Journal of Development and Economic Policies, Vol. 14, No. 1 (2012) 5 -36

Productivity Change in Sudanese Banks

Safiat Ali*

Abstract

This paper examines the change in productivity using a panel data of 16 Sudanese banks during the period 1996-2004. The sample is disaggregated into 14 commercial banks and 2 specialized banks; and into 8 government banks and a similar number of joint-venture banks. Productivity is measured by the Malmquist Index, and the data were analyzed using the Data Envelopment Analysis (DEA) technique under both the intermediation and production approaches. The overall results under both approaches suggest that total factor productivity of Sudanese banks increased during the study period. Banks were able to achieve productivity improvements from becoming more technically efficient than from being more technologically advanced under the intermediation approach while the opposite is true under the production approach. Results similar in spirit are obtained for groups of banks (commercial versus specialized and government versus joint venture banks), where the improvement in average total factor productivity is attributed mainly to technological improvement than to technical efficiency. Furthermore, the observed growth in technical efficiency is attributed more to the growth in managerial efficiency than to the growth in scale efficiency. These results indicate that both the size and technology of Sudanese banks do matter in improving bank efficiency. Thus, by increasing the scale of their operations and improving the technology they use internally and with customers, it is imperative that Sudanese banks could enhance total factor productivity and offer themselves the opportunity of remaining in business. This is particularly so in a sector that is increasingly becoming open for foreign banks.

تغير الإنتاجية في البنوك السودانية

صفيات علي*

ملخص

تبحث هذه الورقة التغيير في الإنتاجية عن طريق تحليل بيانات 16 مصرفاً سودانياً خلال الفترة الممتدة من 1996-2004. العينة شملت 14 مصرفاً تجارياً ومصرفين متخصصين. وثمانية مصارف حكومية وعدد مماثل للمشاريع المصرفية المشتركة. تم إستخدام مؤشر Malmquist لقياس الإنتاجية وتم تحليل النتائج بإتباع تقنية DEA للمقاربتين. يشير البحث الى ان إنتاجية المصارف السودانية إرتفعت خلال فترة البحث. تحسنت إنتاجية البنوك السودانية من خلال تحديث القدرة الفنية والتقنية. هذا التطور التقني مقترناً بتحسينات هيكلية داخلية ومع الزبائن من شانها مساعدة البنوك السودانية على النهوض والإستقرار.

* Assistant Professor, Department of Economics, University of Gezira, Box 20, Medani, Sudan; email: safiatt2005@yahoo.com

1. Introduction

The past two decades have witnessed dramatic changes in the banking industry worldwide, due to rapid financial deregulation, mergers and acquisitions, technological advances and financial innovation. These forces profoundly impact upon the role of banks as financial intermediaries in pooling financial resources from surplus units and allocating them to deficit units for investment and growth purposes.

In this new and dynamic banking environment, the competitiveness of a particular banking system not only depends on the banks' overall operating efficiency but also on the banks' ability to carry out financial innovation in response to new technological changes. Banks' productivity measures are considered good indicators as to how competitive banks are as the industry continues to evolve. Relatively unproductive banks will lose their market shares and be replaced by more productive ones. This holds for individual banks within the industry, or for a particular banking system vis a vis another. In line with functional financial intermediation, institution structures should always change towards those that are more efficient in performing the financial intermediation roles.
This paper assesses the performance of Sudanese banks in terms of productivity growth over the period 1996-2004, using the non-parametric Malmquist Productivity Index (MPI). It appears that no study on this issue has yet been undertaken for Sudanese banks. The importance of such an issue in a globalizing world cannot be more emphasized. This is particulrly so, in view of the role that banks play in the growth process and the efforts currently being made to reform the banking sector in Sudan.

2. Review of Recent Literature

Previous studies conducted on banking efficiency and productivity assessment use various and different concepts of efficiency and productivity. It is therefore essential to fully understand what these concepts mean before attempting to draw conclusions from previous literature. Thus, Total Factor Productivity (TFP) is defined as the ratio of all outputs of a Decision Making Unit (DMU) over all factors of production or inputs. The value indicates how much output vectors can be produced by a unit of input vectors (Coelli et al., 1998). Allocative efficiency deals with the minimization of the cost of producing a given level of output with proper choice of inputs and a given set of input prices, assuming that the organization being examined is already fully technically efficient (Avkiran, 1999). Finally, technical efficiency measures the ability of a DMU to obtain maximum outputs from a given set of inputs while assuming full allocative efficiency. Technical efficiency itself may be confounded by scale effects. Thus, it can be decomposed into pure technical efficiency and scale efficiency. Pure technical efficiency gauges the management performance in maximizing output. Scale efficiency meanwhile reflects whether a DMU is operating at the optimal scale size. There would be scale inefficiencies if the DMU is operating at any other scale size (Avkiran, op. cit.).

Studies that adopt the nonparametric MPI approach to examine bank productivity changes, have been conducted for a number of countries. Alam (2001) and Mukherjee et al. (2001) found positive productivity growth in USA commercial banks in the 1980s. Grifell-Tatje and Lovell (1996), observed that the productivity in Spanish savings had declined during the 1980s. Berg et al. (1992) found that the total productivity of banks in Norway fell in the early 1980s, but subsequently improved through technical efficiency rather than technological progress. Berg et al. (1993) observed that technological progress was a major contributor to the improved productivity of large banks in Finland, Norway and Sweden. Elyasiani and Mehdian (1995) measured the technological changes from a panel data for a sample of small and large banks in the USA during 1979-1986. The authors concluded that small banks have experienced some technological progress, while the reverse was observed for the large banks. Other countries in which bank productivity has been studied using MPI, include Australia (Avkiran, 2000); Korea (Gilbert and Wilson, 1998) and Taiwan (Chen and Yeh, 2000).

In a related study of Turkish banks, Isik et al. (2002) found that public banks experienced the slowest productivity growth while foreign banks saw the fastest productivity growth. However, although all bank groups experienced substantial progress in TFP change, efficiency change, pure efficiency change and scale efficiency change, all recorded notable technical regress, except foreign banks. Isik et al. (op. cit) also observed that both domestic and foreign private banks were more apt at improving technical efficiency through better management practices rather than improvement in scale efficiency. Nevertheless, most productivity growth for public banks came from scale changes.

Casu and Molyneux (2003) employed DEA to investigate whether the productivity efficiency of European banking systems had improved and converged towards a common European frontier during 1993-1997. The geographical coverage of the sample was France, Germany, Italy, Spain and the United Kingdom. All data were converted into the Euro as the reference currency. Their results indicated relatively low average efficiency levels. Nevertheless, it was possible to detect a slight improvement in the average efficiency scores over the study period for almost all banking systems in the sample, except for the Italian system.

Hassan and Hussein (2003) investigated the relative efficiency of the banking industry in Sudan by employing a panel of 17 banks for the years 1992 and 2000. They employed a variety of parametric (cost and profit efficiency) and non-parametric (data envelopment analysis) techniques to examine five efficiency measures (cost, allocative, technical, pure technical and scale efficiency scores). They analyzed the efficiency of the Islamic banks with reference to major sources. In addition, they explained the variations in estimated efficiency scores in terms of relevant explanatory variables. Moreover, they explained productivity growth in the Sudanese banking industry. Their results indicate that the productivity decline in Sudanese banks has been fuelled more by the decline in advances in technology, and by not operating at the right scale, than by decline of technical efficiency. In turn, the productivity decline was mostly as a result of the lack of technology and the regulatory environment in Sudan. The Sudanese banks should improve their X-efficiency by best managing and allocating their inputs. The bank management must be appointed based on competence and expertise and not on political or personal biases. The labor force in the banking sector must be well trained to deal with the range of Islamic banking practices.

The Schure, Wagenvoort and O'Brien report (2004) estimated the productivity of the European banking sector for the period 1993-1997. They found that larger commercial banks were more productive on average than smaller banks. However, the Italian and the Spanish banks were found to be the least efficient. However, from a study on the efficiency of the European banking institutions during 1994-2000, Casu et al. (2004) found that Italian banks had an 8.9% productivity increase; Spanish banks had a 9.5% increase; while French, Germany and English banks had 1.8%, 0.6% and 0.1% productivity increase, respectively. Efficiency improvement for the Italian and Spanish banks was attributed primarily to the cost reduction that these institutions managed to achieve.

Hassan et al. (2005), employing a panel of 31 banks for the years 1998 and 2000 investigated relative efficiency of the banking industry in Bahrain. The results indicate that all banks have improved their efficiency levels and experienced some gains in productivity.

Al-Faraj et al. (2006) investigated the performance of the Saudi commercial banking industry using DEA to evaluate the technical efficiency of Saudi banks for the year 2002 and compared with world mean efficiency scores. Their study revealed that the mean efficiency score of Saudi commercial banks compares very well with the world mean efficiency scores. They recommend that Saudi banks should continue their efforts of adapting new technologies and providing more services in order to sustain competitive advantages as Saudi Arabia continues to deregulate the banking industry.

Hassan (2006) investigated relative efficiency of the Islamic banking industry in the world by analyzing a panel of banks during the period of 1995-2001. Both parametric (cost and profit efficiency) and nonparametric (data envelopment analysis) techniques are used to examine efficiency of these banks. Five DEA efficiency measures – cost, allocative, technical, pure technical and scale efficiency scores – are calculated and correlated with conventional accounting measures of performance. The results indicate that, on the average, the Islamic banking industry is relatively less efficient compared to their conventional counterparts in other parts of the world. The results also show that these efficiency measures are highly correlated with Return on Assets (ROA) and Return on Equity (ROE), suggesting that the efficiency measures can be used concurrently with conventional accounting ratios in determining Islamic bank performance.

Sufian (2007) examined the antecedents of the Malaysian Islamic banking sector's productivity changes during the period 2001-2005. The study employed the Malmquist Productivity Index (MPI) method to isolate efforts to catch up to the frontier (efficiency change) from shifts in the frontier (technological change) and the main sources of efficiency changes. The empirical findings suggest that the Malaysian Islamic banking sector has exhibited productivity regress mainly due to the decline in technological change. This study finds that the foreign Islamic Banking Scheme (IBS) banks have exhibited lower productivity levels compared to their domestic peers. The results suggest that the domestic IBS banks have exhibited higher productivity levels compared to their foreign peers attributed to higher technological progress and efficiency levels.

Heffernan and Fu (2009) studied the banking sectors' trends in TFP changes in China and India between 2000 and 2007 and its components. They also considered the relationship between TFP growth and individual banks' financial performance. They found that TFP growth is largely driven by technical progress/innovation. It was somewhat faster in China than India and strongest among large banks. Foreign banks displayed slower growth than locally owned banks but the association between ownership or listings and TFP change is ambiguous. In China, TFP growth continued to outpace India's but there may be some deceleration with a shift in the underlying components. TFP advances are found to exert important influences onbank-specific equity prices.

Al Shamsi et al. (2009), using newly collected data from a survey distributed to all banks in the United Arab Emirates (UAE), measured economic efficiency in the banking industry, namely allocative, technical, pure technical and scale efficiency. Employing a nonparametric DEA approach, the study estimated the efficiency for a cross section of the UAE banks in 2004. The results indicate that the dominant source of inefficiency in the UAE banking stems from allocative inefficiency rather than technical inefficiency. Furthermore, the main source of the relatively small size, technical inefficiency in the UAE banking industry is not the scale inefficiency but rather pure technical inefficiency. The results further indicate that the UAE banks are able to use their input resources more efficiently when they have more branches, and that newer banks are performing better than older banks, on the average. Moreover, the results show that short experiences of employees affect efficiencies negatively and government ownership tends to reduce efficiency (as the government shares increase in the bank, the efficiency scores get lower). Finally, the most interesting results have to do with finding higher average efficiencies in banks that employ more women, more managers and less national citizens of the UAE. Onour and Abdalla (2010) employed several efficiency measures and productivity changes using DEA to investigate efficiency performance of Islamic banks in Sudan. Their results indicate that among twelve banks included in the sample, only two banks – the largest bank in the group which is government-owned, and a middle-sized, private bank – scored technical efficiency level (i.e. scale and pure technical efficiency). The smallest bank in the group (private-owned), scored pure technical efficiency (i.e., managerial efficiency), but scale-inefficient. These results imply ownership is not a constraint of managerial and scale efficiency but the bank's size is an important factor for scale efficiency.

3. An Overview of Sudan's Banking Sector

Sudan is the largest country in Africa and the 9th largest country in the world with an area of 2.5 million square kilometers of which 12% is arable land, 18% forests, and the remainder being mainly desert (Hussein, 2003). Like many other countries in Sub-Saharan Africa, Sudan has experienced many years of political tension and civil wars since it became independent in 1956 until a comprehensive peace agreement (CPA) was concluded on January 9, 2005 to end the conflict in Southern Sudan.

Sudan is endowed with huge natural resources, including large and rich arable land, and pervasive ecological zones and climatic conditions. As an underdeveloped country, Sudan depends on the production of raw materials and primary commodities.

As such, despite the increasing reliance on oil in more recent years, Sudan remains a predominantly agricultural economy. Prior to oil discovery in 1998, agriculture was the main source of economic growth, contributing about 80% of the country's exports (excluding petroleum) and providing livelihood for 80% of the population (Ahmed, 2004). The 2005 census estimated Sudan's population at 34 million. Although well endowed with natural resources, Sudan's economic performance has been substantially below its potential. Accordingly, Sudan is classified as one of the poorest Sub-Saharan African countries (World Bank, 2006). The vast majority of the population is poor, with an average per capita GDP estimated at US$753 in 2005 and US$970 in 2006 (IMF, 2007).

Like many developing countries, Sudan's financial sector is dominated by commercial banks. Bonds and equity markets which require a mature system of accounting and financial information, are still primitive. Historically, Sudan's financial system has been characterized by excessive government intervention and regulations, centralized lending by the Central Bank to public enterprises, absence of indirect monetary policy instruments, lax bank supervision and an inadequate accounting system.

More recently, Sudan's banking sector has witnessed the most significant developments since the establishment of the Bank of Sudan in 1960. In terms of numbers, the available statistics indicate that in 2004, the banking sector consisted of 26 banks (23 commercial banks and three specialized banks). In 2005, the number of commercial banks increased to 25 banks. The two new banks which started operations in 2005 were El Salam Bank and the Sudanese Egyptian Bank.

In realization of the fundamental role that the sector could play in the development of a market-oriented economy, the government of Sudan has taken positive steps toward reforming banks as part of the efforts to articulate a banking sector that corresponds to the challenges of economic reforms, the privatization efforts, the deregulation of the previously centrally managed economy, and the encouragement of foreign direct investment for financing the rehabilitation of the ageing and technologically out-dated industrial sector together with the expansion in the emerging oil and petrochemical sectors. Measures have also been taken toward strengthening and broadening the role of the Central Bank of Sudan, and also in promoting transparency in the sector. Efforts are also being made to realign the Sudanese financial sector with international financial practices and, at the same time, opening the sector for the establishment and operation of foreign banks. In particular, a number of measures were introduced to improve bank supervision, increase compliance with capital adequacy requirements, and reduce the high level of non-performing loans. These measures comprised upgrading the reporting system at the Bank of Sudan (BOS), provision of mandatory monthly reports on non-performing loans to the BOS and the Board of Directors of the bank concerned, setting foreign exchange exposure limits and improving the existing loan classification system. Sudanese banks still remain very small even by the modest international standard as compared to Islamic banks in other countries. The total amount of deposits of the banking system has been hovering around $500 million since the mid-1990 and is dominated by demand deposits with a share of over 70% whereas saving and investment deposits remain relatively small. This reflects the cash nature of the Sudanese economy where individuals prefer to have instant and easy access to their funds (Kireyev, 2001). The sector also suffers a number of risks. The most important relate to capital inadequacy, liquidity deficiency, non-performing loans and the risk of banking operations.

This study aims to examine productivity of Sudanese banks with the view of assessing how competitive these banks are, or could be, as the industry continues to evolve.

4. Methodology

Two performance indices are often used to examine productivity change for a particular decision making unit (hereafter the bank): (a) the stochastic Tornqvist Index (1936) or the non-stochastic Malmquist Index (1953).

The Tornqvist Index is by far the most popular index number approach adopted in studies on productivity, mainly because: (a) it features a number of economic-theoretic properties as expounded by Diewert (1976, 1981) and Caves et al. (1982b); (b) it does not smooth the pattern of technical progress and; (c) it enables the generation of reasonably close approximations to the actual output and index numbers (Coelli et al., 1998). The index is essentially a weighted geometric average of relative prices with the weights being the simple average of the share values in periods 0 and 1. However, while the Tornqvist Index can be easily computed by using only a single observation in each time period, it requires both price and quantity information that may not be easily obtained, together with the assumptions that all banks are cost minimizers or revenue maximizers (Coelli et al., op.cit.). Furthermore, since the original form of the Tornqvist Index assumes that production is always efficient, it does not allow for the decomposition of productivity change into technical efficiency change, management performance change, and change in technology (Fare et al., 1994).

In contrast, the Malmquist Productivity Index (MPI) is less restrictive. It allows one to: (a) identify productivity changes between two periods from a given panel data without need for price data; and (b) to decompose productivity changes into two components – one due to technical change (shifts in the frontier) and the other due to technical efficiency change (the catching up effect). Fare et al. (1994) extended the original MPI decomposition to derive a third component of productivity change, namely the change in scale efficiency (changes in production scale relative to the optimal scale size). Thus, given the availability of suitable panel data, the MPI gives a richer account of productivity change.

The MPI was initially pioneered and expounded in a consumer theory context by Malmquist (1953). The idea behind the index was to measure the quantity of consumption that an individual requires in a certain year in order to achieve the same utility level of the previous year. The quantity index proposed by the study represents a proportional scaling factor that is expressed as the ratio of two distance functions from different time periods. The formal method of utilizing distance functions in productivity measurement was developed by Caves et al. (1982b) in a general production framework that shows great similarities to the formulation of distance functions of Shepard (1970).

However, Färe and Grosskopf (1992) identified the direct link between the distance function concept of Caves, et al. (1982b), known as the CCD method, and the measures of relative technical efficiency of Farrell (1957), whereby the distance functions are the reciprocals to Farrell's measure of technical efficiency. The concept developed by Caves, et al. (1982b) requires assumptions on the economic behavior of the bank. Farrell (1994) showed that MPI based on the non-parametric linear programming DEA can be decomposed into changes in production technology, technical efficiency and scale efficiency. Because of these virtues, this study adopts the DEA-based MPI under both the intermediation and production approaches.

The Overall MPI

The measurement and the subsequent decomposition of the MPI is based on a production technology defined over the input set, p(x), which represents the set of all output vectors y that can be produced using the input vector x; that is:

$$p(x)=\{ y : x \text{ can produce } y \} \qquad \text{(Equation 1)}$$

The output distance function $d_0^t(x_t, y_t)$ is defined on the output set p(x) as:

$$d_0^t(x_t, y_t) = \min\{\delta : (y_t/\delta) \in p(x_t)\} \qquad \text{(Equation 2)}$$

This function gives a normalized measure of the distance from the location of a bank in the input-output space to the production frontier at time t in the hyper-plane, where inputs are held fixed. The output distance function, $d_0^t(x_t, y_t)$, will take a value less than one if the output vector, y_t, is an element of the feasible production set, $p(x)$, at time t, and a value of unity if y_t is located on the outer boundary of the feasible production set [i.e. $0 \le d_o^t(x_t, y_t) \le 1$]. Furthermore, the output distance function will take a value greater than one if measured relative to the technology of another period s [i.e. $d_o^s(x_t, y_t) > 1$].

The Malmquist total factor productivity index measures the TFP change between two data points, which is calculated by the ratio of the distance of each data point relative to a common technology. Following Fare et al (1994), Ray and Desli (1997), Wheelock and Wilson (1999), and Mukherjee et al. (2001), the Malmquist Index m_0, is calculated as the geometric mean of two MPIs between the base period s, and period t.
Hence:

$$m_0(y_s, x_s, y_t, x_t) = \left[\frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)} \times \frac{d_0^t(y_t, x_t)}{d_0^t(y_s, x_s)}\right]^{1/2} \qquad \text{(Equation 3)}$$

where $d_0^s(x_t, y_t)$ denotes the output distance from period t to period s technology. A value of $m_0 > 1$ indicates positive TFP growth from period s to period t while a value less than unity indicates a decline in TFP.

Caves, Christensen and Diewert (1982a) assumed that there is no technical inefficiency so that $d_0^s(x_s, y_s) = d_0^t(x_t, y_t) = 1$. However, it is common to observe some degree of inefficiency in the operations of most banks. Hence, the assumption that $d_0^s(x_s, y_s) \le 1$ and $d_0^t(x_t, y_t) \le 1$ is likely to be more realistic. Where technical inefficiency is present, the Malmquist output-oriented productivity index defined in Equation 3 can be rewritten as Fare et al., 1989:

$$m_0(y_s, x_s, y_t, x_t) = \frac{d_0^t(y_t, x_t)}{d_0^s(y_s, x_s)}\left[\frac{d_0^s(y_t, x_t)}{d_0^t(y_t, x_t)} \times \frac{d_0^s(y_s, x_s)}{d_0^t(y_s, x_s)}\right]^{1/2} \qquad \text{(Equation 4)}$$

where the ratio outside the square brackets on the RHS of Equation 4 measures the change in output-oriented technical efficiency between periods s and t, and the geometric mean of the two ratios inside the square brackets captures the shift in the technology between the two periods, evaluated at x_s and x_t.

For an empirical application, the CCD (Caves, Christensen and Diewert, 1982b) method calculates for each firm the four distance measures that appear in Equation 4 in each pair of adjacent time periods. This can be done using DEA-like linear programming method suggested by Färe et al. (1994).
Using Equation 4, the following is obtained:

$$\text{Efficiency Change} = \frac{y_t / y_c}{y_s / y_a} \qquad \text{(Equation 5)}$$

$$\text{Technical Change} = \left[\frac{y_t / y_b}{y_t / y_c} \times \frac{y_s / y_a}{y_s / y_b} \right]^{1/2} \qquad \text{(Equation 6)}$$

For the purpose of an empirical application, the CCD (Caves, Christensen and Diewert, 1982b) method calculates for each firm the four distance measures that appear in Equation 5 in each pair of adjacent time periods. This can be done using DEA-like linear programming method suggested by Fare et al. (1994).

Computing MPI Using the DEA Framework

Following Färe et al. (1994), and given the availability of suitable panel data, the required distances using DEA-type linear programs can be calculated. For the i-th bank, four distance functions to measure the TFP change between two periods are calculated. This requires solving four linear programming (LP) problems. The first problem is given by:

$$\begin{aligned} \left[d_0^t\left(y_t, x_t\right)\right]^{-1} &= max_{\Phi\lambda}\ \varphi \\ \text{subject to} \quad -\phi y_{it} + Y_t \lambda &\geq 0 \\ x_{it} - X_t \lambda &\geq 0 \\ \lambda &\geq 0, \end{aligned} \qquad \text{(Equation 7)}$$

where $d_0^t(x_t, y_t)$ denotes the distance from period t observation to period t technology. The second problem is given by:

$$\left[d_0^s\left(y_s, x_s\right)\right]^{-1} = max_{\Phi\lambda}\ \varphi$$
$$\begin{aligned} \textit{subject to} \quad -\phi y_{is} + Y_s\lambda &\geq 0 \\ x_{it} - X_s\lambda &\geq 0 \\ \lambda &\geq 0, \end{aligned} \qquad \text{(Equation 8)}$$

where $d^s(x_s, y_s)$ denotes the distance from period s observation to period s technology. The third problem is given by:

$$\left[d_0^t\left(y_s, x_s\right)\right]^{-1} = max_{\Phi\lambda}\ \varphi$$
$$\begin{aligned} \textit{subject to} \quad -\phi y_{is} + Y_t\lambda &\geq 0 \\ x_{is} - X_s\lambda &\geq 0 \\ \lambda &\geq 0, \end{aligned} \qquad \text{(Equation 9)}$$

where $d^t(x_s, y_s)$ denotes the distance from period s observation to period t technology. The fourth problem is given by:

$$\left[d_0^s\left(y_t, x_t\right)\right]^{-1} = max_{\Phi\lambda}\ \varphi$$
$$\begin{aligned} \textit{subject to} \quad -\phi y_{it} + Y_s\lambda &\geq 0 \\ x_{it} - X_s\lambda &\geq 0 \\ \lambda &\geq 0, \end{aligned} \qquad \text{(Equation 10)}$$

where $d^s(x_t, y_t)$ denotes the distance from period t observation to period s technology. In all these problems, ö is a scalar indicating efficiency change for the i-th firm and λ is an Nx1 vector of constants.

It should be noted that in the linear programming Equations 9 and 10, where production points are compared to added to each. That is, one would calculate these two distance functions relative to a variable returns to scale (VRS), instead of a constant returns to scale (CRS) technology. technologies for different time periods, the Φ parameter need not be greater than or equal to one, because the data points could lie above the feasible production set. This will most likely occur in LP (Equation 10) where a production point from period t is compared to technology in an earlier period, s.

The above approach can be extended to decompose the technical efficiency into scale efficiency and pure technical efficiency components. This requires the solution of two additional LPs, when comparing the production points. These would involve repeating the LP problems in Equations 7 to 10 with the convexity restriction $\Sigma\lambda = 1$.

Bank Samples. For the purposes of the study, annual data are collected from a sample of 16 banks (representing about 62% of the banking industry in Sudan) over the period 1996-2004. These banks are:

- Faisal Islamic Bank (FIB)
- Bank of Khartoum (BOK)
- Omdurman National Bank (ONB)
- Sudanese Islamic Bank (SIB)
- Saving and Social Development Bank (SSDB)
- Islamic Cooperative Development Bank (ICDB)
- Elnilein Industrial Development Bank (EIDB)
- Al Shamal Islamic Bank (AIB)
- Al Baraka Bank (ABB)
- Agricultural Bank of Sudan (ABS)
- Sudanese French Bank (SFB)
- Export Development Bank (EDB)
- Workers National Bank (WNB)
- Saudi-Sudanese Bank (SSB)
- Animal Resources Bank (ARB)
- Tadamoun Islamic Bank (TIB)

Data were obtained from different sources, including the annual reports published by each bank in the sample, and the Statistics and Information Center of the Central Bank of Sudan. In addition to the secondary data, some relevant information on a number of variables were calculated from the balance sheets and income statements published annually by each bank in the sample. Such variables include input prices. Data on inputs and outputs are measured in Sudanese Dinar (SDD).

Intermediation and Production Approaches. The exact definition of input and output variables in banking is still a controversial issue. According to Berger and Humphrey (1992), bank inputs and outputs can be specified using either the intermediation approach or the production approach. The intermediation approach views banks as intermediaries of financial services, while the production approach views banks as service-producing units. The important difference between the two approaches lies in how deposits are treated. The intermediation approach treats deposits as inputs to produce loans; in contrast, the production approach considersdeposits as an output since deposits significantly contribute to the creation of profits (Resti, 1997).

Since the production and the intermediation approaches have advocates and neither has emerged as dominant, the two approaches to estimate efficiency measures are used.

Sets of Variables. The variables required under the two approaches are described below.

There are three sets of variables, namely outputs, inputs, and input prices. All output variables are measured in million Sudanese Dinar (SDD).

- Total investment (INVT) variable includes all types of investments.
- Off balance-sheet or contra accounts (CONTA) transactions variable includes investment returned cheques, exchange bills under collection, letters of credit and investment cheques. Similarly, all input variables are measured in million SDD.
- The total deposits (DEPS) variable includes current, saving and investment deposits both in foreign and local currency.
- Fixed assets variable (FXSS) includes land, buildings, cars and furniture and equipment.
- The WAGE variable includes salaries, wages and allowances.

Descriptive Statistics of the Data

Table 1 reports some descriptive statistics of the data on time varying inputs and outputs for the sampled banks over the study period. It shows for each variable the mean, the maximum (max), the minimum (min), the standard deviation (SD) and the coefficient of variation (CV). It may be observed that except for the year 1999, investment has exhibited an upward trend during the sample period, increasing from an average of SDD1,641 million in 1996 to SDD23,168 million in 2004 with average annual rate of growth of 1.46%. Total wage bill increased from an average of SDD228 million in 1996 to an average of SDD1,151 million in 2004 with average annual rate of growth of 0.45%, while total deposits increased from an average of SDD3,536 million to an average of SDD35,358 million during the study period with average annual rate of growth of one percent. Fixed assets also exhibited a similar trend – it increased from an average of SDD356,99 million in 1996 to an average of SDD4992,46 million in 2004 with average annual rate of growth of 1.44%. The off-balance sheet transactions have increased from SDD2,500 million to SDD23,438 million during the study period with average annual rate of growth of 0.93%.

Also, it is observed that except for the year 1999 and 2002, the SD of the investment has increased during the sample period meaning that the difference between banks regarding investment has increased with time and this is reflected in the CV. The SDs of all other variables also have increased (with few exceptions) during the sample period.

5. Empirical Results

Changes in efficiency over time can be captured through the concept of TFP defined as an index of outputs divided by an index of inputs. To appreciate the relationship between productivity and efficiency in the context of distance functions, it may be recalled that changes in value of the distance function from one year to another could be either due to a movement within the input-output space, or to technical change corresponding to the shift of the production frontier over time.

The linear programming problems in Equations 7-10 are solved, using the computer program DEAP as developed by Coelli (1996), to obtain the different productivity measures.

The MPI is a DEA-based measure of the change in TFP between two points in time, and is calculated as the ratio of the distance of each point relative to the common frontier. On the basis of the methodology outlined, all indices are calculated relative to the previous year and reported for each bank in each year. In addition to the change in total factor productivity (tfpch), the software program used in the analysis (DEAP) enables the calculation of technical efficiency change (teffch), technological change (techch), pure technical efficiency change (pech), and scale efficiency change (sech). The annual rate of growth for each index is obtained by subtracting one from the reported value of the index.

Changes in Productivity of Individual Banks

Tables 2 and 3 report the calculated Malmquist performance indices for the average bank and for individual banks, respectively, under the two approaches over the period 1996-2004. All indices are calculated relative to the previous year so that, with 1996 taken as the base year, indices for the period 1997-2004 are obtained. The first panel of each table reports the results on the productivity change under the intermediation approach.

Table 1: Descriptive Statistics of Output and Input Variables for Sampled Banks, 1996–2004 (in Million SDD)

Year	Variables	Mean	Max	Min	SD	CV
1996	INV	1641.18	6377.30	30.40	1773.20	1.08
	CONTA	2499.93	12158.00	65.80	3744.43	1.50
	DEPS	3535.88	13251.50	281.00	3488.73	0.99
	WAGE	228.09	720.00	40.00	225.55	0.99
	FXSS	356.99	1230.00	57.40	340.62	0.95
1997	INV	2072.18	6856.70	32.50	2080.05	1.00
	CONTA	3931.08	21937.00	48.90	6174.94	1.57
	DEPS	5251.89	14038.10	631.90	4098.30	0.78
	WAGE	306.05	944.40	55.00	283.05	0.92
	FXSS	567.78	1409.60	80.40	422.48	0.74
1998	INV	3010.22	9668.80	108.50	2627.47	0.87
	CONTA	4118.11	16947.00	30.00	5064.92	1.23
	DEPS	6703.37	18941.10	148.40	5912.11	0.88
	WAGE	790.47	5973.00	58.40	1428.72	1.81
	FXSS	680.58	1614.00	78.90	468.30	0.69
1999	INV	2971.78	8730.00	105.40	2622.98	0.88
	CONTA	4945.08	22190.00	41.00	5862.65	1.19
	DEPS	7198.78	16593.00	538.90	5472.18	0.76
	WAGE	548.26	1645.30	66.00	495.30	0.90
	FXSS	803.78	1732.00	94.60	513.68	0.64
2000	INV	5673.21	16896.00	444.80	4984.95	0.88
	CONTA	8344.75	36960.00	61.00	10373.22	1.24
	DEPS	10119.07	31934.00	889.60	8271.53	0.82
	WAGE	671.69	1897.60	137.20	538.12	0.80
	FXSS	1079.83	3339.00	96.70	913.74	0.85
2001	INV	7298.54	30038.00	454.30	7598.16	1.04
	CONTA	14402.58	89204.00	8.80	22497.65	1.56
	DEPS	13470.02	45369.00	1176.70	11896.60	0.88
	WAGE	750.00	1840.90	164.90	557.40	0.74
	FXSS	1207.40	4010.00	239.90	973.55	0.81
2002	INV	7831.01	20462.00	2159.10	4718.40	0.60
	CONTA	14367.85	90123.00	280.10	22253.54	1.55
	DEPS	19475.44	86056.00	2140.20	22250.71	1.14
	WAGE	762.08	1601.80	208.00	443.56	0.58
	FXSS	1437.03	5232.00	308.90	1191.44	0.83
2003	INV	17342.35	124528.00	2348.90	29240.14	1.69
	CONTA	18619.13	114926.00	921.00	27214.43	1.46
	DEPS	24846.13	135723.00	3812.20	32401.65	1.30
	WAGE	892.13	1954.00	212.60	549.42	0.62
	FXSS	2342.76	9727.60	419.00	2498.58	1.07
2004	INV	23168.82	191960.00	2340.00	45725.82	1.97
	CONTA	23437.59	113997.00	1035.10	29077.80	1.24
	DEPS	35358.18	198974.00	6189.70	47321.85	1.34
	WAGE	1151.63	2902.00	219.70	856.16	0.74
	FXSS	4992.46	35707.00	547.50	8595.62	1.72

Source: Author's calculations based on sample data.

The results under the tfpch column in Table 2 indicate that on the average, the TFP of Sudanese banks increased at an annual average rate of 3.7% over the period. Furthermore, banks $[\hat{\beta}_3 * \text{std}(\text{infvol}_{i,t})]$ roductivity growth of 4.8% in 1998; 46.6% in 2000; 6.3% in 2001; 22.9% % in 2004, but have registered productivity decline in 1997, 1999 and 2003. With and average teffch of 2.1% and average techch of 1.5%, the resu $[\hat{\beta}_4 * \text{std}(\text{infvol}_{i,t})]$ at banks in Sudan have been able to achieve productivity improvement by becoming more technically efficient than from being more technologically advanced. The results on the two components of the efficiency change – namely the change in pure technical efficiency (pech) which measures performance due to managerial activity only, and the change in scale efficiency (sech) – suggest that the observed growth in technical efficiency is attributed more to the growth in managerial efficiency than to the growth in scale efficiency.

The CVs for all TFP change indices in Table 2 under both approaches are significantly low indicating that these indices are highly stable.

Table 2: Malmquist Efficiency and Total Factor Productivity Change in Sudanese banks, 1996-2004

Year	Intermediation Approach					Production Approach				
	teffch	techch	pech	Sech	tfpch	teffch	techch	pech	sech	Tfpch
1997	0.870	0.832	0.927	0.938	0.724	0.864	0.865	0.918	0.941	0.747
1998	0.967	1.083	1.028	0.941	1.048	1.131	0.977	1.054	1.073	1.105
1999	1.116	0.812	1.076	1.037	0.906	0.891	1.030	0.931	0.957	0.918
2000	1.140	1.286	1.037	1.099	1.466	0.988	1.243	0.944	1.046	1.228
2001	1.069	0.994	1.035	1.033	1.063	0.978	1.091	1.073	0.911	1.067
2002	0.991	1.239	0.928	1.069	1.229	1.256	1.032	1.103	1.139	1.296
2003	0.858	1.095	1.010	0.850	0.939	0.826	1.238	0.924	0.894	1.022
2004	1.215	0.890	1.106	1.098	1.081	1.003	1.160	0.977	1.026	1.163
Mean	1.021	1.015	1.017	1.004	1.037	0.983	1.072	0.988	0.995	1.055
S.D	0.129	0.179	0.064	0.089	0.222	0.143	0.131	0.075	0.086	0.176
CV	0.126	0.176	0.063	0.089	0.214	0.145	0.122	0.076	0.086	0.167

Source: Author's calculations based on sample data.

At the level of individual banks, the results in the first panel of Table 3 indicate that total factor productivity (tfpch) increased for 11 out of 16 banks while it decreased for five banks, namely ONB, AIB, ABS, SFB and ARB, and varied between a low rate of -8.3% for SFB and a high rate of 14.1% for ABB. For the two components of productivity growth, the results suggest that technical efficiency (teffch) increased for eight banks, declined for five banks, and remained constant for three banks, and varied between a low rate of -1.9% for ARB to a high rate of 11.9% for SIB. Technical change (techch), increased for nine banks and declined for seven banks, and varied between a low rate of -7.2% for AIB to a high rate of 14.2% for ABB. With regard to the two components of technical efficiency change, the results show that pure technical efficiency (pech) increased for six banks and declined for only one bank, while it remained constant for nine banks; it varied between a low rate of (-0.6%) for ABB and a high rate of (10.2%) for AIB. Scale efficiency (sech) increased for seven banks, declined for six banks, and remained constant for three banks; it varied between a low rate of (-4.5%) for FIB and a high rate of (9.6%) for EDB.

Table 3: Malmquist Efficiency and Total Factor Productivity Change for Individual Banks, 1996-2004

Banks	Intermediation Approach					Production Approach				
	teffch	techch	Pech	sech	tfpch	teffch	techch	pech	sech	tfpch
FIB	0.991	1.134	1.038	0.954	1.123	1.000	1.106	1.000	1.000	1.106
BOK	1.007	1.010	1.000	1.007	1.018	0.971	1.045	0.961	1.010	1.015
ONB	1.000	0.975	1.000	1.000	0.975	1.000	1.013	1.000	1.000	1.013
SIB	1.119	1.002	1.079	1.037	1.120	0.981	0.998	1.038	0.944	0.978
SSDB	1.043	1.053	1.028	1.014	1.098	1.013	1.169	1.040	0.974	1.184
ICDB	1.022	0.995	1.004	1.019	1.017	0.984	1.046	1.006	0.978	1.029
EIDB	1.025	1.051	1.000	1.052	1.077	1.032	1.162	0.984	1.048	1.199
AIB	1.061	0.921	1.102	0.963	0.977	1.081	1.011	1.095	0.987	1.093
ABB	0.999	1.142	0.994	1.005	1.141	0.895	1.058	0.931	0.962	0.972
ABS	1.000	0.925	1.000	1.000	0.925	0.881	1.112	0.899	0.979	0.979
SFB	0.992	0.924	1.000	0.992	0.917	1.000	1.047	1.000	1.000	1.047
EDB	1.096	0.971	1.000	1.096	1.065	1.056	1.074	0.984	1.073	1.134
WNB	0.994	1.056	1.000	0.994	1.050	1.005	1.100	1.000	1.005	1.106
SSB	1.000	1.089	1.000	1.000	1.089	1.000	1.085	1.000	1.000	1.085
ARB	0.981	0.978	1.000	0.982	0.959	0.929	1.037	0.944	0.984	0.963
TIB	1..020	1.054	1.029	0.991	1.074	0.928	1.087	0.942	0.985	1.009
S.D	0.040	0.070	0.310	0.030	0.070	0.050	0.050	0.050	0.030	0.080

Source: Author's calculations based on sample data.

The results under the production approach reported in the second panel of Table 2 indicate that average total factor productivity (tfpch) increased at an annual average rate of 5.5% over the study period, greater than that under the intermediation approach. For the two components of productivity growth, the results indicate that technical efficiency (teffch) declined at an average annual rate of 1.7%, while technical change (techch) increased at an average annual rate of 7.2%. Accordingly, total factor productivity change (tfpch) was more attributable to the technological change (techch) than to technical efficiency change (teffch). The results on the two components of efficiency change suggest that the observed rate of deterioration in technical efficiency may be attributed to managerial efficiency (pech) more than to scale efficiency (sech).

At the level of individual banks, the results under Column tfpch in the second panel of Table 3 suggest that under the production approach, total factor productivity (tfpch) varied between a low rate of -3.7 for ARB and a high rate of 19.9 for EIDB. It increased for 12 out of the 16 banks, while it declined for SIB, ABB, ABS and ARB. For the two components of productivity growth, the results show that technical efficiency (teffch) increased for five banks; declined for seven banks; remained constant for four banks; and varied from a low rate of -11.9 for ABS to a high rate of 5.6 for EDB. Technical change (techch) increased for all banks except SIB which recorded a decline of -0.2%. The highest techch (16.9%) is recorded for SSDB. For the two components of technical efficiency change, the results show that pure technical efficiency (pech) increased only for four banks and declined for seven banks, while it remained constant for five banks. ABS experienced the lowest pech of -10.1% while AIB experienced the highest pech of 9.5%. Scale efficiency (sech) increased for four banks, declined for eight banks, and remained constant for four banks. SIB registered the lowest sech of -5.6% while EDB registered the highest sech of 7.3%.

To examine whether the two approaches give different results on total factor productivity change, the usual t-test for the equality of means is undertaken, where the SDs reported in Table 3 were used. The t-value for the average cost efficiency results is 0.83, suggesting that the two means under the two approaches are not significantly different at the 5% significance level.

Changes in Productivity of Groups of Banks

Change in Productivity by Nature of Bank. Table 4 reports the results of the MPI for the average commercial and specialized banks under the two approaches over the study period. The results under Column tfpch in the first panel show that under the intermediation approach, TFP improved for both commercial and specialized banks over the period by annual average rates of 4.2% and 18.5%, respectively, suggesting that specialized banks have achieved higher productivity growth than commercial banks. With average teffch of 0.8% and average techch of 3.4%, commercial banks were able to achieve the productivity improvement from becoming more technologically advanced than from being more technically efficient. Estimates of the two components of efficiency change indicate that the productivity improvement for commercial banks may be attributed to managerial (pech) efficiency. With average techch of 18.5% and zero teffch, specialized banks were able to achieve productivity improvement solely from becoming more technologically advanced.

Table 4. Malmquist Efficiency and Total Factor Productivity Change in Commercial and Specialized Banks in Sudan (1997–2004)

Year	Intermediation Approach					Production Approach				
	teffch	techch	pech	sech	tfpch	Teffch	techch	pech	sech	tfpch
	Commercial Banks									
1997	0.768	0.993	0.871	0.882	0.762	0.932	0.871	0.945	0.986	0.811
1998	0.978	1.027	1.032	0.948	1.005	1.099	0.956	1.046	1.051	1.051
1999	1.086	0.827	1.072	1.014	0.898	0.847	1.055	0.902	0.938	0.893
2000	1.242	1.272	1.094	1.136	1.581	1.058	1.194	0.997	1.061	1.264
2001	1.006	1.028	0.997	1.010	1.035	0.973	1.085	1.049	0.927	1.055
2002	1.075	1.152	0.981	1.096	1.239	1.259	1.020	1.101	1.143	1.284
2003	0.802	1.116	0.957	0.838	0.895	0.776	1.238	0.868	0.894	0.961
2004	1.206	0.921	1.104	1.092	1.111	1.049	1.129	1.020	1.028	1.184
Mean	1.008	1.034	1.011	0.997	1.042	0.989	1.062	0.988	1.001	1.051
S.D	0.171	0.138	0.079	0.106	0.254	0.152	0.121	0.080	0.083	0.172
CV	0.170	0.133	0.078	0.106	0.244	0.154	0.114	0.081	0.083	0.164
	Specialized Banks									
1997	1.000	1.033	1.000	1.000	1.033	1.000	1.267	1.000	1.000	1.267
1998	1.000	1.567	1.000	1.000	1.567	1.000	1.678	1.000	1.000	1.678
1999	1.000	0.821	1.000	1.000	0.821	1.000	0.931	1.000	1.000	0.931
2000	1.000	0.859	1.000	1.000	0.859	1.000	1.058	1.000	1.000	1.058
2001	1.000	1.106	1.000	1.000	1.106	0.924	1.982	1.000	0.924	1.831
2002	1.000	2.089	1.000	1.000	2.089	1.082	1.852	1.000	1.082	2.005
2003	1.000	1.423	1.000	1.000	1.423	0.913	1.345	1.000	0.913	1.227
2004	1.000	1.034	1.000	1.000	1.034	1.096	1.061	1.000	1.096	1.163
Mean	1.000	1.185	1.000	1.000	1.185	1.000	1.349	1.000	1.000	1.349
S.D	0	0.428	0	0	0.428	0.061	0.395	0	0.065	0.391
CV	0	0.361	0	0	0.361	0.048	0.293	0	0.065	0.290

Source: Author's calculations based on sample data.

From the results under the Column tfpch in the second panel of Table 4, it may be observed that during the sample period, average TFP under the production approach improved for both commercial and specialized banks by annual average rates of 5.1% and 34.9%, respectively. Estimates of the two components of productivity growth reveal that the productivity improvements were due to technical change (techch), while the deterioration in technical efficiency may be attributed more to managerial (pech) efficiency than to scale efficiency (sech). Furthermore, with average techch of 34.9% and zero average teffch, specialized banks were able to achieve TFP improvement solely from becoming more technologically advanced.

The CVs for all total factor productivity change indices in Table 4 under both approaches also are significantly low indicating that these indices are highly stable.

Table 5 reports the results of the MPI for commercial and specialized banks under the two approaches. From the tfpch Column under the intermediation approach, it may be observed that TFP for commercial banks increased for 10 out of 14 banks, while it declined for the remaining four banks. For the two components of productivity growth, the results indicate that technical efficiency (teffch) increased for four commercial banks, declined for six banks, and remained constant for four banks. Technical change (techch) increased for nine banks and declined for five banks. The results on the two components of technical efficiency change show that pure technical efficiency increased for four commercial banks, declined for only one bank, and remained constant for nine banks. Scale efficiency increased for four banks, declined for six, and remained constant for six banks. For specialized banks, TFP increased for both banks, with SSDB registering an increase of 28.1%, far higher than the increase of 9.5% for ABS. For the two components of productivity growth, the results suggest that technical efficiency (teffch) remained constant for the two specialized banks, while technical change (techch) increased.

The results in the tfpch Column under the production approach suggest that TFP increased for 11 out of 14 commercial banks and declined for three banks. For the two components of productivity growth, the results show that, as under the intermediation approach, technical efficiency, (teffch) increased for four commercial banks, declined for six banks and remained constant for four banks. Technical change (techch) increased for all banks with the exception of one. For the two components of technical efficiency change, the results show that pure technical efficiency increased for only two banks and declined for seven banks, while it remained constant for five banks. For specialized banks, the results indicate that total factor productivity (tfpch) increased for both banks.

Table 5. Malmquist Efficiency and Total Factor Productivity Change by Nature of Banks (1996-2004)

Bank	teffch	techch	Pech	sech	tfpch	teffch	techch	pech	sech	tfpch
	Commercial Banks									
FIB	0.991	1.134	1.038	0.954	1.124	1.000	1.106	1.000	1.000	1.106
BOK	1.005	1.004	1.000	1.005	1.009	0.971	1.044	0.961	1.010	1.014
ONB	1.000	0.975	1.000	1.000	0.975	1.000	1.013	1.000	1.000	1.013
SIB	1.107	1.009	1.079	1.026	1.118	0.981	0.996	1.038	0.944	0.977
ICDB	1.000	1.029	1.000	1.000	1.029	0.984	1.043	0.988	0.996	1.026
EIDB	1.000	1.074	1.000	1.000	1.074	1.032	1.164	0.984	1.048	1.201
AFB	0.971	0.963	1.013	0.958	0.934	1.081	1.011	1.073	1.008	1.093
ABB	0.999	1.142	0.994	1.005	1.141	0.895	1.085	0.931	0.962	0.972
SFB	0.992	0.923	1.000	0.992	0.916	1.000	1.047	1.000	1.000	1.047
EDB	1.096	0.984	1.000	1.096	1.079	1.056	1.077	0.984	1.073	1.137
WNB	0.954	1.101	1.000	0.954	1.051	1.005	1.100	1.000	1.005	1.106
SSB	1.000	1.118	1.000	1.000	1.118	1.000	1.077	1.000	1.000	1.077
ARB	0.981	0.990	1.000	0.982	0.971	0.929	1.034	0.944	0.984	0.961
TIB	1.021	1.058	1.029	0.991	1.079	0.928	1.087	0.942	0.985	1.009
S.D	0.06	0.07	0.02	0.04	0.07	0.05	0.04	0.04	0.03	0.07
	Specialized Banks									
SSDB	1.000	1.281	1.000	1.000	1.281	1.000	1.297	1.000	1.000	1.297
ABS	1.000	1.095	1.000	1.000	1.095	1.000	1.404	1.000	1.000	1.404
S.D	0.000	0.130	0.000	0.000	0.130	0.000	0.080	0.000	0.000	0.080

Source: Author's calculations based on sample data.

Once more, to examine whether the two approaches give different results, the t-test for the equality of means is applied for commercial and specialized banks using the SDs reported in Table 5. The t-values for the total factor productivity (tfpch) results for commercial and specialized banks are 0.34 and 1.09 respectively, which indicate that there exists no statistically significant difference at the 5% significance level between the two means for each type of banks under the two approaches.

Change in Productivity by Type of Bank Ownership. Table 6 reports the results on the MPI for the average government and joint venture banks under the two approaches over the study period. From the results under the intermediation approach, it is observed that government banks and joint venture banks have recorded positive TFP growth, at annual average rates of 7.6%and 14.3%, respectively, over the study period. For government banks, TFP deteriorated during the 1997-1998, but improved considerably during 2000-2003, although it deteriorated again in 2004. Technical efficiency decreased at an annual average rate of 1.2%, whereas technological change increased at a rate of

8.9%. The results on the two components of efficiency change reveal that the average government bank recorded an increase in pure technical efficiency for three years, a decline for four years, and remained constant for one year. Pure technical efficiency declined at an annual average rate of 0.4% over the period. The average government bank also recorded an increase in scale efficiency for six years and a decline for two years, while scale efficiency declined at an annual average rate of 0.8% over the period. For joint venture banks, TFP under this approach increased in five years and declined in three years. With average techch of 12.7% and average teffch of 1.5%, these banks were able to achieve TFP improvement from becoming more technologically advanced than from being more technically efficient. The results on the two components of efficiency change reveal that the average joint-venture bank recorded an increase in pure technical efficiency in four years and a decline in four years. Pure technical efficiency increased over the period at an annual average rate of 1.8%. The average joint venture bank also recorded an increase in scale efficiency in four years and a decline in four years. Scale efficiency declined over the period at an annual average rate of 0.3%. The results indicate that the improvement in technical efficiency in these banks may be attributed to managerial (pech) efficiency.

The results under the production approach show that government and joint venture banks have, on the average, recorded a positive TFP growth at rates of 11.1% and 19.3%, respectively. For government banks, technical efficiency change decreased at annual average rate of 4.4% over the study period, whereas technological change increased by a rate of 16.1%. The results on the two components of efficiency change suggest that the deterioration in technical efficiency in government banks may be attributed solely to managerial (pech) efficiency. The results for joint venture banks under this approach suggest that TFP increased in six years and declined in only two years. Joint venture banks have been able to achieve such productivity improvement from becoming more technologically advanced (average techch is 15.4%), than from being more technically efficient (average teffch is 3.4%). The results on the two components of efficiency change suggest that the average joint venture bank recorded an increase in pure technical efficiency in five years and a decline in three years. Average scale efficiency increased in three years and declined in five years. Accordingly, the improvement in technical efficiency in joint venture banks may be attributed to improvements in scale efficiency.

The CVs for all total factor productivity change indices in Table 6 under both approaches are also significantly low indicating that these indices are highly stable.

Table 6. Malmquist Efficiency and Total Factor Productivity Change in Government and Joint-Venture Banks in Sudan (1997-2004)

Year	Intermediation Approach					Production Approach				
	Teffch	techch	Pech	sech	tfpch	teffch	techch	pech	sech	tfpch
	Government Banks									
1997	1.051	0.810	1.020	1.030	0.851	0.832	0.974	0.855	0.973	0.810
1998	0.713	1.322	0.922	0.773	0.942	0.961	1.254	1.008	0.954	1.205
1999	1.320	0.650	1.140	1.159	0.858	1.277	0.829	1.172	1.090	1.059
2000	0.916	1.993	0.903	1.014	1.825	0.808	1.719	0.798	1.013	1.389
2001	1.082	1.205	1.030	1.051	1.304	0.785	1.672	1.111	0.706	1.312
2002	1.099	0.928	1.000	1.099	1.020	1.193	0.960	1.006	1.185	1.146
2003	0.835	1.380	0.971	0.860	1.152	1.195	1.092	1.053	1.135	1.304
2004	1.011	0.921	0.999	1.011	0.931	0.759	1.085	0.756	1.003	0.823
Mean	0.988	1.089	0.996	0.992	1.076	0.956	1.161	0.959	0.997	1.111
S.D	0.184	0.425	0.072	0.125	0.327	0.213	0.331	0.151	0.146	0.167
CV	0.186	0.390	0.075	0.126	0.304	0.222	0.285	0.157	0.146	0.198
1997	0.935	0.998	0.960	0.974	0.933	1.349	0.845	1.066	1.266	1.140
1998	1.082	0.992	1.181	0.916	1.073	1.020	1.196	1.067	0.956	1.220
1999	0.947	1.103	0.943	1.004	1.045	0.843	1.099	0.909	0.928	0.927
2000	1.213	1.293	1.042	1.164	1.568	1.093	1.386	1.097	0.996	1.514
2001	0.800	1.209	1.035	0.773	0.967	0.914	0.955	0.996	0.917	0.873
2002	1.281	1.372	0.972	1.317	1.757	1.269	1.456	1.012	1.254	1.848
2003	0.969	0.932	1.063	0.911	0.903	0.961	1.047	1.075	0.893	1.006
2004	0.975	1.188	0.964	1.011	1.159	0.928	1.398	0.891	1.042	1.296
Mean	1.015	1.127	1.018	0.997	1.143	1.034	1.154	1.011	1.023	1.193
SD	0.158	0.156	0.079	0.167	0.315	0.179	0.225	0.078	0.149	0.326
CV	0.156	0.138	0.078	0.168	0.276	0.173	0.195	0.077	0.146	0.273

Source: Author's calculations based on sample data.

Table 7 below reports the results of the MPI at the level of individual government and joint venture banks under the two approaches. It may be observed that under the internediation approach, total factor productivity (tfpch) increased for six out of eight government banks and declined for two banks (ABS and ARB), and varied between a low rate of -2.7% for ABS and a high rate of 20.3% for EIDB. For the two components of productivity growth, technical efficiency (teffch) increased for two government banks, declined for three banks and remained constant for three banks. Technical change (techch) increased for all banks, with the exception of ABS. The results on the two components of technical efficiency change suggest that pure technical efficiency increased for only one government bank (SSDB) and declined also for only one bank (ARB) while it remained constant for six banks. Scale efficiency increased for two banks, declined for three banks, and remained constant for three banks. The results joint venture banks suggest that TFP improved for all banks. The results on the two components of productivity growth indicate that technical efficiency (teffch) increased for two joint venture banks, declined also for two banks and remained constant for four banks. The results on the two components of technical efficiency change show that pure technical efficiency improved for SIB, FIB, and TIB while it remained constant for other banks. Scale efficiency increased for two banks, declined for two banks, and remained constant for four banks.

The results under the production approach reveal that TFP increased for six out of eight government banks and declined for two banks (ABS and ARB). For the two components of productivity growth, the results suggest that technical efficiency (teffch) increased for only one government bank (EIDB), declined for five banks, and remained constant for two banks. Technical change (techch) increased for all banks, except one bank (ABS). Regarding the two components of technical efficiency change, the results show that pure technical efficiency has not improved for any of the government banks, but instead declined for four banks and remained constant for four banks. Scale efficiency increased for only one bank, declined for four banks and remained constant for three banks.

For joint venture banks, TFP improved for all banks. For the two components of productivity growth, the results indicate that technical efficiency (teffch) increased for four joint venture banks, declined for two banks and remained constant also for two banks. Technical change (techch) increased for all banks. The results on the two components of technical efficiency change for joint venture banks suggest that pure technical efficiency improved for three banks and declined also for three banks, and remained constant for the other two banks. Scale efficiency increased for four banks, declined for two banks, and remained constant for two banks.

In summary, results suggest that TFP improved for both government and joint venture banks under the two approaches. However, the improvement in TFP has been higher for joint venture banks compared to government banks. These improvements in productivity for both banks were more attributed to technological change than to technical efficiency change.

Based on the above average results, the following step was to examine whether the two approaches give different results. For this purpose, the t-tests were adopted for the equality of means of the two approaches for both government and joint venture banks using the SDs reported in Table 7. The t-values for the total factor productivity (tfpch) results for government and joint venture banks are 1.43 and 1.96 respectively, which indicate that the two means for each group of banks are not significantly different at the 5% significance level.

Table 7. Malmquist Efficiency and Total Factor Productivity Change by Ownership of Banks (1996-2004)

Bank	Intermediation Approach					Production Approach				
	Teffch	techch	Pech	sech	tfpch	teffch	techch	pech	sech	tfpch
	Government Banks									
BOK	0.948	1.058	1.000	0.948	1.003	0.897	1.150	0.912	0.984	1.032
ONB	1.000	1.158	1.000	1.000	1.158	1.000	1.300	1.000	1.000	1.300
SSDB	1.070	1.100	1.041	1.028	1.177	0.984	1.144	0.984	1.000	1.126
ICDB	1.000	1.089	1.000	1.000	1.089	0.955	1.130	0.964	0.991	1.079
EIDB	1.005	1.196	1.000	1.005	1.203	1.030	1.316	1.000	1.030	1.356
ABS	1.000	0.973	1.000	1.000	0.973	1.000	0.979	1.000	1.000	0.979
WNB	0.981	1.069	1.000	0.981	1.049	0.992	1.141	1.000	0.992	1.133
ARS	0.908	1.080	0.928	0.978	0.981	0.812	1.163	0.829	0.980	0.945
S.D	0.050	0.070	0.030	0.020	0.090	0.070	0.100	0.060	0.020	0.150
FIB	1.123	1.091	1.055	1.064	1.225	1.080	1.250	1.053	1.026	1.350
SIB	1.079	1.082	1.076	1.002	1.167	1.095	1.027	1.035	1.058	1.124
AIB	0.931	1.161	1.000	0.931	1.081	0.921	1.221	0.993	0.928	1.125
ABB	1.000	1.132	1.000	1.000	1.132	1.053	1.102	1.017	1.036	1.160
SFB	1.000	1.092	1.000	1.000	1.092	1.000	1.183	1.000	1.000	1.183
EDB	1.000	1.151	1.000	1.000	1.151	1.179	1.123	0.999	1.180	1.323
SSB	1.000	1.182	1.000	1.000	1.182	1.000	1.150	1.000	1.000	1.150
TIB	0.998	1.126	2.012	0.986	1.123	0.969	1.188	0.997	0.972	1.152
S.D	0.060	0.040	0.350	0.040	0.050	0.080	0.070	0.020	0.070	0.090

Source: Author's calculations based on sample data.

6. Conclusion

Efficiency and productivity of financial institutions, especially banks, has changed significantly over the last years. The deregulation of financial systems, rapid technological advances and free entry of foreign and new private banks helped in this process. Employing Data Envelopment Analysis (DEA) type Malmquist Index, total factor productivity change was examined in 16 Sudanese banks during the period (1996-2004) along with its components – namely change in efficiency and change in technology and innovation. The overall results under both approaches suggest that total factor productivity of Sudanese banks increased during the study period. Banks were able to achieve productivity improvements from becoming more technically efficient than from being more technologically advanced under the intermediation approach while the opposite is true under the production approach.

Results similar in spirit are obtained for groups of banks (commercial versus specialized and government versus joint venture banks), where the improvement in average total factor productivity is attributed mainly to technological improvement than to technical efficiency. Furthermore, the observed growth in technical efficiency is more attributed to the growth in managerial efficiency than to the growth in scale efficiency. These results indicate that both the size and technology of Sudanese banks do matter in improving bank efficiency. Thus, by increasing the scale of their operations and improving the technology they use internally and with customers, it is imperative that Sudanese banks could enhance TFP and offer themselves the opportunity of remaining in business. This is particularly so in a sector that is increasingly becoming open for foreign banks.

The government could play the positive role of creating the appropriate policy environment that helps banks promote efficiency and hence productivity. Furthermore, to increase their productivity, the Central Bank of Sudan should encourage Sudanese banks to raise their paid-up capital and meet Basel capital requirements. Banks could also increase productivity through human capital development and better management and allocation of inputs. Bank management should be chosen on the basis of competence and expertise, while the labor force must well-trained. With globalization and full liberalization of the financial sector, the Central Bank of Sudan will have to offer foreign banks the same treatment as local banks. Foreign banks will provide more comprehensive range of financial services than is currently available through domestic banks. Less efficient banks with high operating costs are likely to suffer from international competition and may be rationed out. Alternatively, in order to compete internationally, such banks have to exploit new technologies such as Automatic Teller Machines (ATM), internet banking, and more efficient counter services to the clients.

References

Agricultural Bank of Sudan. (Various Issues). Annual Reports. Khartoum, Sudan.

Ahmed, E.A. (2004). Economic Analysis of the Irrigated Cotton Production Constrains in Sudan: Case Study of the Gezira Scheme. Farming and Rural Systems Series Vol. 61. Weikersheim, Germany: Margraf Publisher.

Al Baraka Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Al-Faraj, T., K. Bu-Bshait and W. Al-Muhammad. (2006). Evaluating the efficiency of Saudi commercial banks using data envelopment analysis. *International Journal of Financial Services Management* 1(4): 466-477.

Al Shamal Islamic Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Al Shamsi, F., H.Y. Aly and M.Y. El-Bassiouni. (2009). Measuring and explaining the efficiencies of the United Arab Emirates banking system. Applied Economics 2009:1–15.

Alam, I.M.S. (2001). A nonparametric approach for assessing productivity dynamics of large US banks. *Journal of Money*, Credit and Banking Vol. 33: 121-139.

Animal Resources Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Avkiran, N.K. (1999). Decomposing the technical efficiency of trading banks in the deregulated period. Paper presented at the 12th Annual Finance and Banking Conference, Sydney, Australia, 16-17 December.

_________. (2000). Rising productivity of Australian trading banks under deregulation, 1986-1995. *Journal of Economics and Finance* Vol. 24(No.2): 122-140.

Bank of Khartoum. (Various Issues). Annual Reports. Khartoum, Sudan.

Berg, S.A., F.R. Forsund and E.S. Jansen. (1992). Malmquist Indices of productivity growth during the deregulation of Norwegian banking. *Scandinavian Journal of Economics* Vol. 94:S211-S228.

_________, _________, L. Hjalmarsson and M. Suominen. (1993). Banking efficiency in the Nordic Countries. *Journal of Banking and Finance* 17 (2-3): 371-388.

Berger, A.N. and D.B. Humphrey. (1992). Measurement and efficiency issues in commercial banking. In Output Measurement in the Service Sectors, National Bureau of Economic Research Studies in Income and Wealth, Volume 56. Edited by Z. Griliches Chicago: University of Chicago Press.

Casu, B. and P. Molyneux. (2003). A comparative study of efficiency in European banking. Applied Economics Vol. 35: 1865-1876.

_________, C. Girardone and P. Molyneux. (2004). Productivity change in European banking: A comparison of parametric and non-parametric approaches. *Journal of Banking and Finance* Vol. 28(No. 10): 2521-2540.

Caves, D.W., L.R. Christensen and W.E. Diewert. (1982a). Multilateral comparisons of output, input and productivity using superlative index numbers. *Economic Journal* Vol 92: 73-86.

_________, _________ and _________. (1982b). The economic theory of index numbers and the measurement of input, output and productivity. *Econometrica* Vol. 50: 1393-1414.

Central Bank of Sudan. (Various Issues). Annual Reports. Sudan.

Chen, T.Y. and T.L. Yeh. (2000). A measurement of bank efficiency, ownership and productivity changes in Taiwan. *The Service Industries Journal* Vol. 20: 95-109.

Coelli, T.J. (1996). A guide to DEAP, Version 2.1: A data envelopment analysis (computer) program. Center for Efficiency and Productivity Analysis (CEPA) Working Paper 96/08, Department of Econometrics, University of New England, Armidale.

Coelli, T.J., S. Perelman, S.P. Rao and G.E. Battese. (1998). An Introduction to Efficiency and Productivity Analysis. London: Kluwer Academic Publishers.

Diewert, W.E. (1976). Exact and superlative index numbers. Journal of Econometrics Vol. 4(2): 115-145.

_________. (1981). The economic theory of index numbers: A survey. In Essays in the Theory and Measurement of Consumer Behavior, in Honor of Sir Richard Stone. Edited by A. Deaton. Cambridge, England: Cambridge University Press, pp. 163-208.

Elnilein Industrial Development Bank. (Various Issues). Annual Reports. Sudan.

Elyasiani, E. and S. M. Mehdian (1995). The comparative efficiency performance of small and large US commercial banks in the pre- and post-deregulation eras. Applied Economics (November), Vol. 27: 1069-1079.

Export Development Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Faisal Islamic Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Färe, R., and S. Grosskopf (1992). Malmquist Productivity Indexes and Fisher Ideal Indexes. *Economic Journal* Vol. 102(410): 158-160.

_________, _________, S.B. Lindgren and P. Roos (1989). Productivity developments in Swedish hospitals: A Malmquist Output Index Approach. In Data Envelopment Analysis: Theory, Methodology and Application. Edited by A. Charnes, W.W. Cooper, A.Y. Lewin and L.M. Seiford. Boston: Kluwer Academic Publishers, pp 253-272.

_________, _________, Z. M. Norris and Z. Zhang. (1994). Productivity growth, technical progress and efficiency change in industrialized countries. The American Economic Review Vol. 84(1): 66-85.

Farrell, M.J. (1957). The measurement of efficiency. *Journal of the Royal Statistical Society Series A*, CXX (Part 3): 253-290.

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

Grifell-Tatje, E. and C.A.K. Lovell. (1996). Deregulation and productivity decline: The case of Spanish savings banks. European Economic Review Vol. 40: 1281-1303.

Hassan, M. (2006). The X-effiency in Islamic banks. Islamic Economic Studies Vol. 13 (No. 2): 49-78.

_________, K. Al-Sharkas and A. Samad. (2005). An empirical study of relative efficiency of the banking industry in Bahrain. Studies in Economics and Finance Vol 22(2): 40-69.

_________ and K.A. Hussein. (2003). Static and dynamic efficiency in the Sudanese banking system. Review of Islamic Economics No. 14: 5-48.

Heffernan, S. and X. Fu. (2009). Bank productivity changes in two Asian giants. Presented in the UK Efficiency and Productivity Analysis Network (UKEPAN) Conference, Leicester, Nov, 2009.

Hussein, K. (2003). Operational efficiency in Islamic banking: The Sudanese experience. Working Paper No. 1, Islamic Research and Training Institute, Islamic Development Bank, Jeddah.

IMF. (2007). Sudan: Staff Report for the 2007 Article IV Consultation and Staff Monitored Programme: Staff Report, Staff Statement, and Public Information Notice on the Executive Board Discussion and Statement by the Executive Director for Sudan. IMF Country Report No. 07/343, International Monetary Fund, Washington, D. C.

Isik, I., U. Meleke and E. Isik. (2002). Liberalization ownership and productivity in Turkish banking. Economic Research Forum for the Arab Countries, Iran and Turkey (ERF), Working Paper, No, 0218, ERF 9th Annual Conference, Sharja, United Arab Emirates, 26-28 October 2002.

Islamic Cooperative Development Bank. (Various Issues). Annual Reports. Sudan.

Kireyev, A. (2001). Financial reform in Sudan: Streamlining bank intermediation. IMF Working Paper No. 53, IMF Office in Geneva, Switzerland.

Malmquist, S. (1953). Index numbers and indifference surface. Trabajos de Estatistica Vol. 4: 209-242.

Mukherjee, K., S.C. Ray and S.M. Miller. (2001). Productivity growth in large US commercial banks: The initial post-deregulation experience. *Journal of Banking and Finance* Vol. 25 (No. 5): 913-939.

Omdurman National Bank. (Various Issues. Annual Reports. Khartoum, Sudan.

Onour, I. and A.M. Abdalla. (2010). Efficiency of Islamic banks in Sudan: A non-parametric approach. Working Paper Series (WPS) 1012, Arab Planning Institute (API), Kuwait.

Ray, S.C. and E. Desli. (1997). Productivity Growth, Technical Progress and Efficiency Change in Industrialised Countries: Comment. The American Economic Review Vol 87(5): 1033-1039.

Resti, A. (1997). Evaluating the cost-efficiency at the Italian banking system: What can be learned from the joint application of parametric and non-parametric techniques? *Journal of Banking and Finance* Vol 21:. 221-250.

Saudi Sudanese Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Saving and Social Development Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Schure, P., D. O'Brien and R. Wagenvoort. (2004). The efficiency and conduct of European banks: Developments after 1992. Review of Financial Economics Vol 13(4): 371-396.

Shephard, R.W. (1970). Theory of Cost and Production Functions. Princeton: Princeton University Press.

Sudanese French Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Sudanese Islamic Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Sufian, F. (2007). Total factor productivity change of the Malaysian Islamic banking sector: An empirical study. *Journal of Islamic Economics*, Banking and Finance Vol. 5 (No. 1): 73-88.

Tadamoun Islamic Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

Tornqvist, L. (1936). The Bank of Finland's consumption price index. Bank of Finland Monthly Bulletin Vol. 10:1-8.

Continue table 14...

Wheelock, D.C. and P.W. Wilson. (1999). Technical progress, inefficiency and productivity change in US banking, 1984-1993. *Journal of Money, Credit and Banking* Vol. 31 (2): 212-234.

Workers' National Bank. (Various Issues). Annual Reports. Khartoum, Sudan.

World Bank. (2006). Annual Report. World Bank Washington, D. C., ISBNO. 8213-6759-5 Accessed on line at www.worldbank.org.