Cost Structure, Technological Change, and Productivity Growth in the Greek Banking Sector

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Abstract

This paper first empirically investigates the cost structure of the Greek banking sector. Secondly, it provides measures of economies (diseconomies) of scale and quantifies technical change and its sources. Finally, this paper measures total factor productivity growth and identifies its sources. Bank production is presented with two different approaches (the intermediation and the production approach) which are used to specify a translog cost function. The two different translog cost models are estimated through the full information maximum likelihood method of estimation on pooled time series and cross sectional data. The results obtained are not significantly affected by model specification. Both models indicate significant economies of scale and negative annual rates of growth in technical change and in total factor productivity.(JEL G24, G21)

Introduction

In recent years, several studies attempted to investigate, empirically and theoretically, the structure and performance of financial institutions. Most recently, these attempts have been intensified due to significant changes that are taking place in financial industries around the world. For instance, in the United States, deregulation aims toward nationwide banking, particularly through the elimination of geographic restrictions. In 1993, the European Committee of the European Union issued a Second Banking Directive. It was designed for the liberalization of financial markets so that banks could operate freely throughout the European Union. In order to investigate the impact of deregulation on the banking industry, it is necessary to know the cost structure of the industry.

Over the past 12 years, the Greek banking industry has undergone substantial changes due to the fact that Greece became a member state of the European Union. This paper investigates the cost structure, technical change, and productivity growth of the Greek banking industry. Two different approaches, the intermediation and the production approach, are used to specify a translog cost function and, thus, two different models are investigated. The intermediation approach treats deposits and other liabilities as inputs, while the production approach treats them as outputs. Both approaches are investigated because they have been extensively used in the literature, [Benson et al., 1982; Hunter and Timme, 1986; Ashton, 1998; Lang and Welzel, 1998].

Based on the translog cost function, this paper first empirically investigates the cost structure of the Greek banking industry. Second, it obtains measures of economies (disec-

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onomies) of scale. Third, it measures the rate of technical change and its sources and, finally, it measures the rate of growth in total factor productivity and its sources.

Empirical studies investigating the cost structure of the U.S. banking system include the works of Hunter and Timme [1986], Humphrey [1993], Bauer et al. [1993], and Mahajan et al. [1996], among others. Studies examining the cost structure of banks outside the U.S. include the works of Kim and Ben-Zion [1898] for Israeli banking, Parsons et al. [1993] for Canadian banking, Dietsch [1993] and Muldur and Sassenou [1993] for French banking, Ashton [1998] for U.K. banking, and Lang and Welzel [1998] for German banking.

This paper is organized as follows. The first section presents the model, while the second section gives the model specification. The next two sections present the data and discuss the statistical results. The final section provides the conclusions and the policy implications.

Model Definition

In the banking literature there is some debate about what constitutes inputs and outputs for banks. Generally speaking, researchers follow one of the two main approaches of the input and output specification, such as the intermediation approach and the production approach. In this paper, both approaches are used to specify cost functions of the Greek banking industry. Furthermore, banks are assumed to minimize costs for both model specifications.

The intermediation approach [Sealey and Lindley, 1977; Lang and Welzel, 1998; Ashton, 1998] considers banks as financial intermediaries that convert deposits and purchased funds into loans and financial investments. This approach treats loans and other financial assets as outputs, while deposits and other liabilities are treated as inputs. In this paper, a cost function related to the intermediation approach may be presented as:

$$C = g(y_1, y_2, w_1, w_2, w_3) \quad , \tag{1}$$

where y_1 and y_2 represent loans and investment assets and w_1, w_2, and w_3 correspond to the price of labor, capital, and borrowed funds. Thus, according to this approach, the banking industry is viewed as transforming labor, capital, and borrowed funds into loans and investment assets.

The production approach [Benson et al., 1982; Hunter and Timme, 1986; Ashton, 1998] considers banks as transforming labor and capital inputs into two output groups of assets and liabilities. In this paper, a cost function corresponding to the production approach may be presented as:

$$C = g(y_1, y_2, y_3, w_1, w_2) \quad , \tag{2}$$

where, y_1, y_2, and y_3 represent loans, investment assets, and deposits and w_1 and w_2 correspond to the price of labor and capital.

Model Specification

The translog joint cost function for m outputs and n inputs can be written as follows:

$$\ln C = a_0 + \sum_{i=1}^{m} a_i \ln y_i + \sum_{i=1}^{n} \beta_j \ln w_j + \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \delta_{ij} \ln y_i \ln y_j$$
$$+\frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln w_i \ln w_j + \sum_{i=1}^{m} \sum_{j=1}^{n} \rho_{ij} \ln y_i \ln w_j + a_t T +$$
$$\frac{1}{2} a_{tt} T^2 + \sum_{i=1}^{m} \delta_{it} \ln y_i T + \sum_{j=1}^{n} \gamma_{jt} \ln w_j T + \sum_{k} f_k BN_k \quad (3)$$

where C is the total cost, y_i is the quantity of output i, w_j is the price of input j, T is the time trend, and BN_k is a bank specific dummy. By Shephard's lemma, the translog cost function yields the following cost share equations and is used with the translog cost function (3) to form the system to be estimated:

$$S_j = \frac{\partial \ln C}{\partial \ln w_j} = \beta_j + \sum_{i=1}^{n} \gamma_{ij} \ln w_i + \sum_{i=1}^{m} \rho_{ij} \ln y_i + \gamma_{jt} T \qquad (j = 1, 2, ...n) \quad . \quad (4)$$

The cost function must satisfy the following regular properties: twice continuous differentiability, linear homogeneity in input prices, and monotonicity and concavity in input prices. Twice continuous differentiability implies that the second order derivatives of the cost function should be invariant with respect to the order of differentiation. This holds when the following symmetric equalities are satisfied:

$$\delta_{ij} = \delta_{ji} \quad and \quad \gamma_{ij} = \gamma_{ji}, \quad i \neq j \quad . \quad (5)$$

Linear homogeneity in input prices implies that the share equations are homogeneous of degree zero in prices (so that only relative prices matter) and requires:

$$\sum_{j=1}^{n} \beta_j = 1; \sum_{i=1}^{n} \gamma_{ij} = 0 \ (j = 1, 2, ...n); \sum_{j=1}^{n} \rho_{ij} = 0 \ (i = 1, 2, ...m) \ and \sum_{j=1}^{n} \gamma_{jt} = 0 \quad . \quad (6)$$

The monotonicity property requires that the estimated share equations have the correct sign (which is positive for all input shares). Finally, concavity of the cost function implies that the Hessian matrix is negative semidefinite (which is all the principal minors alternate in sign). In this paper, the symmetry (5) and homogeneity (6) restrictions are imposed while monotonicity and concavity are checked after estimation.

The translog cost function does not require the structure of production to be homogeneous in outputs, nor does it impose a homothetic production structure. However, these restrictions are tested statistically and if these restrictions do not hold then the translog cost function (3) is the preferred model. Otherwise, a simplified model is more appropriate than the translog cost function. Thus, the following homogeneity and homotheticity restrictions are tested on the translog model:

$$\sum_{i=1}^{m} \delta_{ij} = 0 \ (j = 1, 2, ..., m) \ and \sum_{i=1}^{m} \rho_{ij} = 0 \ (j = 1, 2, ..., n), \ \text{homogeneity} \quad , \quad (7)$$

$$\rho_{ij} = 0 \ (i = 1, 2, ..., m) \ (j = 1, 2, ..., n), \ \text{homotheticity} \quad . \quad (8)$$

The parameter estimates of the econometric model (cost equation (3) and share equations (4)) have little economic meaning of their own. However, by using these parameter estimates, one is able to calculate and analyze various elasticities and productivity indexes which have standard interpretations. The following elasticities and productivity indexes are considered in this paper.

First, the Allen-Uzawa partial elasticities of substitution (σ_{ij}) and the price elasticities of input demands (ε_{ij}) are considered and calculated from the estimated coefficients of the translog cost function (3) from the following formulas:

$$\sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j},\ i \neq j \quad and \quad \sigma_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i^2},\ i = j \quad , \tag{9}$$

$$\varepsilon_{ij} = \frac{\gamma_{ij}}{S_i} + S_j,\ i \neq j \quad and \quad \varepsilon_{ii} = \frac{\gamma_{ii}}{S_i} + S_i - 1,\ i = j \quad . \tag{10}$$

The cross-partial elasticities of substitution (σ_{ij}) can be either positive, indicating input substituility, or negative, indicating input complementarity. Concavity of the cost function requires that all own-price partial elasticities of substitution (σ_{ii}) are negative at all data points.

Second, long run scale economies (SCE) are considered and are calculated as 1 minus the cost elasticity along an output ray [Brown et al., 1979]. Thus, long run scale economies (SCE) are derived from the following formula:

$$SCE = 1 - \sum_{i=1}^{m} \frac{\partial \ln C}{\partial \ln y_i} \quad , \tag{11}$$

where $\partial lnC/\partial lny_i$ is the marginal cost of product i and is given from:

$$\frac{\partial \ln C}{\partial \ln y_i} = \alpha_i + \sum_{j=1}^{m} \delta_{ij} \ln y_j + \sum_{j=1}^{n} \rho_{ij} \ln w_j + \delta_{it} T \quad (i = 1, 2, ..., m) \quad . \tag{12}$$

SCE indicate the change of total cost as all inputs are changed and the input prices remain constant. SCE are positive for scale economies and negative for scale diseconomies. When SCE are multiplied by 100, it can be interpreted as the percentage difference between total cost and total revenue, which would arise from pricing all outputs at marginal cost [Brown et al., 1979].

Third, the rate of technical change (TCH) and the rate of growth, in total factor productivity (TFP), are calculated from the following formulas [Caves et al., 1981]:

$$TCH = -\frac{\partial \ln C}{\partial t} = -(\alpha_t + \alpha_{tt} T + \sum_{i=1}^{m} \delta_{it} \ln y_i + \sum_{j=1}^{n} \gamma_{jt} \ln w_j) \quad , \tag{13}$$

$$TFP = -\left(\frac{\partial \ln C}{\partial t}\right)\left(\sum_{i=1}^{m} \frac{\partial \ln C}{\partial \ln y_i}\right)^{-1} = -\frac{\alpha_t + \alpha_{tt} T + \sum_{i=1}^{m} \delta_{it} \ln y_i + \sum_{j=1}^{n} \gamma_{jt} \ln w_j}{\sum_{i=1}^{m} \left(\alpha_i + \sum_{j=1}^{m} \delta_{ij} \ln y_j + \sum_{j=1}^{n} \rho_{ij} \ln w_j + \delta_{it} T\right)} \quad . \tag{14}$$

Equation (13) indicates that the general contribution of technical change can be obtained from the negative of the elasticity of cost with respect to time. The negative sign has intuitive appeal because a positive effect from technical change means a reduction in cost. Equation (14) defines productivity growth as the common rate at which all outputs can grow over time with inputs held fixed.

Using equation (13), TCH can be decomposed into the neutral technological effect (T_1), the scale augmenting technological effect (T_2), and the non-neutral technological effect (T_3). T_1 represents a shift of the cost function geometrically towards the origin and is equivalent to Hick's neutral technical change, where the marginal rate of substitution among factors of production is unchanged. T_1 captures the effects of technological factors, such as learning by doing, managerial and organizational changes, and institutional regulations. T_2 is related to the changes in the scale of banks within the sample, and T_3 corresponds to changes in the quality or efficiency of the factors of production. The formulas of these effects are given below:

$$T_1 = -(\alpha_t + \alpha_{tt}T), \quad T_2 = -\left(\sum_{i=1}^{m} \delta_{it} \ln y_i\right), \quad T_3 = -\left(\sum_{j=1}^{n} \gamma_{jt} \ln w_j\right) \quad . \tag{15}$$

Using equation (14), TFP can be decomposed into the neutral technological effect (F_1), the scale augmenting technological effect (F_2), and the non-neutral technological effect (F_3). The formulas of these effects are given below:

$$\begin{aligned} F_1 &= -(a_t + a_{tt}T)\left(\sum_{i=l}^{m} \frac{\partial \ln C}{\partial \ln y_i}\right)^{-1} \\ F_2 &= -\left(\sum_{i=1}^{m} \delta_{it} \ln y_i\right)\left(\sum_{i=1}^{m} \frac{\partial \ln C}{\partial \ln y_i}\right)^{-1} \\ F_3 &= -\left(\sum_{j=1}^{n} \gamma_{it} \ln w_j\right)\left(\sum_{i=1}^{m} \frac{\partial \ln C}{\partial \ln y_i}\right)^{-1} \quad . \end{aligned} \tag{16}$$

Alternative approaches (index number approaches) have been used for measuring technical change and total factor productivity growth. In the majority of empirical studies concerning the banking sector, a time trend is used to capture technical change. In addition, a number of studies have compared the time trend approach to various index number approaches and concluded that in most instances, the former approach outperforms the latter approaches [Baltagi and Griffin, 1988; Humphrey, 1993; Esho and Sharpe, 1995].

Data

Data for the analysis were obtained from the annual reports of six individual banks for the 1982-97 time period. Four of the banks used in the sample are state banks, while the other two are private. State banks control approximately 80 percent of the market and dominate the Greek banking industry. Private banks entered the banking sector in 1987. 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 Labor Bank.

This study specifies three types of outputs: loans (y_1), investment assets (y_2), and time and demand deposits, (y_3). The intermediation approach only uses the first two outputs in the specification of the translog cost function, while the production approach utilizes all of them. Furthermore, this study specifies three input prices: wage rate, the price of capital, and the price of deposits. Note that while the intermediation approach employs all of the above prices in specifying the translog cost function, the production approach only uses the first two. The wage rate (w_1) is obtained by dividing staff expenses by the total number of reported employees. The price of capital (w_2) is computed by dividing capital equipment and occupancy expenses (including depreciation, rental expenses, maintenance and repairs to property and equipment, and property taxes) by fixed assets, net of depreciation. The price of deposits (w_3) is calculated by dividing total interest expenses by the quantity of deposits. Note, the LIMDEP [Green, 1995] software assisted the empirical analysis.

Model Estimation and Statistical Results

Method of Estimation and Estimates

A complete estimated system of equations consists of the translog cost function (3) and the cost share equations (4). The equation system for the intermediation model contains the translog cost function and two share equations (labor and capital), while the production model contains the translog cost function and only one share equation (labor). This is because one share equation has to be dropped from the model since only $n - 1$ equations are linearly independent, due to the homogeneity constrain (6). Thus, the cost share of deposits equation is dropped from the intermediation estimated system, while the cost share of capital equation is dropped from the production system. The estimates are invariant with respect to the choice of the omitted equations [Christensen et al., 1973]. The estimates of the deleted equations (the cost shares of deposits and capital) are obtained by using the adding-up constraints. In order to implement estimation for the two systems of equations (intermediation and production), a stochastic disturbance term is appended in each equation of the systems. In addition, it is assumed that the vector of disturbances in each system is multivariate and normally distributed with mean zero and nonsingular covariance matrix, Ω.

The maximum likelihood method of estimation is used to estimate the two models of simultaneous equations under the maintained properties of symmetry (5) and homogeneity in factor prices (6), while monotonicity and concavity are checked after estimation at each observation. The predicted cost shares in both models are all positive, implying that the cost function is monotonic. Concavity is also satisfied in both models, since the Hessian matrix is negative semidefinite. Thus, in both models, the cost function is well behaved within the region of the sample observation.

Table 1 presents the estimates of the two models and Table 2 reports the basic related diagnostics. Overall, the numbers in Tables 1 and 2 indicate that the estimated cost function of the two models performs well. First, this is supported by the fact that the majority of the estimates are statistically significant (31 out of 33 in the intermediation model and 27 out of 33 in the production model). Second, the R^2 is high in both models. Third, and most importantly, in both models the value of the log-likelihood function is high and statistically significant at the 1 percent level. In addition, tests relating to the structure of production support the translog specification (3). The Wald test statistic indicates that the homogeneity (7) and the homotheticity (8) restrictions are rejected in both models. In terms of the homogeneity restriction, the test results show that ${\chi_5}^2 = 169.79$ with p-value $= 0.0001$ for the intermediation model, and ${\chi_5}^2 = 18.06$ with p-value $= 0.002$ for the production model.

The homotheticity restriction test results show that ${\chi_4}^2 = 166.37$ with p-value = 0.0001 for the intermediation model, and ${\chi_3}^2 = 44.21$ with p-value = 0.0001 for the production model.

TABLE 1
Maximum Likelihood Estimates of the Translog Cost Function:
Intermediation and Production Models

Coeff.	Intermediation	Production	Coeff.	Intermediation	Production
α_0	1.1340	0.18404	ρ_{22}	0.02615	0.04359
	(0.0769) $***$	(0.1195)		(0.00598)$***$	(0.00724)$***$
α_1	0.55581	−0.51753	ρ_{12}	−0.06274	−0.12696
	(0.04660)$***$	(0.23743) $**$		(0.00902)$***$	(0.04273)$***$
α_2	0.21268	0.32802	ρ_{21}	−0.00782	−0.04359
	(0.03223)$***$	(0.04286)$***$		(0.00358) $**$	(0.00724)$***$
α_3	-	0.60175	ρ_{13}	0.08477	-
		(0.18611)$***$		(0.01037)$***$	
β_1	0.27213	0.57547	ρ_{31}	-	−0.06381
	(0.00807)$***$	(0.02964)$***$			(0.03818)$*$
β_2	0.26538	0.42453	ρ_{23}	−0.01832	-
	(0.01616)$***$	(0.02964)$***$		(0.00633)$***$	
β_3	0.46249	-	ρ_{32}	-	0.06381
	(0.01659)$***$				(0.03818)$*$
δ_{11}	−0.06615	−0.68952	α_t	0.15121	0.06959
	(0.03018)$*$	(0.41054)$*$		(0.01127)$***$	(0.01405)$***$
δ_{22}	0.02073	0.07511	α_{tt}	0.00428	0.00707
	(0.01408)	(0.01719)$***$		(0.00110)$***$	(0.00129)$***$
δ_{33}	-	−0.34510	δ_{1t}	0.02095	−0.00362
		(0.29918)		(0.00469)$***$	(0.01685)
δ_{12}	−0.06997	0.02006	δ_{2t}	−0.01267	−0.00919
	(0.02363)$***$	(0.04477)		(0.00272)$***$	(0.00273)$***$
δ_{13}	-	0.53695	δ_{3t}	-	0.00288
		(0.34848)			(0.01505)
δ_{23}	-	−0.11542	γ_{1t}	−0.02522	−0.02389
		(0.04199)$***$		(0.00250)$***$	(0.00225)$***$
γ_{11}	0.16343	0.20339	γ_{2t}	0.00105	0.02389
	(0.01437)$***$	(0.00916)$***$		(0.00190)	(0.00225)$***$
γ_{22}	0.14718	0.20339	γ_{3t}	0.02417	-
	(0.00970)$***$	(0.00916)$***$		(0.00342)$***$	
γ_{33}	0.21109	-	f_1	0.66044	0.67591
	(0.02193)$***$			(0.14519)$***$	(0.14656)$***$
γ_{12}	−0.04976	−0.20339	f_2	1.2535	1.3598
	(0.00475)$***$	(0.00916)$***$		(0.17081)$***$	(0.17319)$***$
γ_{13}	−0.11367	-	f_3	0.13842	0.14117
	(0.01669)$***$			(0.05391) $**$	(0.06090) $**$
γ_{23}	−0.09742	-	f_4	2.2092	1.8306
	(0.01041)$***$			(0.27637)$***$	(0.29337)$***$
ρ_{11}	−0.02203	0.12696	f_5	0.67430	0.75609
	(0.00555)$***$	(0.04273)$***$		(0.11453)$***$	(0.11855)$***$

Notes: Standard errors in brackets, * 10 percent significance, ** 5 percent significance, *** 1 percent significance.

TABLE 2
Basic Statistics: Intermediation and Production Models

Statistics	Intermediation		Production	
	R^2	D.W.	R^2	D.W.
Cost Equation	0.9959	1.982	0.9862	2.252
Labor Equation	0.7895	1.964	0.8073	2.202
Capital Equation	0.7921	2.110	-	-
LF	464.098		232.993	

Notes: LF: Log of the Likelihood Function.

Elasticities

Table 3 presents the Allen-Uzawa partial elasticities of substitution and the price elasticities of input demands for the intermediation and production models. These elasticities are calculated at the sample means of the factor cost shares according to equations (9) and (10). All Allen-Uzawa own-partial elasticities of substitution are negative (σ_{ii}<0), in both models, and ensures concavity of the cost function. Labor and capital appear to be substitutes in both models, but the elasticity of substitution between these inputs is statistically significant only in the production model. Since the intermediation model treats deposits as a production input, in addition to labor and capital, it allows the computation of the elasticities of substitution of deposits with respect to these inputs. The calculated elasticities show that deposits are substitutes for labor and capital. However, only the elasticity of substitution between deposits and capital is statistically significant. This can be the result of banks switching from interbank deposits to customer deposits because of an increase in the price of capital. The findings of the intermediation approach, which is not any statistically significant substituiility between labor and other inputs, is quite reasonable given the rigid institutional structure of labor contracts in Greece. The findings that deposits and capital are substitutes are consistent with studies examining financial institutions of other counties [Murray and White, 1983; Mester, 1987; Esho and Sharpe, 1995].

TABLE 3
Allen-Uzawa Partial Elasticities of Substitution and
Price Elasticities of Input Demands: Intermediation and Production Models

Factor	Intermediation			Production	
	Labor	Capital	Deposits	Labor	Capital
	Allen Partial Elasticities of Substitution (σ_{ij})				
Labor	−0.1784	0.09784	0.02835	−0.1902	0.1863
	(0.2944)	(0.0862)	(0.1427)	(0.0374)***	(0.0366)***
Capital	–	−0.6440	0.2628	–	−0.1825
		(0.1555)***	(0.0787)***		(0.0359)***
Deposits	–	–	−0.1357	–	–
			(0.0782)*		
	Price Elasticities of Input Demands (ε_{ij})				
Labor	−0.0394	0.0244	0.0150	−0.0941	0.0941
	(0.0650)	(0.0215)	(0.0755)	(0.0185)***	(0.0185)***
Capital	0.0216	−0.1607	0.1391	0.0922	−0.0922
	(0.0190)	(0.0388)***	(0.0417)***	(0.0181)***	(0.0181)***
Deposits	0.0656	0.0656	−0.0718	–	–
	(0.0315)*	(0.0196)***	(0.0414)*		

Notes: Standard errors in brackets, * 10 percent significance, ** 5 percent significance, *** 1 percent significance.

Regarding the price elasticities of input demands, both models indicate that all own-price elasticities are less than 1 in absolute values, suggesting inelastic demand for inputs by banks. According to the production model, the demands for labor and capital are very inelastic and both of them have own-price elasticities close to -0.09. Based on the intermediation model, the own-price elasticity of labor and the cross-price elasticities between labor and other inputs are statistically insignificant, which can be attributed to the rigidity of labor contracts in Greece. Overall, the cross-price effects are weaker in substituility and stronger in capital and deposits. These findings are in accordance with the results obtained by other studies [Mester, 1987; Lang and Welzel, 1998].

Scale Economies

As equation (11) shows, long run economies of scale (SCE) are calculated and hold input prices and outputs constant at the sample means of each year. The indices in Table 4 indicate significant economies of scale in both models. In particular, the value of SCE in each year and in the whole time period is significantly greater than zero and indicates the presence of economies of scale. The intermediation model shows lower economies of scale compared to the production model. Moreover, economies of scale increase over time in the intermediation approach, but they do not show any specific pattern in the production approach. Overall, the results of this paper show similarities to studies examining financial institutions of other countries. Such studies include Murray and White [1983] examining Canadian credit unions, Dietsch [1993] investigating French banks, and Mehdian and Rezvanian [1998] studying small U.S. cooperative banks. However, most of the studies on U.S. banks have typically indicated constant returns or diseconomies of scale for banking, particularly for large multibranch banks [Jagtiani and Khanthavit, 1996; Manhajan et al., 1996].

TABLE 4

Economies of Scale by Year: Intermediation and Production Models

Period	Intermediation	Production	Period	Intermediation	Production
1982-97	0.59816	0.87762	1990	0.60719	0.70845
	(0.0546)***	(0.1098)***		(0.0765)***	(0.0766)***
1982	0.50121	0.73412	1991	0.61988	0.72173
	(0.0565)***	(0.0947)***		(0.0797)***	(0.0813)***
1983	0.52672	0.56155	1992	0.61077	0.73486
	(0.0612)***	(0.0579)***		(0.0806)***	(0.0811)***
1984	0.54287	0.71508	1993	0.64433	0.77126
	(0.0627)***	(0.0924)***		(0.08174)***	(0.0834)***
1985	0.53884	0.66178	1994	0.65940	0.75895
	(0.0632)***	(0.0711)***		(0.0833)***	(0.0825)***
1986	0.55119	0.65763	1995	0.66698	0.75136
	(0.0669)***	(0.0661)***		(0.0855)***	(0.0837)***
1987	0.55308	0.83771	1996	0.68007	0.77266
	(0.0687)***	(0.1386)***		(0.0881)***	(0.0856)***
1988	0.56709	0.67558	1997	0.71681	0.87762
	(0.0708)***	(0.0686)***		(0.0924)***	(0.1098)***
1989	0.58408	0.75503			
	(0.0733)***	(0.0826)***			

Notes: Standard errors in brackets, * 10 percent significance, ** 5 percent significance, *** 1 percent significance.

The findings that Greek banks exhibit significant economies of scale imply that Greek banks should be encouraged to expend by merger or to expand their product mix, since it would be cost efficient. The passage of the Second Banking Directive in the EU (January 1, 1993) has created the opportunity for increased banking mergers and acquisitions across as well as within national borders. This is generally in line with the need of the Greek banking industry on the economies-of-scale grounds.

Technical Change

The rate of technical change and its decomposition, calculated in equations (13) and (15), are reported in Table 5 for the intermediation and the production models. The results reported in both models indicate significant negative technical change (such as, technological regress) in each year and in the whole time period. The estimates produced in both models are relatively stable and gradually evolve over time. However, the intermediation model provides higher estimates (in absolute value) than the production model in each year and in the whole time period (1982-97). The mean annual rate of technical change in the intermediation model, over the full sample period (1982-97), is about -0.1565 percent (statistically significant) and in the production model about -0.08891 percent (statistically significant). The year-to-year estimates of the rate of technical change in the intermediation model are between -0.16578 percent and -0.14354 percent, while the production model is between -0.06616 percent and -0.11651 percent. These findings display similarities with the results obtained by other studies. Such studies include Humphrey [1993] studying U.S. banking, Esho and Sharpe [1995] investigating technological change in Australian permanent building societies, and Ashton [1998] examining U.K. retail banking.

In terms of decomposing the rate of technical change to its sources, the numbers in Table 5 indicate that the neutral technological effect (T_1) is the dominant factor, which led to a negative annual overall rate of technical change in both models. In particular, in the intermediation model T_1 = -0.18765 percent (and is statistically significant). This is high enough to offset the non-neutral technological effect (T_3 = 0.03897 percent, and is statistically significant). The scale augmenting effect is small (T_2 = -0.00783 percent) and statistically insignificant. Moreover, in the production model T_1 = -0.12978 percent (and statistically significant). This offsets both the non-neutral technological effect (T_3 = 0.02060 percent, and statistically significant) and the scale augmenting effect (T_2 = 0.02025 percent, and statistically insignificant). Generally, the empirical findings suggest that the neutral technological effect, in both models, is the factor which contributes negatively to the rate of technical change and outweighs the non-neutral technological effect which contributes positively. One possible explanation for the negative neutral technological effect could be the rigid institutional structure of the labor union contracts in Greece. Thus, institutional changes with respect to the labor union contracts are needed in the Greek banking sector to reduce personnel and administrative costs and to guarantee reduction in future operating costs.

In table 5, the year-to-year estimates of the sources of the rate of technological change show that the neutral technological effect (T_1) in both models is negative (and statitstically significant), while the non-neutral technological effect (T_3) is positive (and statistical significant). However, the scale augmenting effect (T_2) does not represent the same sign in both models. In particular, in the intermediation model, it is negative (and statistically significant) in each year of the period 1982-92 and positive (and statistically insignificant) in the rest of the period. In the production model it is positive (and statistically insignificant) over the entire period of the study.

TABLE 5
Technical Change and its Components by Year: Intermediation and Production Models

Period	Intermediation				Production			
	TCH	T_1	T_2	T_3	TCH	T_1	T_2	T_3
1982-97	−0.15650	−0.18765	−0.00783	0.03897	−0.08891	−0.12978	0.02025	0.02060
	(0.0058) * **	(0.0115) * **	(0.00747)	(0.0044) * **	(0.0079) * **	(0.0186) * **	(0.0189)	(0.0019) * **
1982	−0.16126	−0.15550	−0.01055	0.0048	−0.06991	−0.07667	0.01248	−0.00572
	(0.0077) * **	(0.0108) * **	(0.00054) * *	(0.0010) * *	(0.0106) * **	(0.0142) * **	(0.0111)	(0.0005) * **
1983	−0.16028	−0.15978	−0.01220	0.01170	−0.06799	−0.08375	0.01322	0.00254
	(0.0068) * **	(0.0106) * **	(0.0060) * *	(0.0015) * **	(0.0102) * **	(0.0145) * **	(0.0142)	(0.0002) * **
1984	−0.15812	−0.16407	−0.01369	0.01964	−0.06616	−0.09083	0.01359	0.01107
	(0.0060) * **	(0.0104) * **	(0.0064) * *	(0.0021) * **	(0.0094) * **	(0.0149) * **	(0.0154)	(0.0010) * **
1985	−0.15823	−0.16836	−0.014373	0.02485	−0.07258	−0.09791	0.01230	0.01302
	(0.0056) * **	(0.0104) * **	(0.0064) * *	(0.0028) * **	(0.0093) * **	(0.0154) * **	(0.0167)	(0.0012) * **
1986	−0.16436	−0.17164	−0.01980	0.02808	−0.07963	−0.10500	0.01110	0.01426
	(0.0053) * **	(0.0104) * **	(0.0070) * **	(0.0032) * **	(0.0088) * **	(0.0160) * **	(0.0169)	(0.0013) * **
1987	−0.16578	−0.17693	−0.02064	0.03178	−0.08641	−0.11208	0.01061	0.01504
	(0.0053) * **	(0.0106) * **	(0.0071) * **	(0.0036) * **	(0.0088) * **	(0.0166) * **	(0.0179)	(0.0014) * **
1988	−0.16521	−0.18122	−0.01818	0.03419	−0.09165	−0.1191	0.01286	0.01463
	(0.0053) * **	(0.0109) * **	(0.0072) * *	(0.00403)***	(0.0083) * **	(0.0174) * **	(0.0178)	(0.0013) * **
1989	−0.16468	−0.18550	−0.01510	0.03592	−0.09502	−0.12624	0.01558	0.01563
	(0.0054) * **	(0.0113) * **	(0.0074) * *	(0.0042) * **	(0.0085) * **	(0.0182) * **	(0.0193)	(0.0014) * **
1990	−0.15775	−0.18979	−0.01180	0.04383	−0.08496	−0.13332	0.01922	0.02912
	(0.0055) * **	(0.0118) * **	(0.0078)	(0.0047) * **	(0.0079) * **	(0.0190) * **	(0.0204)	(0.0027) * **
1991	−0.16124	−0.19407	−0.01443	0.04726	−0.09271	−0.14040	0.01881	0.02886
	(0.0060) * **	(0.0124) * **	(0.0081)*	(0.0051) * **	(0.0080) * **	(0.0199) * **	(0.0209)	(0.0027) * **
1992	−0.16200	−0.19836	−0.01104	0.04740	−0.09669	−0.14748	0.02042	0.03035
	(0.0067) * **	(0.0130) * **	(0.0080)	(0.0051) * **	(0.0080) * **	(0.0209) * **	(0.0208)	(0.0028) * **
1993	−0.14759	−0.20265	0.00473	0.05042	−0.09230	−0.15460	0.03009	0.03216
	(0.0076) * **	(0.0137) * **	(0.0088)	(0.0054) * **	(0.0086) * **	(0.0219) * **	(0.0214)	(0.0030) * **
1994	−0.14354	−0.20693	0.01090	0.05248	−0.09942	−0.16164	0.03364	0.02856
	(0.0087) * **	(0.0144) * **	(0.0094)	(0.0059) * **	(0.0097) * **	(0.0229) * **	(0.0219)	(0.0026) * **
1995	−0.14391	−0.21122	0.01057	0.05673	−0.10215	−0.16872	0.03435	0.03221
	(0.0092) * **	(0.0152) * **	(0.0095)	(0.0063) * **	(0.0099) * **	(0.0239) * **	(0.0216)	(0.0030) * **
1996	−0.14476	−0.21551	0.00753	0.06321	−0.10847	−0.17580	0.03291	0.03441
	(0.0097) * **	(0.0161) * **	(0.0095)	(0.0071) * **	(0.0107) * **	(0.0250) * **	(0.0245)	(0.0032) * **
1997	−0.14545	−0.21979	0.00315	0.07118	−0.11651	−0.18288	0.03284	0.03351
	(0.0103) * **	(0.0169) * **	(0.0098)	(0.0082) * **	(0.0108) * **	(0.0261) * **	(0.0234)	(0.0031) * **

TCH: rate of technical change, T_1: neutral technological effect, T_2: scale augmenting technological effect, T_3: non-neutral technological effect.
Standard errors in brackets, * 10 percent significance, ** 5 percent significance, *** 1 percent significance.

Total Factor Productivity

The rate of growth in total factor productivity and its components, calculated from (14) and (16) is presented in Table 6 for both models. The results indicate statistically significant negative productivity growth in each year and in the whole time period. The mean annual rate of productivity growth in the intermediation model over the full sample period is about TFP = -0.38946 percent (and is statistically significant). The production model is about TFP = -0.38301 percent (and statistically significant). In the intermediation model, the year-to-year estimates of the growth in factor productivity are between -0.32329 percent and -0.51359 percent. The production model is between -0.15508 percent and -0.47712 percent. Although the negative TFP estimates are surpassing, they are consistent with a number of studies measuring TFP in U.S. banking [Bauer et al., 1993; Esho and Sharpe, 1995]. There are several possible explanations for the poor productivity growth in the U.S. banks. According to Bauer et al. [1993], increased competition in the U.S. banks has increased real operating costs and is measured as a negative TFP. However, the users of banking services have benefited from higher quality of banking services due to intense competition in the sector.

Table 6 presents estimates of the sources of total factor productivity growth. These results, like in the case of technological change, indicate that the neutral technological effect (F_1) is negative and dominates over the scale augmenting (F_2) and the non-neutral (F_3) technological effects. Specifically, in the intermediation (production) model, F_1 = -0.46696 percent and is statistically significant (F_1 = -0.55529 percent and is statistically significant), F_2 = -0.01948 percent and is statistically insignificant (F_2 = 0.08541 percent and is statistically insignificant), and F_3 = 0.09698 percent and is statistically significant (F_3 = 0.08686 percent and is statistically significant). The empirical findings suggest that the neutral technological effect in both models is the factor that contributes negatively to the rate of growth in total factor productivity and outweighs the non-neutral technological effect that contributes positively. As in the case of technological change, one possible reason for the negative neutral technological effect could be the rigid structure of labor contracts. In the future, personnel and administrative costs have to be substantially reduced for the banking sector to achieve efficiency, experience, and positive growth in total factor productivity.

In Table 6, the year-to-year estimates of the sources of total productivity growth show the same signs as in the case of technological change. In other words, in both models, the neutral technological effect (F_1) is negative (and statitstically significant), while the non-neutral technological effect (F_3) is positive (and statistically significant). In the intermediation model, the scale augmenting effect (F_2) changes signs from negative (and statistically significant) during the period 1982-92, to positive (and statistically insignificant) for the rest of the period. In the production model, it is positive (and statistically insignificant) over the entire period of the study.

Conclusions and Policy Implications

The purpose of this paper was to analyze the cost structure of the Greek banking sector and, subsequently, to measure the rate of technical change and the rate of growth in total factor productivity. The paper used two different approaches to specify a translog cost function in modeling the cost structure of the Greek banking sector—the intermediation and the production approach. The intermediation approach treats deposits and other liabilities as inputs, while the production approach treats them both as outputs.

TABLE 6

Total Factor Productivity Growth and its Decomposition by Year: Intermediation and Production Models

	Intermediation				Production			
Period	TFP	F_1	F_2	F_3	TFP	F_1	F_2	F_3
1982-97	−0.38946	−0.46696	−0.01948	0.09698	−0.38301	−0.55529	0.08541	0.08686
	(0.0825) ***	(0.1049) ***	(0.0177)	(0.0209) ***	(0.1662) **	(0.2394) **	(0.0871)	(0.0301) ***
1982	−0.32329	−0.31175	−0.02116	0.0962	−0.26296	−0.28840	0.04696	−0.02153
	(0.0432) ***	(0.0461) ***	(0.0107) **	(0.0024) ***	(0.1088) **	(0.1126) **	(0.0407)	(0.0078) ***
1983	−0.33866	−0.33761	−0.02578	0.02473	−0.15508	−0.19103	0.03015	0.00579
	(0.0493) ***	(0.0541) ***	(0.0126) **	(0.0044) ***	(0.0340) ***	(0.05029)***	(0.0341)	(0.0009)
1984	−0.34590	−0.35892	−0.02996	0.04297	−0.23221	−0.31882	0.04772	0.03888
	(0.0539) ***	(0.0614) ***	(0.0137) **	(0.0076) ***	(0.0934) **	(0.1140) ***	(0.0519)	(0.0131) ***
1985	−0.34311	−0.36507	−0.03194	0.05390	−0.21460	−0.21460	0.03638	0.03852
	(0.0507) ***	(0.0637) ***	(0.0131) **	(0.0096) ***	(0.0637) ***	(0.0637) ***	(0.0481)	(0.0091) ***
1986	−0.36622	−0.38467	−0.04413	0.06258	−0.23259	−0.30668	0.03244	0.04165
	(0.0613) ***	(0.0723) ***	(0.0144) ***	(0.0117) ***	(0.0611) ***	(0.0828) ***	(0.0497)	(0.0091) ***
1987	−0.37094	−0.39589	−0.04618	0.07112	−0.24150	−0.32059	0.03543	0.04365
	(0.0644) ***	(0.0772) ***	(0.0142) ***	(0.0137) ***	(0.1201) **	(0.1598) **	(0.0430)	(0.0211) **
1988	−0.38163	−0.41860	−0.04201	0.07898	−0.28251	−0.36729	0.03965	0.04512
	(0.0707) ***	(0.0861) ***	(0.0149) ***	(0.0159) ***	(0.0757) ***	(0.1050) ***	(0.0557)	(0.0105) ***
1989	−0.39595	−0.44601	−0.03632	0.08638	−0.38791	−0.51533	0.06360	0.06381
	(0.0792) ***	(0.09744)***	(0.0162) **	(0.0183) ***	(0.1515) **	(0.1912) ***	(0.0775)	(0.0222) ***
1990	−0.40161	−0.48316	−0.03005	0.11160	−0.29142	−0.45727	0.06593	0.09991
	(0.0889) ***	(0.1142) ***	(0.0170)*	(0.0248) ***	(0.0949) ***	(0.1476) ***	(0.0715)	(0.0280) ***
1991	−0.42418	−0.51056	−0.03796	0.12434	−0.33318	−0.50454	0.06762	0.10374
	(0.1002) ***	(0.1292) ***	(0.0196)*	(0.0294) ***	(0.1148) ***	(0.1774) ***	(0.0782)	(0.0318) ***
1992	−0.41620	−0.50963	−0.02836	0.12179	−0.36471	−0.55623	0.07702	0.11449
	(0.0986) ***	(0.1286) ***	(0.0190)	(0.0284) ***	(0.1304) ***	(0.2053) ***	(0.0833)	(0.0365) ***
1993	−0.41469	−0.56977	0.01331	0.14177	−0.40353	−0.67569	0.13155	0.14061
	(0.1123) ***	(0.1555) ***	(0.0257)	(0.0359) ***	(0.1743) **	(0.2780) **	(0.1010)	(0.0528) ***
1994	−0.42143	−0.60755	0.03202	0.15410	−0.41247	−0.67056	0.13959	0.11850
	(0.1229) ***	(0.1752) ***	(0.0298)	(0.0414) ***	(0.1682) **	(0.2617) **	(0.0987)	(0.0421) ***
1995	−0.43213	−0.63426	0.03176	0.17036	−0.41084	−0.67855	0.13817	0.12954
	(0.1322) ***	(0.1918) ***	(0.0313)	(0.0476) ***	(0.1635) **	(0.2611) ***	(0.0952)	(0.0455) ***
1996	−0.45246	−0.67360	0.02355	0.19759	−0.47712	−0.77328	0.14479	0.15137
	(0.1471) ***	(0.2176) ***	(0.0321)	(0.0588) ***	(0.2026) **	(0.3280) **	(0.1171)	(0.0501) ***
1997	−0.51359	−0.77612	0.01115	0.25137	−0.45957	−0.75103	0.14953	0.14193
	(0.1925) ***	(0.2909) ***	(0.0360)	(0.0871) ***	(0.2214) **	(0.3609) **	(0.1278)	(0.0693) **

Notes: TFP: total factor productivity growth, F_1: neutral technological effect, F_2: scale augmenting technological effect, F_3: non-neutral technological effect. Standard errors in brackets, * 10 percent significance, ** 5 percent significance, *** 1 percent significance.

The results obtained were not significantly affected by the model specification used. First, they showed that both models supported the fact that the Greek banking industry exhibited significant economies of scale. This finding indicates that certain actions such as, mergers and acquisitions, could improve the cost ratio and cost efficiency of the Greek banking sector. Second, both models indicated negative annual rates of growth in technical change and in total factor productivity. The dominant source, which forms the overall rates of growth in technical change and in total factor productivity, was the negative neutral technological effect and outweighed the positive non-neutral technological effect. In both models, the scale augmenting technological effect appeared to be statistically insignificant. These findings suggest that an improvement of the overall efficiency of the Greek banking system could result through reforms in the labor market, by reducing personnel and administrative costs, and making managerial and organizational changes (cash management improvements, and the expanded use of ATM innovations).

The empirical findings and the operational characteristics of the Greek banking system provide certain policy implications that should be taken into consideration by managers and policy makers for the banking sector to achieve positive productivity growth and more efficiency. The findings imply that operating cost should be decreased through changes in labor union contracts and other organizational changes, such as the learning-by-doing process, cash management improvements, and the expanded use of ATM innovations. This argument is supported by the findings that the neutral technological effect is negative and is the factor which determines the overall rate of growth in total factor productivity growth. Finally, the presence of significant economies of scale provides the possibility for an increase in productivity of the Greek banking system, only if the efficient banks take over and improve the inefficient ones through mergers and acquisitions.

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