Bank of Greece and the Commercial Bank of Greece, almost completely dominated the banking industry. As a result, banks abstained from adopting advanced technology due to the absence of competition in the industry. Towards the end of the 1980s, the Greek banking industry gradually moved towards a more deregulated system due to international developments and the need to participate in the Single European Market and the EMU. In the 1990s, the Greek banking industry was affected by the harmonization of national regulations within the EU and mainly by the enactment of the Second Banking Directive in 1992, which sought to facilitate the liberalization of financial markets and to enable banks and other financial institutions to operate throughout the European Union (EU) under a single banking license.

In this paper, the investigation of productivity growth is achieved by applying a non-parametric method developed by Fare et al. (1989) which computes total factor productivity (TFP) growth by using a Malmquist index of productivity change. Within this framework, productivity growth may occur due to a combination of industry-wide technological change, i.e. a shift in production surface, and a change in technical efficiency at the level of the operating unit, i.e. movement towards or away from the production surface. The Malmquist index can be decomposed to capture these two components, i.e. technological change and change in technical efficiency. Furthermore, the efficiency component can be decomposed into a pure technical and a scale efficiency change component. This paper also presents technical efficiency measures for the entire period 1982-1997 and for the sub-periods 1982-1992 and 1993-1997, which illustrate how closely an operating unit functions in relation to the production frontier. Technical efficiency indicates the degree to which the operating unit produces the maximum feasible output for a given level of inputs, or uses the minimum amount of feasible inputs to produce a given level of output. Higher efficiency from one period to another does not necessarily suggest that the operating unit achieves higher productivity since technology may have changed.

There are a large number of non-parametric studies that examine the banking industries around the world. The papers by Berger and Humphrey (1997) and Goddard et al. (2001) provide an extensive review of the literature on the efficiency and productivity of financial institutions. There is, however, a small number of non-parametric studies that have investigated the efficiency and productivity growth of the Greek banking industry. The most recent non-parametric studies include work by Noulas (1997), Giokas (1991) and Vassiloglou and Giokas (1990), but these studies are limited to a small time horizon. In particular, the first study refers to the 1991-1992 period while the second and third to the years 1988 and 1987, respectively. In addition, the studies by Giokas (1991) and Vassiloglou and Giokas (1990) examine the relative efficiency of the branches of only one bank, the Commercial Bank of Greece. It should also be noted that there are few parametric studies that examine the efficiency and productivity of the Greek banking sector. Among this research are studies by Apergis and Rezitis (2004), and Christopoulos and Tsionas (2001). The first study examines the cost structure, technical change and productivity in the banking industry for the period 1982-1997 using a traditional translog cost function approach. However, this study does not measure the degree of efficiency of the Greek banking industry due to the inability of the approach used to do so. The other study examines the economic efficiency of Greek banking during the period 1993-1998 using a stochastic frontier approach.

The paper is organized as follows: Section II describes the Malmquist TFP index while Section III presents the data. Section IV discusses the empirical results and Section V provides the conclusions.

II. Methodology

A. Productivity Change

Productivity change over time is an indicator of the performance of an industry. This study calculates the Malmquist productivity index as a measure of total factor productivity change. The Malmquist index approach has been used in a variety of studies related to the financial sector to measure productivity change. In particular, this approach has been applied in studies such as Berg et al. (1992) to examine the productivity of the Norwegian banking sector during the deregulation of the 1980s; Fukuyama (1995) to measure efficiency and productivity growth in the Japanese banking industry during the 1989-1991 period; Noulas (1997) to compare efficiency and productivity differences among state and private banks in Greece during the 1991-1992 period; Leightner and Lovell (1998) to construct productivity indices for Thai banks for the period 1989-1994; Gilbert and Wilson (1998) to study the effects of deregulation on the productivity of Korean banks during the period 1991-1994; Mukherjee et al. (2001) to explore productivity growth for a group of large US commercial banks over the initial post-regulation period 1984-1990; Canhoto and Dermine (2003) to examine banking efficiency and productivity in Portugal during the deregulation period 1990-1995; and Casu et al. (2003) to investigate productivity change in European banking during the 1994-2000 period.

The advantages of the Malmquist productivity index are that it does not make assumptions about the optimizing behavior of the producers and it allows for inefficiency (Fare et al. 1994). Furthermore, the Malmquist index does not rely on econometric estimation, but instead it uses a nonparametric approach similar to that used by data envelopment analysis (DEA). The advantages of using a nonparametric approach are that it avoids imposing a parametric specification for the underlying technology as well as for the distributional assumption of the inefficiency term. However, there are some weaknesses associated with a nonparametric approach. First, since a nonparametric method is deterministic and attributes all the variation from the frontier to inefficiency, a frontier estimated by it is likely to be sensitive to measurement errors or other noise in the data. In other words, it does not deal with stochastic noise. Another weakness of a nonparametric method is that it does not permit statistical tests and hypotheses to pertain to production structure and the degree of inefficiency. In this paper, a nonparametric approach is used because it is relatively less data demanding, i.e., it works quite well with a small sample size, compared to a parametric approach. Thus, the small sample size of this study, which contains only 6 banks, is conducive to the use of a nonparametric approach.

The Malmquist productivity index, as presented by Fare et al. (1989), is linked with the use of distance functions, which describes multi-input, multi-output production technology without the involvement of explicit price data and the need to specify behavioral assumptions such as profit maximization or cost minimization. Distance functions are classified into output and input distance functions. An output (input) distance function is defined as the reciprocal of the maximum (minimum) proportional expansion (contraction) of the output (input) vector given an input (output) vector (Fare et al., 1994). In this study, output distance functions are used. It should be stated that a production technology should be determined before an output distance function is defined. Let a multiple-input and multiple-output production technology at time t ($\mathbf{S}^t$) be defined as:

$$\mathbf{S}^t = \{(\mathbf{x}^t, \mathbf{y}^t) : \mathbf{x}^t \text{ can produce } \mathbf{y}^t\}, \quad t = 1,\dots,T, \tag{1}$$

where $\mathbf{x}^t$ is an (N×1) input vector and $\mathbf{y}^t$ is an (M×1) output vector. Then the output distance function at time t is defined as:

$$D_o^t(\mathbf{x}^t, \mathbf{y}^t) = \inf\{\theta : (\mathbf{y}^t/\theta) \in \mathbf{S}^t)\}, \quad t=1,\dots,T. \tag{2}$$

The distance function in (2) is defined as the reciprocal of the maximum proportional expansion of the output vector, $\mathbf{y}^t$, given input vector, $\mathbf{x}^t$, under period t technology. If the output vector is on the boundary or frontier of technology, then the value of the distance function is one, i.e. the production is technically efficient, otherwise it is less than one, i.e. the production is technically inefficient. Fare et al. (1989) showed that the Malmquist total factor productivity index is represented as the geometric mean of two Malmquist indexes and is defined as:

$$M_o(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\, \mathbf{x}^t, \mathbf{y}^t) = \tag{3}$$

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

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

where $M_o^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\, \mathbf{x}^t, \mathbf{y}^t)$ and $M_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\, \mathbf{x}^t, \mathbf{y}^t)$ are Malmquist indices measuring productivity change between periods $t+1$ and t and are defined using technology at time t and $t+1$ respectively. In addition, Fare et al. (1989) indicated that the Malmquist productivity index given by equation (3) can be decomposed into two components: the efficiency change (*FCH*) component which measures how much closer to the production frontier the operating unit is in period $t+1$ compared to period t and it is referred as the catching up effect, and the technical change (*TCH*) component which captures the change in the production technology as a shift in the production frontier. Thus, equation (3) is written as follows:

$$M_o(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}, \mathbf{x}^t, \mathbf{y}^t) = \frac{D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_o^t(\mathbf{x}^t, \mathbf{y}^t)} \times \left[\frac{D_o^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})} \times \frac{D_o^t(\mathbf{x}^t, \mathbf{y}^t)}{D_o^{t+1}(\mathbf{x}^t, \mathbf{y}^t)} \right]^{1/2}, \tag{4}$$

where: $$FCH = \frac{D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_o^t(\mathbf{x}^t, \mathbf{y}^t)} \tag{5}$$

and $$TCH = \left[\frac{D_o^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})} \times \frac{D_o^t(\mathbf{x}^t, \mathbf{y}^t)}{D_o^{t+1}(\mathbf{x}^t, \mathbf{y}^t)} \right]^{1/2} \tag{6}$$

Productivity advances occur if $M_o(\bullet)>1$. In a similar way, improvements in efficiency occur if $FCH>1$ and technical advances occur if $TCH>1$. Fare et al. (1994) showed that the efficiency change (*FCH*) component of the index could be written as the product of two components: the pure efficiency change (*PCH*) component and the scale efficiency change component (*SCH*). In particular:

$$PCH = \frac{D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1} \mid VRS)}{D_o^t(\mathbf{x}^t, \mathbf{y}^t \mid VRS)} \tag{7}$$

and $$SCH = \left[\frac{D_o^t(\mathbf{x}^t, \mathbf{y}^t \mid VRS)}{D_o^t(\mathbf{x}^t, \mathbf{y}^t)} \times \frac{D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1} \mid VRS)} \right]^{1/2}, \tag{8}$$

where *VRS* is variable returns to scale and $D_o(\bullet|VRS)$ indicates distance functions calculated under the assumption of variable returns to scale. Values of $SCH>1$ indicate that the operating unit has become more scale efficient.

In order to estimate the component distance functions of the Malmquist index, the data envelopment analysis (DEA), a non-parametric technique of linear programming, is used. More specifically, the Malmquist productivity index (4) is calculated by solving four linear programming problems, each one of which corresponds to each of the four distance functions: $D_o^t(\mathbf{x}^t, \mathbf{y}^t)$, $D_o^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})$, $D_o^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})$, $D_o^{t+1}(\mathbf{x}^t, \mathbf{y}^t)$. By assuming constant returns to scale, these distance functions are calculated by using the fact that the output distance function is reciprocal to Farrell's (1957) output-based technical efficiency measurement (Fare et al. 1994). Therefore, the distance function $D_o^t(\mathbf{x}^t, \mathbf{y}^t)$ for each $k'=1,\ldots,K$ is calculated as follows:

$$\left(D_o^t(\mathbf{x}^{k',t},\mathbf{y}^{k',t})\right)^{-1} = \max\theta^{k'} \tag{9}$$

subject to

$$\theta^{k'} y_m^{k',t} \leq \sum_{k=1}^{K} z^{k,t} y_m^{k,t} \qquad m = 1,...,M;$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq x_n^{k',t} \qquad n = 1,...,N;$$

$$z^{k,t} \geq 0 \qquad k = 1,...,K,$$

where *k=1,…,K* banks producing *m=1,…, M* outputs, $y_m^{k,t}$, at each time period *t=1,…,T*. These outputs are produced with the use of *n=1,…,N* inputs, $x_n^{k,t}$, and $z^{k,t}$ is the intensity variable identifying to what extent a particular bank is employed in production. The other three distance functions are calculated similarly, substituting the appropriate index (i.e. *t* or *t+1*). In order to derive the decomposition of the efficiency change (*FCH*) component (5) into the pure efficiency change (*PCH*) component (7) and the scale efficiency change (*SCH*) component (8), the calculation of two more distance functions is needed. These functions are: $D_o^t(\mathbf{x}^t,\mathbf{y}^t \mid VRS)$ and $D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1} \mid VRS)$ and, as indicated, they should be calculated under the variable returns to scale technology. This is achieved if the restriction $\sum_{k=1}^{K} z^{k,t} = 1$ is added in the linear programming problem (9).

B. Technical Efficiency

The Malmquist productivity index and its components presented previously are calculated on the basis of measures of technical efficiency. Technical efficiency measures are calculated for each bank each year of the period 1982-1997 based on the DEA model (9). Note that in this paper $D_o^t(\mathbf{x}^{k',t},\mathbf{y}^{k',t})$ or $1/\theta^{k'}$ defines the output oriented technical efficiency measure which varies between zero and one (Coelli et al. 1997). This technical efficiency measure is not only influenced by the pure technical efficiency, but also by the production scale. Thus, the above technical efficiency measure, which can be viewed as the overall technical efficiency (*OTE*), can be decomposed into pure technical efficiency (*PTE)* and scale efficiency (*SCE*) components. Therefore, the constant returns to scale technology assumption of model (9) is relaxed to those of variable returns to scale (VRS) and non-increasing returns to scale (NIRS) by incorporating the restrictions $\sum_{k=1}^{K} z^{k,t} = 1$ and $\sum_{k=1}^{K} z^{k,t} \leq 1$, respectively. Therefore, two more efficiency measures are produced based on $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid VRS)$ and $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid NIRS)$. In particular, the pure efficiency (*PTE*) measure is given by $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid VRS)$, since it excludes the production scale impact and the scale efficiency (*SCE*) measure which is defined as the ratio of $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t})$ to $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid VRS)$, that is:

$$SCE_{k'} = \frac{D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t})}{D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid VRS)}. \tag{10}$$

Note that $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t}) \leq D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid NIRS) \leq D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid VRS) \leq 1$. This indicates that $SCE_{k'} \leq 1$. If $SCE_{k'} = 1$, then bank k' is scale efficient; if $SCE_{k'} < 1$, then bank k' is scale inefficient due to either decreasing returns to scale (DRS) as $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid NIRS) = D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid VRS)$ or increasing returns to scale (IRS) as $D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid NIRS) < D_o^t(\mathbf{x}^{k',t}, \mathbf{y}^{k',t} \mid VRS)$.

The explanation of differences in efficiency among banks relies on a second step in the analysis which computes a limited dependent variable (Tobit) regression on the efficiency scores, i.e. *PTE* and *SCE*. Bank characteristics exogenous to the operating process but assumed to be sources of the different efficiency levels are incorporated in this step. The equation (right-censored at unity) for the Tobit model is:

$$Z_{k'}^* = \beta' X_{k'} + \varepsilon_{k'}, \tag{11}$$

where $\quad Z_{k'} = 1, \quad if \quad Z_{k'}^* \geq 1,$

or $\quad Z_{k'} = Z_{k'}^*, \quad if \quad Z_{k'}^* < 1,$

where β is a vector of estimated parameters, $Z_{k'}^*$ is the limited dependent variable, i.e. *PTE* or *SCE*, $X_{k'}$ is a vector of independent variables, i.e. bank specific characteristics, and $\varepsilon_{k'}$ is assumed to be a normal, i.i.d. error term.

Coelli et al. (1997) discuss several ways in which environmental variables can be accommodated in a DEA analysis. The term "environmental variables" is usually used to describe factors which could influence the efficiency of a firm. In this case, such factors are not traditional inputs and are assumed to be outside the control of the manager. The two-stage method used in this paper involves the solution of a DEA problem in a first-stage analysis which comprises only the traditional outputs and inputs. In the second stage, the efficiency scores obtained from the first stage are regressed on the environmental variables. The main disadvantage of this method is that if the variables used in the first stage are highly correlated with the variables used in the second stage, then the results could be biased. Although there are a number of alternative approaches to dealing with environmental variables, in most cases Coelli et al. (1997) recommend the use of the two-stage approach because of its several advantages. The main advantages of the two-stage approach are that it can accommodate more than one variable; it can accommodate both continuous and categorical variables; it makes no prior assumption regarding the direction of the effect of the categorical variable; hypothesis tests can be performed to test if the variables have any significant effect on efficiency; and the method is simple and easy to calculate.

III. Data

In the banking literature, there is some debate about what constitutes inputs and outputs for banks. Most banking studies have tended to adopt one of the two main approaches to the input and output specification, i.e., the intermediation approach and the production approach. The intermediation approach considers banks as financial intermediaries that convert deposits and purchased funds into loans and financial investments. This approach treats loans as outputs, while deposits and other liabilities are treated as inputs. Outputs are measured in value terms and costs include both interest expenses and production costs. On the other hand, the production approach considers banks as producers of loan services and deposit accounts using capital and labor as inputs. Outputs are measured in terms of the number of accounts serviced and costs include production costs but not interest expenses. This study uses the intermediation approach, which is the approach most commonly used in the literature (Favero and Papi 1995, Fukuyama 1995, among others).

Data used in this analysis are those used in Apergis and Rezitis (2004). More specifically, the data were obtained from the annual reports of six individual banks for the period 1982 to 1997. Four of the banks used in the sample were state banks, while the other two were private. State banks controlled approximately 80% of the market and dominated the Greek banking industry during the period under consideration. Private banks actually began to enter the banking sector just after 1987. The Greek financial-credit system is characterized by one of the smallest number of credit institutions in the EU. Its characteristics include the prevailing role of a few large state-owned banks, a small share of foreign-owned banks and the presence of a few Greek banks with international operation. The state banks included in the sample are the National Bank of Greece, the Commercial Bank of Greece, the Ionian Bank, and the Bank of Macedonia and Thrace. The private banks are the Alpha Credit Bank and the Ergo Bank.

This study specifies two output and three input variables (Noulas 1997). Variables in values are defined in real terms where 1992 is the base year. In particular, the two output variables (y_1 and y_2) are defined as the *value of loans and advances* (y_1), which includes short and long term loans and advances to industry and customers, and the *value of investment assets* (y_2), which includes shares and other variable-income securities, participation in companies, investments in fixed income securities and government securities. The three input variables (x_1, x_2 and x_3) are defined as *labor* (x_1), which is the total number of full-time employees, *capital expenses* (x_2), which is defined as fixed assets, including tangible fixed assets (such as buildings, lots, land, furniture, office equipment, etc. net of depreciation) and intangible fixed assets (such as research and development expenses, goodwill, software, underwriting expenses, restructuring expenses, etc.), and, finally, the *value of deposits* (x_3), which includes bank bonds and site, saving and time deposits. Table 1 reports the descriptive statistics of the variables used in the analysis for the period 1982-1997. The Data Envelopment Analysis Program (DEAP) of Coelli (1997) is used to compute productivity and efficiency measures presented in this paper. The multi-stage DEA is used to compute the efficiency measures such as overall technical efficiency (*OTE*), pure technical efficiency (*PTE*) and scale efficiency (*SCE*) measures.

Table 1. Descriptive statistics by bank for the period 1982-1997

Bank		Variables						
		y_1	y_2	x_1	x_2	x_3	c	m
1	Mean	165.314	161.555	3067.688	17.343	307.328	0.516	0.123
	St. Dev.	45.791	81.773	499.711	6.124	89.484	0.021	0.030
	Min	108.160	56.391	2480.000	7.668	168.380	0.496	0.080
	Max	271.131	304.312	3906.000	29.285	460.423	0.565	0.187
2	Mean	336.731	119.321	6589.875	13.370	667.950	0.730	0.174
	St. Dev.	29.810	136.545	736.261	4.073	93.795	0.140	0.010
	Min	271.357	26.136	5120.000	7.032	460.674	0.498	0.142
	Max	372.734	369.714	7658.000	21.856	830.132	0.876	0.188
3	Mean	61.684	8.347	1241.188	3.761	119.494	0.803	0.026
	St. Dev.	29.743	5.787	513.910	1.558	63.428	0.055	0.008
	Min	25.579	2.713	559.000	1.929	34.773	0.685	0.014
	Max	119.014	20.164	2221.000	6.653	242.012	0.871	0.040
4	Mean	1072.835	467.565	14614.813	47.077	2636.398	0.718	0.583
	St. Dev.	204.744	513.538	1339.755	10.906	500.181	0.160	0.047
	Min	652.726	73.545	11695.000	30.082	1709.432	0.500	0.490
	Max	1319.476	1390.725	16119.000	70.411	3521.124	0.894	0.646

Table 1. (Continued) Descriptive statistics by bank for the period 1982-1997

Bank		Variables						
		y_1	y_2	x_1	x_2	x_3	c	m
5	Mean	148.838	65.812	2989.250	6.711	327.204	0.729	0.080
	St. Dev.	20.146	79.501	589.526	2.195	66.443	0.154	0.009
	Min	124.932	7.380	2195.000	3.869	209.461	0.500	0.067
	Max	200.810	245.264	4097.000	13.103	436.440	0.899	0.098
6	Mean	37.119	7.108	948.313	1.738	53.548	0.836	0.016
	St. Dev.	14.798	10.771	432.331	0.887	30.131	0.193	0.006
	Min	5.302	0.207	178.000	0.589	2.753	0.513	0.003
	Max	59.018	28.470	1520.000	2.957	97.893	0.990	0.022

Notes: y_1 is value of loans, y_2 is value of investment assets, x_1 is number of full-time employees, x_2 is capital expenses, x_3 is value of deposits, c is concentration index, m is market share. Variables in values are in million drachmas and are defined in real terms (1992 base year).

The efficiency scores, i.e. *PTE* and *SCE*, are regressed on the bank specific factors using a Tobit model, since levels of efficiency vary from zero to one. Consequently, the Tobit models for examining the relationship between each efficiency measure and bank specific characteristics in this paper can be constructed as follows:

$$PTE_{k'} = f_1(m_{k'},\ c_{k'},\ t,\ t^2,\ d_2,\ d_3,\ d_4,\ d_5\ \ d_6,\ d_{1993}) \qquad (12)$$

$$SCE_{k'} = f_2(m_{k'},\ c_{k'},\ t,\ t^2,\ d_2,\ d_3,\ d_4,\ d_5\ \ d_6,\ d_{1993}), \qquad (13)$$

where $m_{k'}$ is the market share of bank k'; $c_{k'}$ is the service concentration, which is the sum of the squared ratios of the value of each output to total value of outputs of bank *k*'; t (t^2) is the time trend (squared); d_i, where i=1, 2…6, is a bank specific dummy variable, which corresponds to each bank in the sample; d_{1993} is a dummy variable, which takes the value of zero for the period 1982-1992 and the value of one for the period 1993-1997. The market share is utilized in order to capture size. A positive (negative) effect of the market share indicates that efficiency increases (decreases) with size. The service concentration is used to measure a bank's degree of specialization. Values of service concentration close to one indicate that a bank is specialized in a single product. A positive (negative) effect on this variable suggests that specialization increases (decreases) efficiency. A positive (negative) effect of the time trend shows that efficiency increases (decreases) over time while the effect of the time trend squared shows the rate of efficiency change over time. The effect of each bank specific dummy variable indicates how the efficiency level of each bank is shifting in relation to the efficiency of bank 1. Finally, the effect of the d_{1993} dummy variable indicates whether the efficiency level for the 1993-1997 period, during which substantial financial changes took place, is different from that of the 1982-1992 period. The bank specific dummy variables are included to capture differences between banks with reference to factors such as ownership status (public versus private), managerial quality and labor relations, among others. It is worth mentioning that some of the traditional features of the Greek banking system, which mainly characterize the state-controlled banks, are strict labor relations, inadequate staff motivation and inadequate management. Since the behavioral objectives are different between public and private banks, it would also be appropriate for the sake of comparison to divide the sample into public/private sub-samples and perform DEA for each sub-sample (Coelli et al. 1997). However, in the present study this approach is not suitable due to the small sample size, since only two private and four public banks were examined.

IV. Empirical Results

A. Technical Efficiency

Table 2 presents the mean level of the various efficiency measures, i.e. overall (*OTE*), pure (*PTE*) and scale efficiency (*SCE*) for each year of the period 1982-1997, for the whole period and for the two sub-periods 1982-1992 and 1993-1997.[1] It is worth noting that these two sub-periods are considered because, as discussed in the Introduction, substantial changes took place in the Greek banking industry after 1992. The results indicate that the mean level of overall efficiency is 0.913 for the whole period and for the two sub-periods. This implies that banks could have increased outputs by 8.7%, on average while still using the same level of inputs.

The average values of the two technical efficiency components, i.e. *PTE* and *SCE*, for the period 1982-1997 (sub-periods: 1982-1992 and 1993-1997) are 0.982 (0.977, 0.994) for pure technical efficiency and 0.929 (0.934, 0.918) for scale efficiency. This indicates that pure technical inefficiency constitutes a smaller source of inefficiency than scale inefficiency for the banks in the sample under consideration. In other words, the major loss of efficiency for the sample banks is identified as improper scale operation. A comparison of the technical efficiency components of

[1] The statistics in Table 2 are also available by bank from the author.

Table 2. Mean technical efficiency measures and frequency distribution of bank returns to scale

Year	Mean technical efficiency measures			Frequency distribution of returns to scale		
	OTE	*PTE*	*SCE*	*IRS*	*CRS*	*DRS*
	Level of technical efficiency			Number of banks		
1982	0.789	0.935	0.843	3	3	0
1983	0.804	0.946	0.850	2	4	0
1984	0.925	0.947	0.977	2	4	0
1985	0.932	0.965	0.966	1	5	0
1986	0.935	0.987	0.947	2	4	0
1987	0.922	0.982	0.939	2	4	0
1988	0.896	0.985	0.910	3	3	0
1989	0.957	1.000	0.957	2	4	0
1990	0.979	0.999	0.980	0	5	1
1991	0.933	0.999	0.934	1	4	1
1992	0.972	1.000	0.972	2	4	0
1993	0.915	1.000	0.915	2	4	0
1994	0.945	1.000	0.945	2	3	1
1995	0.968	1.000	0.968	2	4	0
1996	0.855	0.991	0.863	4	2	0
1997	0.882	0.979	0.901	5	1	0
1982-1997	0.913	0.982	0.929	35 (36.46%)	58 (60.42%)	3 (3.13%)
1982-1992	0.913	0.977	0.934	20 (30.30%)	44 (66.67%)	2 (3.03%)
1993-1997	0.913	0.994	0.918	15 (50.00%)	14 (46.67%)	1 (3.34%)

Notes: *OTE* is overall technical efficiency, *PTE* is pure technical efficiency, *SCE* is scale efficiency, *IRS* is increasing returns to scale, *CRS* is constant returns to scale, *DRS* is decreasing returns to scale. Figures in parenthesis give cumulative frequency distribution results.

the two sub-periods shows that the sub-period 1982-1992 has a lower (higher) mean level of pure (scale) efficiency than that of the sub-period 1993-1997. The empirical finding that the pure technical efficiency is higher in the second sub-period than in the first one, is attributed to the increased competition and internationalization of the Greek banking system, which happened in the second sub-period due to the accelerated liberalization and deregulation of the financial system. These factors, together with the fast adoption of information technology by the banks, have caused major structural changes in the Greek banking industry during the second sub-period, which may have moved the banks away from an optimal scale of operation. This is indicated by the finding that scale efficiency is lower in the second sub-period than in the first. The increased competition of the Greek banking sector during the second sub-period is supported by the study of Hondroyiannis et al. (1999) which provides evidence that the Greek banking industry has decreased its oligopolistic character and has moved towards conditions of monopolistic competition during the period 1993-1995.

Table 2 also presents the frequency distribution of bank returns to scale for each year of the period 1982-1997. It also shows the cumulative frequency distribution for the whole period and for the two sub-periods. The results indicate that while most of the banks operated under *CRS* in the first sub-period, they moved to *IRS* in the second one. This finding further accords with the aforementioned argument that the use of information technology during the second sub-period has moved the banks away from an optimal scale of operation. The finding that banks operated under *CRS* in the first sub-period is supported by the study of Kalafocas and Mantakas (1996), which indicates that scale economies did not exist in the Greek banking industry during the 1980-1989 period.

Table 3 presents Tobit results of pure (*PTE*) and scale (*SCE*) efficiency scores on the bank specific factors according to models (12) and (13). It should be stated that most of the estimated coefficients in both models are statistically significant and indicate that the models fit the data well. Furthermore, the high values of the R-Squared, i.e. 0.83 for the *PTE* and 0.86 for the *SCE* model, show that the explanatory power of the Tobit models are significant. The results show that market share has a positive impact on both *PTE* and *SCE* scores at the 0.05 significance level. That is, banks exploit economics of scale as their sizes expand. A positive relationship exists between the banks' service concentration and both *PTE* and *SCE* scores at the 0.1 and 0.05 significance level, respectively. In other words, banks with a higher service concentration enjoy higher *PTE* and *SCE* due to the existence of gains from specialization. The effect of the time trend variable is positive on both *PTE* and *SCE* scores at the 0.01 significant level, implying that *PTE* and *SCE* increase with time. However, the impact of the time trend squared variable is negative on both efficiency scores at the 0.05 significant level, indicating that the rate of change of both *PTE* and *SCE* decreases with time. The coefficients of the bank specific dummies (d_2-d_6) show that there is significant variation of both efficiency scores throughout the sample banks. Finally, the coefficient of the d_{1993} dummy variable has a positive effect on the *PTE* score at the 0.05 significant level, but a negative effect on the *SCE* score at the same significant level. This implies that banks in the 1993-1997 sub-period have higher (lower) *PTE* (*SCE*) scores than those in the 1982-1992 sub-period.

Table 3. Tobit results of pure technical efficiency and scale efficiency

Variable	*PTE*	*SCE*
Intercept	0.8310 ***	0.7384 ***
	(0.05)	(0.09)
m	1.1571 **	1.8165 **
	(0.50) *	(0.87)
c	0.6212	1.8268 **
	(0.33)	(0.87)
t	0.0159 ***	0.0279 ***
	(0.01)	(0.01)
t^2	-0.00076 **	-0.0015 **
	(0.00)	(0.00)
d_2	-0.0885 **	-0.1270 *
	(0.04)	(0.07)
d_3	-0.0059	-0.0442 **
	(0.04)	(0.02)
d_4	0.4932 **	0.5992 **
	(0.20)	(0.27)
d_5	-0.0039	-0.0018 *
	(0.02)	(0.00)
d_6	0.0891 **	0.0458 **
	(0.04)	(0.02)
d_{1993}	0.0278 **	-0.0183 **
	(0.01)	(0.01)
σ	0.0514 ***	0.0972 ***
	(0.00)	(0.01)
Log likelihood	148.64	187.58
R-squared	0.83	0.86

Notes: *PTE* is pure technical efficiency, *SCE* is scale efficiency, Int. is intercept, *m* is market share, *c* is concentration index, *t* is time trend, *d* is bank specific dummy, d_{1993} is 0 before 1993 and - 1 otherwise, σ is the standard deviation of the residuals of the model. ***, ** and * indicate that the coefficients are significantly different from 0 at the 0.01. 0.05 and 0.1 levels, respectively. The figures in parentheses are standard errors.

B. Productivity change

Table 4 presents the Malmquist productivity index, i.e., total factor productivity change (*TFP*), and its components, technical efficiency change (*FCH*), technical change (*TCH*), pure efficiency change (*PCH*) and scale efficiency change (*SCH*), for the period 1982-1997 and for the two sub-periods 1982-1992 and 1993-1997.[2] If the value of the Malmquist productivity index or any of its components is less (greater) than one, it denotes deterioration (improvement) in performance. The results indicate that total factor productivity (*TFP*) increased at an average rate of 2.4% per year over the entire 1982-1997 period. On average, this improvement is ascribed to a technical progress (*TCH*) of 1.2% and to an efficiency improvement (*FCH*) of 1.2%. The latter, in turn, is attributed to a scale efficiency improvement (*SCH*) of 0.8% and to a smaller pure efficiency improvement (*PCH*) of 0.4%.

Table 4. Malmquist productivity index and its components

Year	*FCH*	*TCH*	*PCH*	*SCH*	*TFP*
1982-1983	1.015	1.047	1.014	1.001	1.063
1983-1984	1.222	0.716	1.002	1.220	0.874
1984-1985	1.012	1.109	1.025	0.988	1.123
1985-1986	1.010	1.120	1.027	0.984	1.131
1986-1987	0.986	1.064	0.995	0.992	1.049
1987-1988	0.973	1.103	1.003	0.970	1.073
1988-1989	1.073	1.023	1.016	1.057	1.098
1989-1990	1.025	0.789	0.999	1.026	0.809
1990-1991	0.948	1.105	0.999	0.949	1.047
1991-1992	1.047	0.977	1.001	1.046	1.023
1992-1993	0.932	1.017	1.000	0.932	0.948
1993-1994	1.039	1.032	1.000	1.039	1.073
1994-1995	1.028	1.059	1.000	1.028	1.088
1995-1996	0.874	1.122	0.991	0.882	0.980
1996-1997	1.038	1.002	0.988	1.051	1.040
1982-1997	1.012	1.012	1.004	1.008	1.024
1982-1992	1.020	0.997	1.007	1.012	1.017
1993-1997	0.992	1.053	0.995	0.998	1.044

Notes: *FCH* is technical efficiency change, *TCH* is technical change, *PCH* is pure efficiency change, *SCH* is scale efficiency change, *TFP* is the total factor productivity change (Malmquist productivity index).

[2] The statistics in Table 4 are also available by bank from the author.

Comparing the two sub-periods, 1982-1992 and 1993-1997, the second sub-period has a higher *TFP* than the first one, with an average rate of 4.4% versus 1.7% per year. The finding that *TFP*, on average, is higher in the second sub-period could be attributed to the increased competition and internationalization of the Greek banking system, which took place in the second sub-period due to the accelerated liberalization and deregulation of the financial system. It is worth mentioning again the study of Hondroyiannis et al. (1999), which provides evidence of increased competition in the Greek banking sector during the second sub-period.

It is evident that the source of the total factor productivity growth, in the case of the second sub-period, comes entirely from an average technical progress of 5.3% per year, since there is an average deterioration in efficiency of –0.8% per year. The aforementioned deterioration, in turn, is ascribed to a pure efficiency deterioration of -0.5% and to a scale efficiency deterioration of -0.2%. Note that the opposite is true for the first sub-period in which the source of the total factor productivity growth comes exclusively from an average improvement in efficiency of 2% per year, since there is an average technical regress of -0.3% per year. This efficiency improvement is due to a slight pure efficiency improvement of 0.7% and to a strong scale efficiency improvement of 1.2%.

The empirical finding that total factor productivity growth, which originates exclusively from technical change, is higher in the second sub-period than in the first, is attributed to the rapid adoption of new information technology by Greek banks. The deterioration in efficiency observed during the second sub-period could be attributed to the presence of adjustment costs related to the use of this new technology. As for the first sub-period, given the empirical finding of technical regress, banks used the existing technology as efficiently as possible and, for this reason, total factor productivity growth during this sub-period resulted solely from improvements in efficiency.

V. Conclusions

This study examines productivity growth and technical efficiency in the Greek banking industry for the period 1982-1997. Furthermore, it compares productivity growth before and after 1992, since after 1992 the Greek banking industry has experienced a rapid acceleration of liberalization and deregulation. This paper uses the Malmquist productivity index to measure and decompose the total factor productivity growth, as well as the DEA method to measure technical efficiency. It should be noted that one of the main limitations of the DEA method is the presence of outliers which may influence the empirical results, especially in the present study, since the sample used consists of only six banks. However, the results of the present study, in terms of bank level efficiency and productivity measures, do not show big discrepancies among banks. This indicates an absence of outliers in the sample.

The results indicate that productivity growth increased on average by 2.4% per year over the entire period. The findings of increased productivity growth after deregulation in the present study are in accordance with banking industry results obtained in other studies. For instance, the paper by Casu et al. (2003) suggests clear productivity growth for Italian and Spanish banks during deregulation, a growth mainly ascribed to technical progress. Additional papers indicating improvement in productivity due to deregulation are the studies by Mukherjee et al. (2001) for US banks, Gilbert and Wilson (1998) for Korean banks, and Leightner and Lovell (1998) for Thai banks. Most of the aforementioned studies attribute their findings of accelerated productivity to technical progress. There is, however, a number of empirical studies which does not support the claim that deregulation increases productivity in the banking sector, i.e., the studies by Humphrey and Pulley (1997) for US banks, and Casu et al. (2003) for French and German banks.

The empirical results show that the average level of overall technical efficiency is 91.3%, suggesting that banks could have increased outputs by 8.7% with the existing level of inputs. The high overall technical efficiency scores of the present study are in line with banking industry results obtained in other studies. For example, high technical efficiency scores are presented by Christopoulos and Tsionas (2001) for Greek banks, Favero and Papi (1995) for Italian banks, and Elyasiani and Mehdian (1995) for US banks. The finding of the present paper that the mean overall technical efficiency is the same for the two sub-periods agrees with the study of Berger and Humphrey (1997) suggesting that the conventional wisdom which implies that deregulation improves efficiency is not always supported by empirical studies. For instance, among the studies indicating that efficiency was relatively unchanged by deregulation are the studies by Elyasiani and Mehdian (1995) for US banks and Hao et al. (2001) for Korean banks. Furthermore, research by Khumbakar et al. (2001) on Spanish banks reported that efficiency was diminished after deregulation. On the other hand, among the studies reporting improvements in efficiency after deregulation are the studies by Berg et al. (1992) of Norwegian and Australian banks, and Canhoto and Dermine (2003) of Portuguese banks.

References

Apergis, Nicholas, and Anthony Rezitis (2004), "Cost structure, technical change and productivity growth in the Greek banking sector", *International Advances in Economic Research* **10**: 1-15.

Berger, Allen N., and David B. Humphrey (1997), "Efficiency of financial institutions: International survey and directions for future research", *European Journal of Operational Research* **98**: 175-212.

Berg, Sigbjon A., Finn R. Forsund, and Eilev S. Jansen (1992), "Malmquist indices of productivity growth during the deregulation of Norwegian banking, 1980-1989", *Scandinavian Journal of Economics* **94** (Supplement): 211-228.

Canhoto, Ana, and Jean Dermine (2003), "A note on banking efficiency in Portugal, new vs. old banks", *Journal of Banking & Finance* **27**: 2087-2098.

Casu, Barbara, Claudia Girardone, and Philip Molyneux (2003), "Productivity change in European banking: A comparison of parametric and non-parametric approaches", *Journal of Banking and Finance* (in press).

Christopoulos, Dimitris K., and Efthimios G. Tsionas (2001), "Banking economic efficiency in the deregulation period: Results from heteroscedastic stochastic frontier models", *The Manchester School* **69**: 656-676.

Coelli, Tim, Dodla Sai Prasada Rao, and George E. Battese (1997), *An Introduction to Efficiency and Productiviry Analysis*, Boston, Kluwer Academic Publishers.

Coelli, Tim (1997), "A guide to DEAP version 2.1: A data envelopment analysis (computer) program", Working Paper 96/08, Centre for Efficiency and Productivity Analysis.

Elyasiani, Elyas, and Seyed M. Mehdian (1995), "The comparative efficiency performance of small and large commercial banks in the pre and post deregulation eras", *Applied Economics* **27**: 1069-1079.

Fare, Rolf, Shawna Grosskopf, and C. A. Knox Lovell (1994), *Production Frontiers*, Cambridge University Press.

Fare, Rolf, Shawna Grosskopf, Bjorn Lindgren, and Paul Ross (1989), "Productivity developments in a Swedish hospital: A Malmquist output index approach", Discussion Paper 89-3, Southern Illinois University, Illinois.

Farrell, Michael J. (1957), "The measurement of productive efficiency", *Journal of the Royal Statistical Society, Series A* **120**: 253-82.

Favero, Carlo A., and Luca Papi (1995), "Technical efficiency and scale efficiency in the Italian banking sector: A non-parametric approach", *Applied Economics* **27**: 385-395.

Fukuyama, Hirofumi (1995), "Measuring efficiency and productivity growth in Japanese banking: A non-parametric approach", *Applied Financial Economics* **5**: 95-117.

Giokas, D. I. (1991), "Bank branch operational efficiency: A comparative application of DEA and the loglinear model", *Omega International Journal of Management Science* **19**: 549-557.

Gilbert, R. Alton, and Paul W. Wilson (1998), "Effects of deregulation on the productivity of Korean banks", *Journal of Economics and Business* **50**: 133-155.

Goddard, John, Philip Molyneux, and John O. S. Wilson (2001), *European Banking: Efficiency, Technology and Growth*, Chichester, UK, John Wiley and Sons.

Hao, Jonathan, William C. Hunter, and Won K. Yang (2001), "Deregulation and efficiency: The case of private Korean banks", *Journal of Economics and Business* **53**: 237- 254.

Hondroyiannis, George, Sarantis E. Lolos, and Evangelia Papapetrou (1999), "Assessing competitive conditions in the Greek banking system", *Journal of International Financial Markets, Institutions and Money* **9**: 377-391.

Humphrey, David B. and Lawrence B. Pulley (1997), "Banks' responses to deregulation: Profits, technology, and efficiency", *Journal of Money, Credit and Banking* **29**: 23-93.

Karafolas, S. and G. Mantakas (1996), "A note on cost structure and economies of scale in Greek banking", *Journal of Banking and Finance* **20**: 377-387.

Khumbakar, Subal C., Ana Lozano-Vivas, C. A. Knox Lovell, and Iftekhar Hasan (2001), "The effects of deregulation on the performance of financial institutions: The case of Spanish saving banks", *Journal of Money, Credit, and Banking* **33**: 101-121.

Leightner, Jonathan E. and C. A. Knox Lovell (1998), "The impact of financial liberalization on the performance of the Thai banks", *Journal of Economics and Business* **50**: 115-131.

Mukherjee, Kankana, Subhash C. Ray, and Stephen M. Miller (2001), "Productivity growth in large US commercial banks: The initial post-deregulation experience", *Journal of Banking and Finance* **25**: 913-939.

Noulas, Athanasios G. (1997), "Productivity growth in the Hellenic banking industry: State versus private banks", *Applied Financial Economics* **7:** 223-228.

Vassiloglou, M. and D. I. Giokas (1990), "A study of the relative efficiency of bank branches: An application of data envelopment analysis", *Journal of Operational Research Society* **41**: 591-597.