PRODUCTIVITY EFFICIENCY OF THE SYSTEMIC BANKS: EVIDENCE FROM GREECE

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Abstract

This study delves into the productivity efficiency of Greek systemic banks for the years 2013 and 2014, that is, the two years following the recapitalization process of the Greek banking system. Greece's ongoing debt crisis has severely inflicted domestic banks by causing significant losses in their bond portfolio through the PSI scheme. The immediate consequences were loan portfolio restructurings and capital injections from the Hellenic Financial Stability Fund (HFSF) in order to rebuild the banking system. Employing Data Envelope Analysis to test banking efficiency, we calculate the Malmquist productivity indices for the post-recapitalization period. Our results display that all Greek systemic banks enjoy a remarkable productivity increase of 17.3% according to the geometric mean approach and 18% according to the weighted mean approach.

Keywords: Malmquist Index, Greek Banks, Banking Productivity, DEA

JEL Classification: G21; G23

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1 Introduction

Banking efficiency has been at the epicenter of bank management, shareholders and market regulators for several years. However, the investigation of banking efficiency became necessary once European rescuers decided in late 2011 that a second bail-out of Greece would require a big write-down of its public debt. This bail-out scheme known as the recapitalization of the Greek systemic banks called for further research on the outcome of such rescue plans.

This study aims at investigating the technological as well as the technical efficiency of Greek systemic banks that underwent dramatic structural changes following the recapitalization process of 2012. Our main research question is whether the recapitalization of Greek systemic banks improve their efficiency. To the best of our knowledge, this is the first academic attempt to probe into the effects of recapitalization on Greek banks' efficiency and performance. For this purpose, we employ the Malmquist index for productivity employing Data Envelopment Analysis (DEA). More specifically, employing the Malmquist productivity index we test bank productivity in terms of technological, technical and scale efficiency. Our examination period covers 2012 and 2013, that is the year that recapitalization took place and the subsequent year.

Several theories have been propounded in the pertinent literature to explain banking efficiency such as the intermediation approach, the production or value added approach, the user cost approach, and the transactions-cost approach. According to intermediation approach, bank deposits are converted into loans, that is, deposits are considered as financial inputs. The value added approach assumes that banks use labor and capital to generate deposits and loans (Mester, 1987; Berger and Humphrey, 1992). Banks collect funds from depositors in order to provide loans to their customers. Therefore, deposits should be regarded as outputs because of the continuously increasing competition among financial organisms to convince potential depositors to trust their financial institution. On the other hand, the user-cost approach assigns an asset as an output if the financial returns more than offset the opportunity cost of funds. In similar way, a liability item is seen as an output if the financial costs are less than the opportunity costs. If none of these conditions is satisfied, the assets or the liability is categorized as input (Berger and Humphrey, 1992). Finally, according to Wyckoff's approach (Berger and Humphrey (1992) deposits are neither outputs nor inputs, but they are financial instruments with a flow of a wide variety of complex and subtle services received by deposit customers.

The structure of the current study is as follows. Section 2 describes the recapitalization process, while section 3 analyzes the pertinent literature. Section 4

presents the research design of the study and section 5 presents the main empirical findings. Finally, section 6 provides the concluding remarks of the study.

2 The recapitalization process

Greece's accession in the Euro area in 2001 was treated with great enthusiasm by local media and market participants. The impression at the time was that Greece's inclusion in the core of European economies would act as a catalyst to accelerate its real convergence with the advanced European countries at both the economic and social level. Greece enjoyed the benefits of the single currency, but did not try to meet the obligations arising from its adoption. In the economy in particular, growth was strong, but was led by domestic demand, which was fueled by borrowing, both public and private. The production base did not adjust accordingly and competitiveness declined rapidly, resulting in a deterioration of the external deficit. Public spending kept increasing, while revenue lagged behind, leading to large deficits and historically high levels of public debt (Bank of Greece, 2014).

The consequences of the ensuing debt crisis were remarkable for almost all Greek banks that underwent significant hair-cuts through the Private Sector Involvement (PSI) scheme that reduced the face value of Greece's sovereign bonds by more than 50%. The write-down brought the Greek banks low, because they held much of the debt. As a result, a recapitalization program tailored-made to Greek banks was implemented in 2012 in order to rescue these banks from default. The bail-out package included €50 billion for the Hellenic Financial Stability Fund (HFSF) in order to rebuild the banking system. Of this, €17 billion covered losses in defunct banks. Another €5 billion was a reserve, in case more holes open up. Most of it, €27.5 billion were directed to recapitalize Greece's four biggest banks—Alpha, National Bank of Greece (NBG), Piraeus and Eurobank. At least 10 per cent of new capital came from private investors to keep the banks from being effectively nationalized. Following recapitalization, all systemic banks launched seasoned equity offerings (SEOs) by issuing warrants in addition to new shares. SEOs attracted an unprecedented investor interest by reducing remarkably the stockholding of HFSF. Today, the HFSF holds 57.2% of the National Bank of Greece, 67.3% of Piraeus Bank, 69.9% of Alpha Bank and 35.4% of Eurobank which are the four systemic banks of Greece.

3 Literature review

The literature is rich regarding the effects of economies of scale and bank efficiency. For example, Glass and McKillop (1991) probed into the efficiency of Irish banking for a period spanning from 1972 to 1990. The results showed no evidence of economies of scale. On the contrary, the banking sector was found to exhibit diseconomies of scope in the first years of operation, while a reversal occurred and economies of scale pertained in the late of 1980s.

Berg et al. (1992) explored productivity growth during the deregulation of the Norwegian banking industry. The results showed productivity retardation for the average bank prior to the deregulation, but notable growth thereafter. Elyasiani and Mehdian (1995) compared the efficiency performance of small and large US commercial banks in the pre- and post-deregulation era. Their findings suggested that in the pre-deregulation environment, small banks were more efficient than the large ones. However, in the deregulated environment small and large banks were equally efficient.

Favero and Papi (1995) measured the technical and scale efficiencies in the Italian banking industry using 174 Italian banks taken over in 1991. Efficiency was best explained by productivity specialization, size and to a lesser extent by location. The authors found a positive relationship between bank size and efficiency. Employing the Malmquist index, Fukuyama (1995) investigated the nature and extend of bank efficiency and productivity growth in Japan. The results showed a Malmquist index greater between 1989 and 1990 than between 1990 and 1991. Moreover, the results showed an improved productivity and innovation and deterioration in efficiency for both periods under examination.

Dietsch (1997) analyzed X and scale-efficiencies for French Banks for the 1988-1992 period. The results showed that average X-efficiencies of the French banks were in the range of 70% to 90%. These results confirmed the existence of scale economies in the French banking industry. Noulas (1997) used the Malmquist index to investigate the productivity growth of the Greek banking industry for 1991 and 1992. His results indicated that, although productivity had increased for state and private banks, the sources of this growth were different. In fact, state banks' productivity were due to technological progress, while private banks' productivity came from increased efficiency.

Jackson et al. (1998) analyzed productivity growth for Turkish commercial banks during the period 1992-1996. Turkish commercial banks experienced productivity growth with the exception of 1993-1994. Private and foreign banks displayed higher productivity growth compared to the state owned banks. Worthington (1998) investigated the efficiency and productivity growth in deposit taking institutions in Australia. His results indicated that most building societies experienced productivity gain in the past years. This was largely due to technological progress rather than efficiency

improvements. Worthington claimed that productivity growth due to an increase in efficiency over the period, was the result of improvements in scale efficiency.

Fernández et al. (2001) studied economic efficiency for 142 intermediaries from 18 countries over the period 1989-1998. Their sample comprised financial intermediaries from North America, Europe and Japan. Their estimates of efficiency scores showed large gains primarily due to growth in pure technical efficiency. Mean technical efficiency in European and Japanese banks were significantly greater than those in North American. Finally, the results demonstrated that the best managed commercial banks were located in Europe, while Japanese banks were the most scale efficient.

Caceres (2002) investigated productivity growth in Chilean banking over the period 1989 to 1999. His results indicated that after a period of frenzy productivity growth, the banking sector experienced lower and relatively stable rates of productivity change. Moreover, the results revealed that small banks displayed a large number of inefficient banks. The Malmquist index was high from 1996 onward and there were no large technical inefficiencies in the Chilean banking industry.

Mörttinen (2002) computed banking sector labor productivity Tornqvist indices for Finland, Sweden, United Kingdom, Italy, Germany and France over a period varying from 11 to 20 years. The results showed that the Finnish banking sector productivity improved through a substantial reduction size of labor force, whereas output growth was rather modest.

Tortosa-Ausina et al. (2002) explored productivity growth and productive efficiency for Spanish saving banks over the period 1992-1998. Their results showed that productivity growth had occurred mainly due to improvement of production possibilities and that the mean efficiency remained fairly constant over time.

Reddy (2005) measured productivity growth of the banking industry in India during 1996-2002. He found that bank Total Factor Productivity (TFP) remained unaltered, while the contribution of technological progress towards productivity declined. However, technical efficiency and scale efficiency had been enhanced for all banks. Public sector banks enjoyed higher TFP than old private banks. In contrast, both new private and foreign banks recorded decline in TFP growth.

Guarda and Rouabah (2009) analyzed technical change and efficiency change using quarterly reporting data from Luxembourg's banking sector for the period 1994-2007. The results showed that productivity in Luxembourg's bank grew by about 1% per quarter over the sample period. The standard decomposition of the Malmquist productivity index suggested that most of the productivity growth was from efficiency change rather than technical change.

Ngo and Nguyen (2012) evaluated the efficiency and TFP changes of Thai banking system in the period of 2007-2010 using panel data of 27 major banks in Thailand. The results demonstrated that local banks remained stable, foreign banks experienced some improvement in their TFPs, while some became worst performers in the system. The authors attributed these results to the Thai banking system which is currently running at decreasing returns to scale situation, which means that Thai banks are wasting resources in over-expansion.

Hadad et al. (2011) estimated Malmquist productivity indices for Indonesian banks over the period Q1 2003 to Q2 2007 using the nonparametric, slacks-based, SORM approach for efficiency and super-efficiency estimation. Based on the Malmquist analysis, the dynamics of the average productivity of banks were found to be relatively stable during the analysed period, implying that the main driver of the productivity change in the financial intermediary activities of Indonesian banks was the improvement in their intermediation technology.

Neupane (2013) investigated the change in efficiency and productivity of banking industry during the period of 2007/08 to 2011/12 and analyzed the effects of various indicators on the efficiency of the 22 commercial banks in Nepal. The results revealed that the productivity change of commercial banks in Nepal has improved over the sample period and that the increase in productivity change in Nepalese commercial banks was attributed to the technical progress rather than efficiency components. It also reports that the decline in efficiency change was due to decline in both pure efficiency change and scale efficiency change.

Gwahula (2013) measured the productivity change of Tanzanian commercial banks for the period 2005-2011 using the Malmquist Productivity Index (MPI). In particular, the author gauged changes in technical efficiency, in technological change, in pure technical efficiency, in scale efficiency and in total factor productivity. The results showed an improvement in efficiency change by 67 percent, a technical change improvement by 83 percent, pure technical change improvement by 67 and scale efficiency change by 50 percent for most of commercial banks. However, the efficiency gains during the period under investigation were due to improvement in technical efficiency rather than scale efficiency.

4 Research design

4.1 Data

Our dataset contains all Greek systemic banks, that is, National Bank of Greece, Eurobank, Alpha Bank and Piraeus Bank, and the examination period covers 2013 and 2014, that is, the two years after the recapitalization process. All data were extracted from Bankscope. Following Worthington (1998), Caceres (2002) and Reddy (2005), among others, we adopt the value added approach in order to measure total productivity changes in the Greek banking industry between 2013 and 2014. We selected these two years in order to examine the effects of recapitalization on the total productivity efficiency of the Greek banks. In line with the existing literature, we use three outputs and three inputs variables based on the value added approach. Output variables include total deposits, total customer loans, and investments defined as equity investments and government securities. On the other hand, the inputs are personnel expenses, other operating expenses, and total fixed assets. Table 1 provides a summary of descriptive statistics for the six variables. According to these statistics, total loans of the Greek systemic banks are equal to 56,726,025,000€ and 54,235,500,000€ in 2013 and 2014, respectively. Total deposits are 75,342,300,000€ and 72,352,675,000€ for 2013 and 2014 while exceed 7 billion Euros in both years. On the other hand, personnel expenses are relatively lower in 2014 (842,325,000€) compared to 2013 (864,100,000€) and the same is true for other operating expenses. In contrast, fixed assets increased from 1,265,975,000€ in 2013 to 1,332,550,000€ in 2014.

Table 1. Inputs and outputs for the Greek Systemic banks in 2013 and 2014 (in 000 of Euros)

	Loans 2014	Loans 2013	Deposits 2014	Deposits 2013	Investments 2014	Investments 2013
Mean	54,235,500	56,726,025	72,352,675	75,342,300	7,949,700	7,326,900
Median	53,350,000	57,022,050	71,113,550	74,594,400	7,514,400	8,120,850
St. Dev.	11,094,840	9,859,118	12,684,413	12,967,387	1,778,852	1,890,599
Max	68,109,000	67,250,000	87,155,000	90,773,000	10,466,000	8,542,900
Min	42,133,000	45,610,000	60,028,600	61,407,400	6,304,000	4,523,000

	Personnel Expenses 2014	Personnel Expenses 2013	Operating Expenses 2014	Operating Expenses 2013	Fixed Assets 2014	Fixed Assets 2013
Mean	842,325	864,100	1,590,850	1,912,225	1,332,550	1,265,975
Median	817,650	773,200	1,431,800	1,879,450	1,259,600	1,269,450
St. Dev.	246,207	341,472	380,727	343,986	598,129	419,662
Max	1,163,000	1,337,000	2,156,000	2,363,000	2,109,000	1,755,000
Min	571,000	573,000	1,343,800	1,527,000	702,000	770,000

4.2 Model specification

To gauge the efficiency of the Greek banking industry in the post-recapitalization period, we use the non-parametric frontier method of Data Envelopment Analysis (DEA) to estimate the Malmquist Total Factor Productivity Changes (TFPC) indices. The use of the Malmquist Productivity Index (MPI) presents a number of advantages. First, price data are not required. Second, it accommodates multiple inputs and outputs without the need to aggregate them. Third, it does not make any restrictive value assumptions for the units, such as cost minimization or profit maximization, as required by other indices (e.g. Tornqvist and Fisher). Fourth, it allows decomposition into three components: a) production technology, b) pure technical efficiency, and c) economies of scale. The MPI and its components take values below and above unity. In specific, a value equal to one suggests that a bank's performance remains unaltered whereas a value greater than one represents an improvement and a value less than one implies a decline.

4.2.1 The MPI decomposition

The Malmquist TFP index, which measures productivity change, can be split into technical efficiency change (TEC) and technological change (TC). Fare et al. (1994) specified an output-based Malmquist productivity change index as[1] :

[1] A production process, which uses input vector x_t to produce output vector y_t at time t and t+1 can be defined:

$p^t(x_t) = \{y_t : x_t \text{ can produce } y_t\}$ (1),

$P^{t+1}(x_{t+1}) = \{y_{t+1} : x_{t+1} \text{ can produce } y_{t+1}\}$ (2)

The output distance function can be defined as: $d^t(x^t, y^t) = \min\{p : (y^t / p) \in P^t(x^t) = [\max\{p : (py^t) \in P^t(x^t)\}]^{-1}$ (3)

$$m(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{d^t(x_{t+1}, y_{t+1})}{d^t(x_t, y_t} * \frac{d^{t+1}(x_{t+1}, y_{t+1})}{d^{t+1}(x_t, y_t} \right]^{\frac{1}{2}} = \frac{d^{t+1}(x^{t+1}, y^{t+1})}{d^t(x_t, y_t)} \left[\frac{d^t(x_{t+1}, y_{t+1}}{d^{t+1}(x_{t+1}, y_{t+1}} * \frac{d^t(x_t, y_t)}{d^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} \quad (1)$$

Where, x_t input vector at time t;

x_{t+1} input vector at time t+1;

y_t output vector at time t;

y_{t+1} output vector at time t+1;

d^t output distance function at time t;

d^{t+1} output distance function at time t+1.

In Equation (1), the ratio outside the brackets is equal to the change of technical efficiency between time t and time t+1. It represents the distance of the observed production from the maximum potential production. The ratio inside the brackets of Equation (1) is the geometric mean of two productivity indices and represents the change in production technology between time t and t+1. Technical efficiency change can be further decomposed as the product of pure technical efficiency change (PECH) and scale efficiency change (SECH). In particular, we have the equation:

$$\left[\frac{d^{t+1}(x_{t+1}, y_{t+1})}{d^t(x_t, y_t)} \right] = \frac{{d_r}^{t+1}(x^{t+1}, y^{t+1})}{d^t(x_t, y_t)} \left[\frac{{d_r}^{t+1}(x_{t+1}, y_{t+1}}{{d_r}^t(x_t, y_t)} * \frac{{d_r}^t(x_t, y_t)}{{d_r}^{t+1}(x_{t+1}, y_{t+1})} \right] \quad (2)$$

The ratio outside the brackets in Equation (2) represents the pure change of technical efficiency subject to a distance function (d_r) with variable returns to scale, between time t and t+1. The component inside the brackets of Equation (2) represents the effects of economies of scale on productivity. The complete decomposition of the MPI for the geometric and weighted mean respectively is:

$m_1(x_t, y_t, x_{t+1}, y_{t+1})$ = technological change * technical efficiency change =

= technological change * [pure change of technical efficiency * scale change] (3)

and

$m_2(x_t, y_t, x_{t+1}, y_{t+1})$ = technological change * technical efficiency change =

$$= \sum_n^1 \left(\frac{BAi}{TA} \text{*technological change of bank i)} * \sum_n^1 \left(\frac{BAi}{TA} \text{*technical efficiency change of bank i)} =\right.\right.$$

$$= \sum_n^1 \left(\frac{BAi}{TA} \text{*technological change of bank i)} * \sum_n^1 \left(\frac{BAi}{TA} \text{* pure change of technical efficiency. of}\right.\right.$$

$$\text{bank i)} * \sum_n^1 \left(\frac{BAi}{TA} \text{*scale change of bank i)}\right] \quad (4)$$

Where BA_i is the assets of bank i,

TA is the total assets of all systemic banks in the sample.

Equation (4) describes the Weighted Average Method (WAM) which is also used to measure efficiency by taking into consideration size effect, that is, all banks do not have equal weight in geometric mean's calculation. According to the WAM approach, each bank should affect the MPI based on its size as measured by total assets. Total assets of each bank are divided by the sum of total assets of all banks and this ratio is multiplied by all the indices (i.e. TEC, PECH, SECH, etc).

4.2.2 DEA models

To determine the MPI, we use Equations (1) and (2) and compute technological change, technical efficiency change and pure efficiency change, and then we derive scale change by dividing technical

efficiency change by pure technical efficiency change. Each output distance function corresponds to one particular output-orientated DEA linear program. Among technological change, technical efficiency change, and pure technical efficiency change, there are six output distance functions and, thus, a total of six different DEA models have to be formulated:

$$d^{t+1}(x_{t+1}, y_{t+1}), d^{t+1}(x_t, y_t), d^t(x_t, y_t), d^t(x_{t+1}, y_{t+1}), d_r^{t+1}(x_{t+1}, y_{t+1}), \text{ and } d_r^t(x_t, y_t)$$

$$d^t(x_t, y_t) = \max_{\phi,\lambda} \phi,$$

$$\text{st-} \phi y_{it} + Y_{t\lambda} \geq 0$$

$$x_{it} - X_{t\lambda} \geq 0$$

$$\lambda \geq 0$$

$$\phi \text{ unrestricted in sign}$$

Where x is the number of inputs, y is the number of outputs, and i is the number of banking firms.

5 Empirical results

Table 2 presents the empirical results from the productivity efficiency of the four Greek systemic banks for the two years following the recapitalization, that is, 2013 and 2014. As we have already mentioned, values above unity imply improvement, while values below unity display deterioration. Looking at the results we observe that all Greek systemic banks have a TEC value above unity implying that technical efficiency has improved between the two years under study. However, Eurobank displays the highest technical improvement which is equal to 11%. Overall, the geometric mean of TEC is 1.092, that is, a 9.2% increase in technical efficiency, while that of WAM is 1.117 (11.7%). Turning into the two components of TEC, that is, pure technical efficiency change (PECH) and scale efficiency scale (SECH), we observe values higher than one suggesting an improvement in performance related to technology for all systemic banks. Moreover, the total factor productivity change (TFPC), which is the product of TEC and TC, has geometric mean higher than 1 (1.173) suggesting an enhancement of total productivity of Greek banks in the post-recapitalization period by 17.3%. The improvement in TFPC is also observed when each bank is separately examined confirming that the increased total productivity is a wider phenomenon among systemic banks with Piraeus Bank displaying the highest improvement by 13.8%. Finally, we see that weighted mean values are slightly higher than those of geometric ones implying that large banks perform better than small ones.

Overall, the above results show that, after a period of significant downturn and structural changes, Greek systemic banks are back on their feet enjoying operating profits (not shown in our tables) as well as technical and productivity efficiency soon after the PSI and then ensuing haircut in their bond portfolio. Therefore, one can conclude that bond and loan portfolio restructuring may positively affect bank efficiency when this is associated with technological and scale efficiency changes. Moreover, we can conclude that capital infusion, such as that occurred in the Greek banking system through recapitalization, can assist banks in improving efficiency and productivity soon after a period of losses and illiquidity. Our results aim to provide useful insights to bank managers and policy-makers alike about the relationship between technical efficiency and profitability. Though, this relationship is not directly tested in the current study, the profitability of Greek banks seem to be in parallel with technical and productivity efficiency which are deemed to be the main drivers of performance enhancement.

Table 2. Malmquist Total Factor Productivity Changes (TFPC) indices for systemic Greek banks

	TEC	TC	PECH	SECH	TFPC
Alpha Bank	1.049	1.073	1.043	1.006	1.126
National Bank of Greece	1.095	1.047	1.076	1.018	1.146
Piraeus Bank	1.044	1.09	1.035	1.009	1.138
Eurobank	1.110	1.022	1.012	1.097	1.134
Geometric mean	1.092	1.074	1.034	1.056	1.173
Weighted mean	1.117	1.056	1.107	1.009	1.180

Note: Technical efficiency change (TEC), technological changes (TC), pure technical efficiency change (PECH), scale efficiency scale (SECH) and total factor productivity change (TFPC)

6 Conclusions

There is no doubt that the Greek financial system is undergoing considerable ownership, structural and corporate restructuring. Greece's debt crisis had inflicted all Greek banks and especially those exposed to sovereign bonds. The PSI was a turning point for those banks which had invested in Greek government bonds that underwent a haircut that exceeded 50% and there was an increasing trend of Non-Performing Loans (NPLs) in their loan portfolio. As a result, there has been a drastic deterioration in the asset quality of their portfolios and an abrupt decrease in their profitability rendering the Greek banks incapable of drawing liquidity from the financial markets. The immediate response to this situation was an unprecedented capital injection from the HFSF amounting to almost 40 billion Euros which typically nationalized almost all Greek banks. Since then a wave of mergers between the four systemic banks and smaller banks led to the dramatic decrease in the number of bank institutions, branches and employees.

In light of these structural changes, the current study attempts to delve into the productivity and efficiency changes that occurred in the two years following the recapitalization period. Employing the Malmquist approach, we measured technical, technological, scale and total productivity changes in the post-recapitalization period. The results showed efficiency and productivity improvements for all Greek systemic banks. In specific, Eurobank appears to have the highest technical improvement which is equal to 11%. This can be mainly attributed to the capital infusion coming from foreign private equity funds that saw this bank as a good opportunity to invest their money in deeply undervalued stocks that would render high capital gains in the future. Similarly, the rest of systemic banks enjoyed improvements in their productivity after a period of restructuring in their assets portfolio. These results suggest that capital assistance can boost both technological and scale efficiency thus leading to total productivity even in periods of financial turmoil and liquidity struggle. Future research should be directed to the investigation of stock market and operating performance of these banks.

References

1. Bank of Greece (2014), "The chronicle of the Great crisis, Center for Culture Research and Documentation". http://www.bankofgreece.gr/BogEkdoseis/The%20Chronicle%20Of%20The%20Great%20Crisis.pdf
2. Berg S. A., Førsund F. and Jansen, E. (1994), "Malmquist indices of productivity growth during the deregulation of Norwegian banking 1980-89", Scandinavian Journal of Economics Supplement, Vol. 94, pp. 211-228.
3. Berger, A.N., and D.B. Humphrey, D.B. (1992), "Measurement and Efficiency Issues in Commercial Banking", in Z. Griliches, ed., Output Measurement in the Service Sectors, National Bureau of Economic Research, Studies in Income and Wealth, University of Chicago Press Vol. 56: 245-79.
4. Caceres, J. (2002), "Efficiency and productivity in the Chilean banking industry", Working Paper, Tinbergen Institute.
5. Dietsch, M. (1997), "The efficiency of French banking industry", Managerial Finance, Vol. 23 No. 1, pp. 48-56.
6. Elyasiani, E. and Mehdian, S. (1995), "The comparative efficiency performance of small and large US commercial banks in the pre and post deregulation eras", Applied Economics, Vol. 27, pp. 1069-79.
7. Fare, R., Grosskopf, S., Norris, M., and Zhang Z. (1994), "Productivity growth, technical progress, and efficiency change in industrial countries", American Economic Review, Vol. 84 No. 1, pp. 66-83.
8. Favero, C. and Papi, L. (1995), "Technical efficiency and scale efficiency in the Italian banking sector: A non-parametric approach", Applied Economics, Vol. 27, pp. 385-395.
9. Fernández, A. I., Gascón, F. and González, E. (2001), "Economic efficiency and value maximization in banking firms, 7th European Workshop on Efficiency and Productivity Analysis (7EWEPA), Oviedo September 2001.
10. Fukuyama, H. (1995), "Measuring efficiency and productivity growth in Japanese banking: A nonparametric frontier approach", Applied Financial Economics, Vol. 5, pp. 95-107.
11. Hadad, M., Hall, M., Kenjegalieva, K., Santoso, W. and Simper, R. (2011), "Productivity changes and risk management in Indonesian banking: A Malmquist analysis", Applied Financial Economics, Vol. 21, pp. 847–861.
12. Glass, J. C. and McKillop, D. G. (1991), "Efficiency in Irish banking: Theory and evidence", Applied Financial Economics, Vol. 1 No. 4, pp. 235-240.
13. Guarda, P. and Rouabah, A. (2009), "Bank productivity and efficiency in Luxembourg: Malmquist indices from a parametric output distance function", working paper, http://www.bcl.lu/fr/media/Conferences/Perfilux_3_1_Guarda.pdf
14. Gwahula, R. (2013), "A DEA-based Malmquist productivity index approach in assessing performance of commercial banks: Evidence from Tanzania, European Journal of Business and Management, Vol. 5 No. 6, pp. 25-34.
15. Jackson, P., Fethi, M. D. and Inal, G. (1998), "Efficiency and productivity growth in Turkish commercial banking sector: A non-parametric approach", European Symposium on: Data Envelopment Analysis, Wernigerode, Germany, 16-18 October, 1998.
16. Malmquist, S. (1953), "Index numbers and indifference surfaces, Trabajos de Estadistica, Vol. 4, pp. 209-242.
17. Mörttinen, L. (2002), "Banking sector output and labor productivity in six European countries, Bank of Finland discussion papers, Vol. 12.
18. Neupane, B. (2013), "Efficiency and productivity of commercial banks in Nepal: A Malmquist index approach", Asian Journal of Finance & Accounting, Vol. 5 No. 2, pp. 220-243.

19. Ngo, D-T. and Nguyen, L. (2012), "Total factor productivity of Thai banks in 2007-2010. An application of DEA and Malmquist index", Journal of Applied Finance and Banking, Vol. 2 No. 5, pp. 27-42.
20. Noulas, A. (1997), "Productivity growth in the Hellenic banking industry: State versus private banks", Applied Financial Economics, Vol. 7, pp. 223-228.
21. Reddy, A. (2005), "Banking sector deregulation and productivity change decomposition of Indian banks", Finance India, Vol. 19 No. 3, pp. 983-1001.
22. Tortosa-Ausina E., Grifell-Tatjě E., Armero, C. and Conesa, D. (2002), "Sensitivity analysis of efficiency and Malmquist productivity indices: An application to Spanish savings banks", Centre for Applied Economic Research, working paper.
23. Worthington, A. (1998)' "Technical efficiency and technological change in Australian building societies, 1993/94-1996/97, Workshop on Research into Financial Institutions, Centre for Australian Financial Institutions (CAFI), Brisbane 12/13 November 1998.