# Efficiency of Sudanese Banks: A Stochastic Frontier Approach (1996-2004)

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## ABSTRACT

Motivated by the catalytic role that the banking sector could play in the economy, this paper examined the efficiency of Sudanese banks under the intermediation and production approaches using the Stochastic Frontier method and panel data for 16 banks during the period 1996-2004. The results under both approaches indicate that Sudanese banks are inefficient. Nonetheless, specialized and joint venture banks are relatively less inefficient than commercial and government banks, respectively. Most important, although the majority of Sudanese banks operate under increasing returns to scale, these banks suffer from diseconomies of scale and have not yet exploited the advantages of increasing returns to scale as the very low estimates of overall average cost efficiency indicate. With an average efficiency score lower than the world's average, coupled with measures to open up the sector for foreign banks, Sudanese banks could survive fierce competition only by improving efficiency toward the world best practice frontiers. Efficiency could be improved through a number of measures, including the improvement of productivity through human capital development, the introduction of new technologies and internet banking services (involving automation and computerization) and, most important, through a credible management chosen on the basis of competence and expertise.

**Key words:** *Stochastic frontier approach (SFA), Efficiency, Sudanese Banks.*

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# كفاءة المصارف السودانية: أسلوب الحدود العشوائية (1996-2004)

## الملخص

نظرا للدور الذي تلعبه المصارف في الاقتصاد، هدفت هذه الورقة إلى تحليل الكفاءة الاقتصادية للمصارف السودانية باستخدام الأسلوب المعلمى لتقدير دالة التكلفة (أسلوب الحدود العشوائية) و طريقتان لقياس كفاءة المصارف، هما طريقة التوسط و طريقة الإنتاج. تتكون عينة الدراسة من 16 مصرفا سودانيا توفرت حولهم البيانات للفترة 1996-2004. و قد أجرى التحليل على مستوى كل بنك على حده و كذلك على مستوى كل مجموعه من البنوك. وتشير النتائج التطبيقية إلى عدم كفاءة المصارف السودانية إستنادا على طريقة التوسط و طريقة الإنتاج. كذلك، توصلت الدراسة إلى أن المصارف المتخصصة و المشتركة أكثر كفاءة نسبيا من المصارف التجارية و الحكومية في السودان، على التوالي. وفيما يتعلق بأهم النتائج التطبيقية حول اقتصاديات الحجم بالمصارف السودانية، فقد لوحظ أن المصارف السودانية لديها نزعة متواصلة للعمل في ظل ظروف عائدات الحجم المتزايدة. و بما أن المصارف السودانية صغيرة الحجم، فإنه بإمكانها كسب مزيد من الكفاءة عن طريق زيادة أحجامها. و لتحسين كفاءة المصارف السودانية يجب إتباع عدة مقاييس، أهمها، تحسين الإنتاجية من خلال تطوير رأس المال البشري، تطوير التقنية المصرفية وإدخال الخدمات المصرفية عبر الإنترنت والاهم من ذلك أن تكون الإدارة كفؤة و مختارة على أساس الخبرة و المنافسة.

## INTRODUCTION

More recently, the banking industry has been undergoing far-reaching structural changes, whereby the processes of liberalisation, globalisation and integration have dramatically changed the banking landscape around the world. The efficient-structure hypothesis entails that banks that are able to operate more efficiently than their competitors, incur lower costs and achieve higher profits and increased market shares that may result in increased concentration. Therefore, according to this hypothesis, efficiency is the factor that positively influences both market shares and bank profits.

Efficiency of the banking sector is considered a precondition for macroeconomic stability (Ngalande, 2003) and is also of paramount importance for effective monetary policy execution (Hartman, 2004). Furthermore, efficient allocation of financial resources by banks has positive implications for economic growth (Galbis, 1977). For these reasons, policymakers, regulators and managers have been concerned with the issue of how efficiently banks transform their various inputs into multiple financial products. As a such, the issue of how efficiency in the banking sector can be enhanced has gained importance at the micro and macroeconomic levels. At the micro level, while financial institutions used to enjoy local oligopolies and therefore make rewarding profits, such advantages are shrinking due to growth in competition. At the macroeconomic level, banks' efficiency is a socially optimal target since it reduces the average cost of financial transactions and therefore enhances the society's welfare.

This paper examines the cost efficiency of Sudanese banks over the period 1996-2004 by applying the Stochastic Frontier Approach (SFA) under both the intermediation and production frameworks. In addition to the aforementioned reasons of the benefits of efficient banking systems, the study is also motivated by the efforts that are currently being made by Sudan's government to reform and articulate the financial sector as part of the efforts to address the challenges facing the economy, including privatization and deregulation of the previously centrally managed economy.

The rest of the paper is organized as follows: Section (2) provides an overview of the recent literature on the efficiency of banks. Section (3) gives an overview of the banking sector in Sudan. Section (4) is devoted to the research methodology adopted in the present study, with its two components, namely the methods of analysis and the sampled banks and related data. Section (5) reports the empirical results, while section (6) summarizes the results and concludes the paper.

## OVERVIEW OF LITERATURE

The theoretical literature on productive efficiency originated in the works of Koopmans (1951), Debreu (1951), and Shephard (1953). The first attempt to estimate efficiency was found in Farrell (1957), who used linear programming techniques to estimate efficiency in U.S. agriculture. Research on efficiency estimation continued through the development of Stochastic Frontier Approach (Meeusen and van den Broeck, 1977; Aigner, Lovell, and Schmidt 1977; Battese and Corra 1977; Berger and Humphrey, l99l; Mester, 1993, 1996; Cebenoyan *et al*. 1993; Elyasiani and Mehdian (1990); Altunbas *et al* 1994, 1995; Drake and Weyman-Jones, 1992; and Berger *et al*., 1993b). Data Envelopment Analysis (DEA) was developed at about the same time by Charnes, Cooper, and Rhodes (1978). Each of these techniques has subsequently been extended and developed further [see Kumbhakar and Lovell (2000) for a modern textbook treatment of the Stochastic Frontier Approach, and Cooper, Seiford, and Zhu (2004) for the Data Envelopment Analysis].

At the empirical level, Berger and Humphrey (1997) thoroughly surveyed 130 cross-country studies that applied the frontier efficiency approach to financial institutions in 21 countries. Six cross-country comparisons were reviewed, five of them based on the non-parametric approaches such as Data Envelopment Analysis (DEA) and two of them based on the parametric approaches such as the Distribution Free Approach (DFA) and the Thick Frontier Approach (TFA).

Kablan (2007) examined the efficiency of West African Economic Monetary Union (WAEMU) banks after the period of banking crises (1993-1996). The study used Data Envelopment Analysis method (DEA) for assessing technical efficiency and Stochastic Frontier Analysis (SFA) with cost functions. The study found that WAEMU banks efficiency is responsive to variables like financial soundness, the ratio of bad loans per country, the banking concentration and the GDP per capita. Detailed analysis reveal that local private banks are most efficient, followed by foreign banks. Again, Mostafa (2008) has measured the relative efficiency of the top 100 African banks using a cross-sectional data for the year 2005. He found out that the performance of several banks is sub-optimal, suggesting the potential for significant improvements.

Kiyota (2009) provided a comparative analysis of profit efficiency and cost inefficiency of commercial banks operating in 29 Sub-Saharan African countries during 2000-2007. Two-stage procedure is employed. The first method involves the estimation of profit and cost efficiency using the stochastic frontier approach. In the next stage, the Tobit regression is employed to provide cross-country evidence on the impact of environmental factors on efficiency of African commercial banks. Especially, it examines whether foreign banks are more profit efficient than domestic banks, while investigating relationships between bank efficiency and bank specific factors such as lending rate, deposit rate, funding claims strategy and net interest margin. It also investigates the impact of bank efficiency on those bank level factors as well as financial deepening (domestic credit to private sector, percent of GDP/money and quasi money (M2) as percent of GDP). Based on a range of performance ratios as well as stochastic cost and profit frontier estimation, with regard to the profit efficiency foreign banks have tended to outperform domestic banks. In particular, SSA foreign banks whose ownership is originated from Sub-Saharan African financial institutions with more than 50 percent share are more profit efficient than non Sub-Saharan African (Non-SSA) foreign banks. On the other hand, the findings of the study suggest that Non-SSA foreign banks are more cost efficient than SSA foreign as well as domestic banks for the period of 2000-2003. In addition, SSA foreign banks are the most cost efficient during the 2005-2006. Nevertheless, on the whole, there is not a big difference among all banks. In terms of efficiency by the bank size, the research findings indicate that the smaller the bank, the higher profit efficiency will be in all three types of banks. The trend for cost efficiency is that medium or relatively large banks whose total assets are within the range of 100 to 1000 in US million dollars tend to be the most cost efficient.

Hamiltona, Qasrawib and Al-Jarrah (2010) analyzed cost and profit efficiency in the Jordanian banking sector over the period 1993-2006 using a parametric approach (stochastic frontier analysis). The results obtained from this research show (i) the existence of profit efficiency levels well below those corresponding to cost efficiency and (ii) alternative profit efficiency being below standard profit efficiency. These results imply either the existence of market power in the Jordanian banking sector with respect to the setting of prices and/ or the existence of differences in the quality of bank outputs, reflected in the differences in prices. Additionally, the research shows that while Islamic banks are less cost efficient than commercial and investment banks, they are more profit efficient.

In the context of Sudan, the most relevant studies of efficiency of Sudanese banks are those of Nazirrudin and Abed Elrahman (2003) and Hussein (2003). Both studies adopted the stochastic froontier approach. Nazirrudin and Abed Elrahman (2003) measured the technical efficiency of Sudanese full-fledged Islamic banks during 1989-1998 and compared these estimates with those for foreign joint vebture banks. It is observed that while all banks were technically inefficient, foreign joint venture banks were more technically efficient than domestic banks. The source of inefficiency appeared to be problems of ownership, lack of banking technologies, severe economic sanctions and lack of competency in managing the high risk of Islamic financing modes. Hussein (2003) estimated the operational efficiency of 17 Sudanese Islamic banks during 1990-2000. The author observed that Islamic banks do not create inefficiency *per se*. Furthermore, although efficiency was almost stable between 1990 and 2000, there were wide efficiency differences between banks. The state owned banks are the most cost inefficient, while smaller banks are more efficient than larger banks.

### *1. An Overview of Sudan's Banking Sector:*

Like many developing countries, Sudan's financial sector is dominated by commercial banks. Bonds and and equity markets, which require a mature system of accounting and financial information, are still primitive. Historically, Sudan's financial system faced a host of problems, including 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 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 inflows particularly in the industrial and emerging oil and petrochemical sectors. Measures were also 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.

Along similar lines, the Bank of Sudan has also made considerable efforts to build-up its capacity for managing liquidity in the economy, improving the effectiveness of monetary policy and for achieving harmony between fiscal policy and monetary policy. For this purpose, the Monetary Operation Unit (MOU) was established in the Bank of Sudan. The Unit commenced its work in August 2003 to undertake early warning operations with a view to avoid any monetary discrepancies that might affect the macro-economic objectives. The decree of establishing the Unit specified its functions in the following:

(i) Monitoring the daily position of liquidity in the economy according to the directions and objectives of monetary policy.

(ii) Monitoring the implementation of open market operations that are intended to correct the monetary path, and issue daily instructions to the concerned departments in the Bank of Sudan to adhere to required direction.

(iii) Preparing daily, weekly, monthly, quarterly and annual reports on the monetary performance.

(iv) Conducting forecasts of the monetary position on weekly, monthly and quarterly basis.

The MOU continued its work throughout the year 2004 and contributed in following up the monetary performance beside the liquidity management in order to achieve the macro-economic objectives.

In addition, the comprehensive banking policy introduced in 2004 aimed at establishing the national payment system, building the infrastructure of banking technology, developing electronic banking service and Central Bank information system. Thus, in 2006 the Electronic Cheque clearing was introduced through image-based exchange of data, while the National payments switch project was completed with all banks' branches connected with the Electronic Banking information network.

The year 2006 also witnessed the establishment of the Bank of Southern Sudan (BOSS) as a result of the Comprehensive Peace Agreement, which required restructuring the Central Bank of Sudan during the interim period to reflect the duality of the banking system in Sudan. Furthermore, the Central Bank of Sudan developed two sets of banking instruments, Islamic and conventional, to regulate and monitor the implementation of a single monetary policy. For this purpose, two financing windows were established. One of these is an Islamic financing window in Northern Sudan under the deputy Governor of the Central Bank of Sudan to adopt Islamic instruments for national monetary policy in Northern Sudan, while the other is the conventional window in the Bank of Southern Sudan (BOSS) headed by the deputy governor of the Central Bank of Sudan to adopt conventional instruments in national monetary policy in Southern Sudan. In 2007, a profit margin of 10% per annum has been determined as an indicative rate to be applied on Murabaha type of finance in local and foreign currency for Islamic banks, and interest rate of 10% per annum (as an indicative rate) for local and foreign currency for conventional banks.

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 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 paper applies the Stochastic Frontier Approach (SFA) under both the intermediation and production frameworks to examine the cost efficiency of Sudanese banks over the period 1996-2004. In addition to the benefits noted above of efficient banking systems, the study is also motivated by the efforts that are currently being made by Sudan's government to reform and articulate the financial sector as part of its efforts to address the challenges facing the economy, including privatization and deregulation of the previously centrally managed economy.

## THE METHODOLOGY

The Stochastic Frontier Approach (SFA), also known as the econometric frontier approach, specifies a functional form for the cost, profit, or production relationship among inputs, outputs, and environmental factors, allowing for a random error. SFA posits a composed error model where inefficiencies are assumed to follow an asymmetric distribution, usually the half-normal, while the random errors follow a symmetric distribution, usually the standard normal. The logic is that the inefficiencies must have a truncated distribution because they cannot be negative. Both the inefficiencies and the errors are assumed to be orthogonal to the input, output, or environmental variables included in the estimation equation. The estimated inefficiency for any firm is taken as the conditional mean or mode of the distribution of the inefficiency term, given the observation of the composed error term. The assumption of half-normal distribution of inefficiencies is relatively inflexible and presumes that most firms are clustered near full efficiency. In practice, however, other distributions may be more appropriate (Greene, 1990). Some studies on financial institutions consider the deviation of each firm from the average practice frontier rather than from the best efficiency (practice) frontier at any one point in time (Berger and Humphrey, 1997).

One positive aspect of the SFA approach is that it will always rank the efficiencies of the firms in the same order as their cost function residuals, no matter which specific distribution assumptions are imposed. That is, firms with lower costs for a given set of input prices, output quantities, and any other regressors in the cost function will always be ranked as more efficient since the conditional mean or mode (given the estimate of the residual) is always increasing in the size of the residual. This property of SFA has intuitive appeal for a measure of performance for regulatory purposes: a firm is ranked high in the efficiency scale if it keeps cost relatively low for its given exogenous conditions. This is likely to prove helpful in meeting consistency conditions, which are primarily based on rank orderings.

Banks are multi-product firms producing a vector of outputs from a vector of inputs. Using duality theory, the multi-product cost function dual to the production function can be written as:

$$C = f(y, w) \qquad (1)$$

where C is the total cost, y is the vector of outputs, and w is the vector of input prices. Aigner, Lovell and Schmidt (1977) and Meeusen and Broeck (1977) independently utilized this function to build the stochastic frontier cost function. The original specification involved a production function specified for cross section data which has an error term with two components, one to account for random effects and another to account for technical inefficiency. The cost model can be expressed in the following form:

$$Ci = Zi^{\beta} + (vi + ui), \qquad i = 1,\ldots, N \qquad (2)$$

where N is the number of banks; $C_i$ is the cost (or the logarithm of the cost) of production of the i-th firm; $Z_i$ is a kx1 vector of (transformations of the) outputs and input prices of the i-th firm; $\beta$ is a vector of unknown parameters; the $v_i$ are random variables which are assumed to be iid $N(0, \sigma^2_v)$, and independent of the non-negative random variables $u_i$ which are assumed to account for the cost of inefficiency in production and have a half-normal distribution.

This original specification has been used more recently in a vast number of empirical applications. The specification has also been altered and extended in a number of ways, including the specification of more general distributional assumptions for the

$u_i$, such as the truncated normal or two-parameter gamma distributions, the extension of the methodology to the estimation of systems of equations, and so on (see Forsund, Lovell and Schmidt, 1980; Schmidt, 1986; Bauer. 1990; and Green, 1993). Battese and Coelli (1992) proposed a stochastic frontier production (cost) function for (unbalanced) panel data that has firm effects assumed to be distributed as truncated normal or half normal random variables, and are also permitted to vary systematically with time (t). In this case, the model in equation (2) is extended to take the form:

$$Cit = Zit^{\beta} + (vit + uit), \quad i = 1,\dots, N , t = 1,\dots,T \qquad (3)$$

where $C_{it}$ is (the logarithm of) the cost of production of the i-th firm at time t; $Z_{it}$ is a kx1 vector of (transformations of the) outputs and input prices of the i-th firm at time t; $\beta$ is a vector of unknown parameters; the $v_{it}$ are random variables which are assumed to be iid N(0, $\sigma_v^2$) and independent of the $u_{it}$ = $e^{-\eta(t-T)}$, where the $u_{it}$ are non-negative random variables, assumed to account for technical inefficiency and to be id as truncated normal at zero of the N(0, $\sigma_u^2$) distribution; $\eta$ is a parameter to be estimated. The panel data used in estimating equation (3) need not be complete (i.e. it could be unbalanced panel data) .

This model utilizes the parameterization of Battese and Corra (1977) who replaced $\sigma_v^2$ and $\sigma_u^2$ with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$. The parameter $\gamma$ must lie between 0 and 1, and this range can be searched to provide a good starting value to use in an iterative maximization process such as the Davidon-Fletcher-Power (DFP) algorithm. The log-likelihood function is given by:

$$\ln L = (N/2) \ln (2/\pi) - N \ln\sigma - ½\, \sigma^2 \sum_{i=1}^{N} \varepsilon_i^2 + \sum_{i=1}^{N} \ln[\varphi(\varepsilon_i \lambda/\sigma)] \qquad □(3)$$

where $\varepsilon = u_i + v_i$ and $\varphi$ (.) is the standard normal density function. Jondrow *et al.* (1982) showed that the ratio of variability, $\sigma$, can be used to measure a bank's mean efficiency, where $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\lambda = \sigma_u/\sigma_v$.

The maximum likelihood procedure involves three steps. In the first step we obtain unbiased OLS estimates of equation (3), except the estimate of the constant term. Second, the OLS estimates are used to obtain the starting values. The estimates corresponding to the largest log-likelihood value in the second step are used in the iterative maximization procedure in the third step. The inefficiency measure of the i-th bank depends on the value of the unobservable $u_i$ being predicted. This is achieved by deriving expressions for the conditional expectation of these factions of the $u_i$, conditional upon the observed value of ($u_i$ + $v_i$). The mean of this conditional distribution for the half normal model is given by:

$$E(u_i/\varepsilon) = \left[\frac{\sigma\lambda}{1+\lambda^2}\right]\left[\frac{\varphi\left(\frac{\varepsilon_i\lambda}{\sigma}\right)}{\psi\left(\frac{\varepsilon_i\lambda}{\sigma}\right)} + \frac{\varepsilon_i\lambda}{\sigma}\right] \quad (4)$$

where $\varphi(.)$ and $\psi(.)$ are the standard normal density and the standard cumulative distribution, respectively. An efficiency measure can be calculated as the exponential transformation of the raw estimate of $u_i$ [i.e. exp ($u_i$)] and can be shown to be defined as:

$$\exp(u_i) = E(C_i^*/u_i = 0, Z_i)/(C_i^*/u_i, Z_i) \quad (5)$$

where $C_i^*$ is the cost of the i-th firm, which is equal to $C_i$ when the dependent variable is measured in original units, and to exp($C_i$) when the dependent variable is in logarithm. The cost frontier for the i-th bank at time t is defined as the ratio of the stochastic cost frontier to the observed cost. The stochastic frontier is defined by the value of cost use if the technical inefficiency effect ($u_{it}$) was zero (i.e., the bank was fully efficient in terms of cost). We note that in the cost function of equation (2) the $u_{it}$ defines how far the firm operates above the cost frontier. If allocative efficiency is assumed, the $u_{it}$ is closely related to cost of technical inefficiency. If this assumption is not made, the interpretation of the $u_{it}$ in a cost function is less clear, with both technical and allocative efficiencies possibly involved. Thus, in the remainder of this paper we shall refer to efficiencies measured relative to a cost frontier as cost or economic efficiencies.

The Stochastic Cobb-Douglas cost function defined for multiple outputs is specified in the form:

$$\ln C_{it} = \beta_o + \sum_{i=1}^{n} \beta_i \ln y_{it} + \sum_{i=1}^{n} \alpha_i \ln w_{it} + U_{it} + V_{it} \qquad (6)$$

where $\ln y_{it}$ and $\ln w_{it}$ are the logarithms of the levels of output and input prices, respectively; $U_{it}$ [= exp(- $\eta$ (t-T)] are non-negative random variables associated with cost inefficiency and distributed as half normal as N( $\mu$ , $\sigma_u^2$ ); $\eta$ is a parameter to be estimated, which measures the importance of time varying inefficiencies; and the $V_{it}$ are random errors assumed to be iid as N(0, $\sigma_v^2$ ) and independent of the $U_{it}$ . For reasons related to the presence of multicollinearity in a model, many parameters could turn out to be insignificant on the basis of the usual t-test (Coelli, 1995). Therefore, it is preferable to carry out the one-sided generalized likelihood test, which involves more than one parameter at the same time. The generalized likelihood ratio (LR) is defined by:

$$LR = -2 \ln [L(H_0)/L(H_1)] = -2 [\ln L(H_0) - \ln L(H_1)] \qquad (6)$$

where $L(H_0)$ is the log likelihood value of a restricted frontier model, as specified by a null hypothesis, and $L(H_1)$ is the log likelihood value of the general frontier model under the alternative hypothesis. This test statistic has approximately a chi-square (or a mixed chi-square) distribution with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses. If the inefficiency effects are not present in the model, as specified by the null hypothesis $H_0$: $\gamma$ = 0 (the null hypothesis is true), then this test statistic is usually assumed to be asymptotically distributed as a chi-square random variable with degrees of freedom equal to the number of restrictions involved. If the null hypothesis is rejected, which suggests the presence of inefficiency, the LR statistic is approximately distributed according to a mixed chi-square distribution. In this case, the critical values for the generalized likelihood-ratio test are obtained from table 1 in Kodde and Palm (1986). Finally, we note that in the stochastic cost frontier approach, economies of scale are measured by the reciprocal of the cost elasticity, $\varepsilon(y, w)$, given by:

$$\varepsilon(y, w) = \{\Sigma\, \partial \ln c(y, w)/\partial \ln y_i\}^{-1} = (\Sigma_{i=1}^{m} \beta_i)^{-1} \qquad (7)$$

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 treats 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 considers deposits as an input to produce loans; in contrast, the production approach treats deposits as an output since they significantly contribute to the creation of profits (Resti 1997).

Since each approach has its advocates and neither has emerged as dominant or superior, the two approaches are adopted in this paper to estimate efficiency measures. The variables required under the two approaches are described below. There are three sets of variables, namely outputs, inputs, and input prices (see table A.3 of the appendix for the list of variables and their codes under each category). The output variables consist of: total investment (INVT) variable, which includes all types of investments; off balance-sheet or contra accounts (CONTA) transactions variable, which includes investment returned cheques, exchange bills under collection, letters of credit and investment cheques. The inputs category consists of: the WAGE variable, which includes salaries, wages and allowances; the total deposits (DEPS) variable, which includes current, saving and investment deposits both in foreign and local currency; fixed assets variable (FXSS), which includes land, buildings, vehicles and furniture and equipment. The price variables consist of: the price (unit cost) of fixed capital, denoted UCK, which is computed as the value of depreciation divided by the value of fixed assets; the price (unit cost) of labor, denoted UCL, which is defined as the total wage and salaries divided by the total number of employees; the price (unit cost) of funds, denoted UCF, which is defined as total profits distributed to depositors divided by investment deposits.

Annual data for the period 1996-2004 were collected for 16 banks representing 62% of the banking industry in Sudan. These banks and their codes are listed in Table (A.1) of the appendix. 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. The relevant information on a number of variables, including input prices, were calculated from the balance sheets and income statements published annually by each bank in the sample. Data on inputs, outputs, and some prices are measured in the Sudanese Dinar (SDD).

## THE EMPIRICAL RESULTS

Using the stochastic frontier approach, Cobb-Douglas stochastic frontier cost functions expressed in natural logarithms as given in equation (6) are estimated under both the intermediation and production approaches using the software Frontier 4.1, which is based on an iterative maximum likelihood procedure described in Coelli (1995). The explanatory variables under each approach consist of a set of output varaibles and a set of input price variables. Under the intermediation approach, the set of output variables consists of total investment (INVT) and off-balance sheet transactions or contra accounts (CONTA), all measured in million SDD, while the set of input price variables consists of the unit cost of funds (UCF) measured in percentage points, the unit cost of labor (UCL) measured in thousand SDD per worker per year, and the unit cost of fixed capital (UCK) measured in percentage points. Under the production approach, on the other hand, the set of output variables consists of total investment (INVT), off-balance sheet transactions or contra accounts (CONTA), and total deposits (DEPS), all measured in SDD millions, while the set of input price variables consist of the unit cost of labor (UCL) measured in thousand SDD per worker per year, and the unit cost of fixed capital (UCK) measured in percentage points.

The results are reported in three subsections. Sub-section (5.1) reports the set of results for all banks in the sample; sub-section (5.2) reports the set of results according to the nature of banks (commercial and specialized banks); sub-section (5.3) presents the set of results according to the type of bank ownership (government and joint-venture banks). In each sub-section, we report the estimated cost functions under the intermediation and production approaches, as well as the corresponding cost efficiency scores based on the estimated cost functions. All critical values of the chi-square distribution correspond-ing to the LR statistic are obtained from Table 1 of Kodde and Palm (1986).

1. **Cost Efficiency of Individual Banks:**

Table (1) reports the maximum-likelihood estimates of the parameters of the stochastic frontier cost function for the entire sample of banks under the intermediation and production approaches. The results under the intermediation approach reveal that all estimated coefficients have the expected signs and are significantly different from zero at the one or five percent significance levels, excep the coefficients of the input prices UCF and UCK. The parameter Gamma ($\gamma$) is significantly different from zero at the one percent level, and its value indicates that the proportion of the one-sided error component in the total variance of the error term in the model is around 93 percent. Accordingly, the vast majority of the residual variation is due to technical inefficiency since the inefficiency proportion ($u_i$) in the total error dominates the random error. The absolute value of the LR statistic (estimated at 66) exceeds the 8.27 critical value. Hence the null hypothesis (of no technical inefficiency) is rejected at the one percent level. These results unambiguously suggest the presence of technical inefficiency in the operation of Sudanese banks. Furthermore, in view of equation (7), the point estimate of the output coefficients (0.18 + 0.07 = 0.25) implies a scale elasticity of 4, meaning that Sudanese banks operate under conditions of increasing returns to scale. This means that Sudanese banks have small sizes and could realize efficiency gains by increasing the scale of production.

Table (1): Estimated Cost Functions for Sudanese Banks: The Intermediation and Production Approaches

| Regressor | Intermediation Approach | | | Production Approach | | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | t-ratio | Coefficient | Standard Error | t-ratio |
| Constant | 1.25 | 0.31 | 3.96 | 0.40 | 0.32 | 1.24 |
| ln (INVT) | 0.18 | 0.04 | 4.10 | 0.10 | 0.04 | 2.19 |
| ln (CONTA) | 0.07 | 0.03 | 2.16 | 0.03 | 0.03 | 1.08 |
| ln (DEPS) | - | - | - | 0.33 | 0.07 | 4.88 |
| ln (UCF) | 0.07 | 0.05 | 1.42 | - | - | - |
| ln (UCL) | 0.49 | 0.07 | 7.11 | 0.08 | 0.05 | 1.54 |
| ln (UCK) | 0.07 | 0.08 | 0.94 | 0.34 | 0.07 | 4.81 |
| Sigma- | 1.46 | 0.62 | 2.37 | 0.84 | 0.39 | 2.13 |
| squared | 0.93 | 0.03 | 29.9 | 0.89 | 0.06 | 15.8 |
| Gamma | -66.00 | | | - | | |
| Likelihood-ratio test statistic (LR) | | | | 56.10 | | |

Source: Own calculations based on sample data

The results under the production approach indicate that all the estimated coefficients have the expected signs, and are significantly different from zero, except those for contra account (CONTA) and the price of labor (UCL), which are statistically insignificant. The other results are more or less similar in spirit to those obtained under the intermediation approach. The parameter gamma ($\gamma$) is significantly different from zero, and its value indicates that the proportion of the one-sided error component in the total variance of the error term in the model is around 89 percent. The absolute value of the LR (estimated at 56.1) is much larger than the 8.27 critical value. Accordingly, the null hypothesis of no technical inefficiency is rejected, meaning that the vast majority of the residual variation is due to technical inefficiency and that the inefficiency proportion ($u_i$) in the total error dominates the random error. These results unambiguously suggest the presence of technical inefficiency in the operation of Sudanese banks. Furthermore, the point estimate of the output coefficients (0.10 + 0.03 + 0.33 = 0.46), implies a scale elasticity of 2.17. Once more, this means that Sudanese banks operate under increasing return to scale and could therefore realize efficiency gains by increasing the scale of production.

Table (2) reports the cost efficiency scores for each bank in the sample, calculated (using the software alluded to above) as the average over the period 1996-2004 of the exponential transformations of the raw estimates of the residuals $u_{it}$ (as in equation 5) based on the estimated cost functions in table (1). In interpreting these results, we note that cost efficiency is bounded from above by one, so that the perfectly cost efficient bank would exhibit an estimated cost efficiency score equal to one. The results under the intermediation approach show that the average cost efficiency score for the whole sample is 0.31, implying an average inefficiency of about 0.69. This very low (high) efficiency (inefficiency) score could be explained by the high operational and financial costs in Sudanese banks. The cost of finance in Islamic banks is high because risks are higher compared to those for conventional banks. The reason is that, in addition to normal credit risks, Islamic banks adopt modes of finance whereby they share both profits and losses with their clients. For this reason, Islamic banks need greater liquidity compared to conventional banks, to cover themselves against the possibility of huge losses and the ensuing high risks such as loss of assets if the client credit worthiness is overestimated.

Table (2): Average Cost Efficiency Scores of Individual Banks in Sudan, 1996-2004

| Bank | Cost Efficiency Scores | |
|---|---|---|
| | Intermediation approach | Production approach |
| Fisal Islamic Bank | 0.19 | 0.31 |
| Bank of Khartoum | 0.16 | 0.26 |
| Omdurman National Bank | 0.23 | 0.35 |
| Sudanese Islamic Bank | 0.43 | 0.57 |
| Saving and Social Development Bank | 0.54 | 0.63 |
| Islamic Cooperative Developme-nt Bank | 0.48 | 0.59 |
| Elnilein Industerial Development Bank | 0.32 | 0.45 |
| Alshmal Islamic Bank | 0.23 | 0.36 |
| Al Baraka Bank | 0.27 | 0.40 |
| Agricultural Bank of Sudan | 0.18 | 0.19 |
| Sudanese-French Bank | 0.35 | 0.63 |
| Export Development Bank | 0.52 | 0.51 |
| Workers National Bank | 0.94 | 0.95 |
| Saudi-Sudanese Bank | 0.48 | 0.60 |
| Animal Resource Bank | 0.49 | 0.68 |
| Tadamon Islamic Bank | 0.31 | 0.51 |
| Mean | 0.31 | 0.43 |
| Standard deviation | 0.19 | 0.18 |

Source: Own calculations based on sample data

At the level of individual banks, the results reveal that over the study period WNB is the most efficient bank with cost efficiency score of 0.94, while BOK is the most inefficient bank with cost efficiency score of 0.16 (inefficiency score of 0.84), followed by the ABS. We may note that BOK invests more in premises and fixed assets relative to other banks (see appendix A.1).

The results under the production approach reveal that cost efficiency scores are higher for all banks than those under the intermediation approach, with average cost efficiency of 0.43. The WNB remained the most efficient bank with cost efficiency score of 0.95. This time, however, the ABS interchanged position with the BOK as the most inefficient bank with cost efficiency score of 0.19. To explore whether the two sets of results are different, we ran a t-test for the equality of average cost efficiency under the two approaches, where the t-statistic is calculated using the standard deviations reported in table (2). The t-value is estimated at 6.83, suggesting that the two means are significantly different at the 1% significance level.

2. **Cost Efficiency by Nature of Banks:**

Table (3) reports the maximum-likelihood estimates of the parameters of the stochastic frontier cost functions under the intermediation and production approaches for two groups of banks, namely commercial banks and specialized banks. The results under the intermediation approach suggest that all estimated parameters for commercial banks have the expected signs and are significantly different from zero at the one percent level, except the input price variables UCF and UCK, which are statistically insignificant. The parameter Gamma ($\gamma$) is significantly different from zero at the one percent level, indicating the presence of technical inefficiency in the operation of commercial banks. Furthermore, the proportion of the one-sided error component in the total variance of the error term in the model is around 89 percent. These results indicate that the vast majority of the residual variation for commercial banks is due to technical inefficiency and that the inefficiency proportion ($u_i$) in the total error dominates the random error. The absolute value of the LR statistic (estimated at 62) exceeds the 8.27critical value. Hence the null hypothesis (of no technical inefficiency) is rejected at the one percent level, implying the presence of technical inefficiency in commercial banks. Finally, the point estimate of the output coefficients (0.18 + 0.13 = 0.31) implies a scale elasticity of 3.23. Once more, this suggests that commercial banks operate under conditions of increasing returns to scale and could therefore realize efficiency gains by increasing the scale of production.

The estimated parameters of the stochastic cost frontier for specialized banks are significantly different from zero at the one percent level and have the expected signs, except for the input price variable UCF, which has the wrong sign but statistically insignificant, and UCK which has the wrong sign but statistically significant. The parameter Gamma ($\gamma$) is equal to zero indicating the absence of technical inefficiency in the operation of specialized banks. The LR statistic (evaluated at 4.8) is less than the 5.1 critical values. Hence the null hypothesis (of no technical inefficiency) is accepted at the five percent level, implying the absence of technical inefficiency in specialized banks. Finally, the reciprocal of the point estimate of the output coefficients (0.36 + 0.09 = 0.45) implies a scale elasticity of 2.22, meaning that specialized banks operate under conditions of increasing returns to scale.

Table (3): Estimated Cost Functions for Commercial and Specialized Banks in Sudan

| Regressor | Commercial Banks | | | Specialized Banks | | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | t-ratio | Coefficient | Standard Error | t-ratio |
| | Intermediation Approach | | | | | |
| Constant | 1.39 | 0.34 | 4.08 | 4.14 | 1.88 | -2.20 |
| ln (INVT) | 0.18 | 0.05 | 3.71 | 0.36 | 0.10 | 3.63 |
| ln (CONTA) | 0.13 | 0.05 | 2.67 | 0.09 | 0.03 | 2.78 |
| ln (UCF) | 0.08 | 0.05 | 1.57 | 0.12 | 0.27 | -0.46 |
| ln (UCL) | 0.42 | 0.09 | 4.91 | 0.66 | 0.13 | 5.20 |
| ln (UCK) | 0.06 | 0.08 | 0.81 | 1.62 | 0.31 | -5.26 |
| Sigma-squared | 1.01 | 0.57 | 1.79 | 0.03 | 0.01 | 2.87 |
| Gamma | 0.89 | 0.07 | 13.6 | 0.00 | 0.00 | 0.00 |
| Likelihood-ratio test statistic (LR) | -61.00 | | | -4.80 | | |
| | Production Approach | | | | | |
| Constant | 0.53 | 0.35 | 1.53 | 4.56 | 1.22 | 3.74 |
| ln (INVT) | 0.11 | 0.05 | 2.21 | 0.47 | 0.21 | 2.27 |
| ln (CONTA) | 0.10 | 0.04 | 2.49 | 0.05 | 0.05 | 0.97 |
| ln (DEPS) | 0.35 | 0.07 | 4.87 | -0.42 | 0.42 | 1.00 |
| ln (UCL) | 0.09 | 0.05 | 1.76 | 0.85 | 0.34 | 2.52 |
| ln (UCK) | 0.25 | 0.08 | 3.00 | 0.61 | 0.36 | 1.69 |
| Sigma-squared | 0.39 | 0.18 | 2.12 | 0.08 | 0.03 | 3.03 |
| Gamma | 0.73 | 0.14 | 5.14 | 0.00 | 0.00 | 0.00 |
| Likelihood-ratio test statistic (LR) | -52.00 | | | -2.80 | | |

Source: Own calculations based on sample data.

The results for commercial banks under the production approach indicate that all the estimated parameters of the cost function have the expected signs and are significantly different from zero at the one or five percent levels, except the coefficient of the input price variable UCL which is statistically insignificant. The parameter

Gamma ($\gamma$) is significantly different from zero at the one percent level, indicating the presence of technical inefficiency in the operation of commercial banks. The value of the parameter suggests that the proportion of the one-sided error component in the total variance of the error term in the model is around 73 percent, indicating that the vast majority of the residual variation for commercial banks is due to technical inefficiency and that the inefficiency proportion ($u_i$) in the total error dominates the random error. The absolute value of the LR statistic for commercial banks (estimated at 52) exceeds the 8.27 critical values. Hence the null hypothesis (of no technical inefficiency) is rejected at the one percent level, implying the presence of technical inefficiency in commercial banks. Finally, the point estimate of the output coefficients (0.11 + 0.10 + 0.35 = 0.56) implies a scale elasticity of 1.79, meaning that commercial banks operate under conditions of increasing returns to scale. For specialized banks, the estimated parameters of the stochastic cost frontier under the production approach have the expected signs, except the coefficient of DEPS, which has the wrong sign and is statistically insignificant. The economic implication of this result is that 'DEPS' as an output does not affect the optimal cost of specialized banks. The estimated parameters of INVT and UCL are statistically significant at the five percent level, while the remaining parameters are insignificant. Once more, the parameter Gamma ($\gamma$) is equal to zero indicating the absence of technical inefficiency in the operation of specialized banks. The absolute value of the LR statistic (estimated at 2.8) is less than the 5.1 critical values. Hence the null hypothesis (of no technical inefficiency) is accepted at the five percent level, implying the absence of technical inefficiency in specialized banks. The point estimate of the output coefficients (calculated as 0.47 + 0.05 - 0.42 = 0.10, including the insignificant coefficient of DEPS, and as (0.47+0.05 = 0.52), excluding the coefficient of DEPS) implies that scale elasticity of specialized banks is about 10, including DEPS, or 1.9, excluding DEPS. In either case, we may conclude that specialized banks operate under conditions of increasing returns to scale.

Employing the estimated cost functions in table (3), we calculated in table (4) the cost efficiency scores for commercial and specialized banks under both the intermediation and the production approaches. The results are averages for the period

1996-2004. The average cost efficiency scores for the commercial and specialized banks under the intermediation approach are estimated at 0.39 and 1.00, respectively, implying that specialized banks are perfectly efficient while commercial banks experience an average inefficiency score of 0.61. The WNB figured out as the most efficient commercial bank with a cost efficiency score of 0.94, while the BOK turned out as the most inefficient commercial bank with a cost efficiency score of 0.21, followed by FIB with a score of 0.23.

Table (4): Average Cost Efficiency Score by Nature of Banks in Sudan, 1996-2004

| Bank | Cost Efficiency Scores | |
|---|---|---|
| | Intermediation approach | Production approach |
| Commercial Banks | | |
| Fisal Islamic Bank | 0.23 | 0.43 |
| Bank of Khartoum | 0.21 | 0.39 |
| Omdurman National Bank | 0.31 | 0.53 |
| Sudanese Islamic Bank | 0.51 | 0.73 |
| Islamic Cooperative Development Bank | 0.54 | 0.70 |
| Elnilein Industerial Development Bank | 0.41 | 0.63 |
| Alshmal Islamic Bank | 0.30 | 0.50 |
| Al Baraka Bank | 0.33 | 0.53 |
| Sudanese-French Bank | 0.45 | 0.83 |
| Export Development Bank | 0.56 | 0.57 |
| Workers National Bank | 0.94 | 0.95 |
| Saudi-Sudanese Bank | 0.57 | 0.75 |
| Animal Resource Bank | 0.61 | 0.87 |
| Tadamon Islamic Bank | 0.39 | 0.70 |
| Mean | 0.39 | 0.61 |
| Standard Deviation | 0.19 | 0.17 |
| Specialized Banks | | |
| Saving and Social Development Bank | 1.00 | 1.00 |
| Agricultural Bank of Sudan | 1.00 | 1.00 |
| Mean | 1.00 | 1.00 |
| Standard Deviation | 0.00 | 0.00 |

Source: Own calculations based on sample data.

The results under the production approach suggest that the average cost efficiency scores for the commercial and specialized banks are 0.61 and 1.00, respectively, implying that specialized banks are perfectly efficient while commercial banks experienced an average inefficiency score of 0.39. The WNB figured out as the most efficient commercial bank with a cost efficiency score of 0.95, while BOK is the most inefficient bank with a cost efficiency score of 0.34. These results are almost identical to those under the intermediation approach. To examine whether the average scores under the two approaches are equal or not, we calculated the t-statistic using the standard deviations reported in table (4). For commercial banks the t-statistic is 7.53, suggesting that the two mean values are significantly different at the 1% significance level[1].

### 5.1 Cost Efficiency by Type of Bank Ownership:

Table (5) reports the maximum-likelihood estimates of the parameters of the stochastic frontier cost functions for government and joint venture banks under the intermediation and production approaches. he results for government banks under the intermediation approach reveal that all the estimated parameters are significantly different from zero at the one or five percent levels and have the expected signs, except the coefficient of CONTA which has the wrong sign and is also statistically insignificant. The parameter Gamma ($\gamma$) is significantly different from zero at one percent level, indicating the presence of technical inefficiency in the operation of government banks. The value of gamma suggests that the proportion of the one-sided error component in the total variance of the error term in the model is around 97 percent. Thus, the vast majority of the residual variation is due to technical inefficiency and that the inefficiency proportion ($u_i$) in the total error dominates the random error. The absolute value of the LR statistic (estimated at 23) exceeds the 8.27 critical value. Hence the null hypothesis (of no technical inefficiency) is rejected at the one percent level, implying the presence of technical inefficiency in government banks. The point estimate of the output coefficients in this function is calculated as (0.24 - 0.03 = 0.21) including the insignificant coefficient of CONTA, and as (0.24), excluding the coefficient of CONTA. Accordingly, the scale elasticity of government banks is about 4.76, including

[1] Obviously, a similar test cannot be conducted for specialized banks since the two mean efficiency scores are equal.

CONTA, or 4.17 excluding CONTA. In either case, we may conclude that government banks operate under conditions of increasing returns to scale.

The results for joint venture banks under the intermediation approach reveal that all the estimated parameters of the cost function have the expected signs and are significantly different from zero at the one or five percent levels, except the coefficients of UCF and UCK which are statistically insignificant. The parameter Gamma ($\gamma$) is significantly different from zero at the five percent level, and its value suggests that the proportion of the one-sided error component in the total variance of the error term in the model is around 59 percent, indicating that more than half of the residual variation is due to technical inefficiency and that the inefficiency proportion ($u_i$) in the total error dominates the random error. The absolute value of the LR statistic (estimated at 25.9) exceeds the 8.27 critical value. Hence the null hypothesis (of no technical inefficiency) is rejected at the one percent level. These results unambiguously suggest the presence of technical inefficiency in the operations of joint venture banks. The point estimate of the output coefficients (0.19 + 0.15 = 0.34) implies a scale elasticity of about 2.94, meaning that joint venture banks operate under conditions of increasing returns to scale.

Table (5): Estimated Cost Functions for Government and Joint Venture Banks in Sudan, 1998-2004

| Regressor | Government Banks | | | Joint Venture Banks | | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | t-ratio | Coefficient | Standard Error | t-ratio |
| **Intermediation Approach** | | | | | | |
| Constant | 0.03 | 0.35 | 0.08 | 2.68 | 0.48 | 5.52 |
| ln (INVT) | 0.24 | 0.06 | 3.80 | 0.19 | 0.06 | 3.36 |
| ln (CONTA) | -0.03 | 0.03 | -0.96 | 0.15 | 0.05 | 2.85 |
| ln (UCF) | 0.02 | 0.05 | 3.36 | 0.12 | 0.07 | 1.60 |
| ln (UCL) | 0.71 | 0.10 | 7.25 | 0.28 | 0.09 | 35.00 |
| ln (UCK) | 0.17 | 0.08 | 2.28 | 0.12 | 0.13 | 0.09 |
| Sigma-squared | 0.21 | 0.11 | 1.88 | 0.24 | 0.12 | 1.97 |
| Gamma* | 0.97 | 0.02 | 51.9 | 0.59 | 0.23 | 2.54 |
| Likelihood-ratio test statistic (LR) | -23.00 | | | -25.00 | | |
| **Production Approach** | | | | | | |
| Constant | 0.57 | 0.34 | 1.67 | 2.26 | 0.49 | 4.58 |
| ln(INVT) | 0.08 | 0.06 | 1.29 | 0.17 | 0.06 | 2.96 |
| ln(CONTA) | -0.05 | 0.03 | 1.73 | 0.11 | 0.06 | 1.85 |
| ln(DEPS) | 0.38 | 0.08 | 4.78 | 0.16 | 0.09 | 1.74 |
| ln(UCL) | 0.04 | 0.46 | 8.11 | 0.13 | 0.07 | 1.73 |
| ln(UCK) | 0.48 | 0.89 | 5.43 | 0.22 | 0.10 | 2.30 |
| Sigma-squared | 1.53 | 0.81 | 1.89 | 0.17 | 0.08 | 2.31 |
| Gamma | 0.96 | 0.21 | 46.2 | 0.42 | 0.28 | 1.50 |
| Likelihood-ratio test statistic (LR) | -15.00 | | | -24.00 | | |

Source: Own calculations based on sample data.

The results for government banks under the production approach reveal that all estimated parameters are significantly different from zero at the one percent level and have the expected signs, except the coefficient of CONTA which has the wrong sign and is also statistically insignificant, and the coefficient of INVT which has the right sign but statistically insignificant. The parameter of Gamma ($\gamma$) is significantly different from zero at the one percent level, indicating the presence of technical inefficiency in the operation of government banks. The value of gamma suggests that the proportion of the one-sided error component in the total variance of the error term in the model is around 96 percent, indicating that the vast majority of the residual variation is due to technical inefficiency and that the inefficiency proportion ($u_i$) in the total error dominates the random error. The absolute value of the LR statistic (estimated at 15) exceeds the 8.27 critical values. Hence the null hypothesis (of no technical inefficiency) is rejected at one percent level, implying the presence of technical inefficiency in government banks. The point estimate of the output coefficients in this function is (0.08 -0.05 + 0.38 = 0.41) including the insignificant coefficient of CONTA, and (0.08 + 0.38 = 0.46), excluding the coefficient of CONTA. This implies a scale elasticity of about 2.44 including CONTA or 2.17 excluding CONTA. Thus, government banks operate under conditions of increasing returns to scale.

With regard to joint venture banks, the results reveal that all estimated parameters have the expected signs, but only the coefficients of INVT and UCK are statistically significant at the one and five percent levels, respectively. The parameter of Gamma ($\gamma$) is different from zero, indicating the presence of technical inefficiency in the operation of joint venture banks. The value of gamma indicates that around 42 percent of the proportion of the one-sided error component in the total variance of the error term in the model is due to technical inefficiency. The absolute value of the LR statistic (evaluated at 24) exceeds the 8.27 critical values. Hence the null hypothesis (of no technical inefficiency) is rejected at the one percent level, implying the presence of technical inefficiency in joint venture banks. The point estimate of the output coefficients (0.17 + 0.11+ 0.16 = 0.44) implies a scale elasticity of about 2.27, meaning that joint venture banks operate under conditions of increasing returns to scale.

Employing the estimated cost functions in table (5), we calculated in table (6) the annual average cost efficiency scores for government and joint venture banks under both the intermediation and the production approaches over 1996-2004. The average cost efficiency scores for the government and joint venture banks under the intermediation approach are 0.23 and 0.72, respectively. The WNB figured out as the most efficient government bank with a cost efficiency score of 0.91, while BOK ranked as the most inefficient government bank with a cost efficiency score of 0.12. With regard to joint venture banks, we observe that EDB ranked as the most cost efficient with a cost efficiency score of 0.92, while FIB ranked as the most inefficient joint venture bank with a cost efficiency score of 0.49.

Table (6): Average Cost Efficiency Scores of Banks by Type of Ownership, 1996-2004

| Bank | Cost Efficiency Scores | |
|---|---|---|
| | Intermediation approach | Production approach |
| | Government Banks | |
| Bank of Khartoum | 0.12 | 0.18 |
| Omdurman National Bank | 0.17 | 0.24 |
| Saving and Social Development Bank | 0.52 | 0.56 |
| Islamic Cooperative Development Bank | 0.39 | 0.49 |
| Elnilein Industrial Development Bank | 0.25 | 0.32 |
| Agricultural Bank of Sudan | 0.13 | 0.13 |
| Workers National Bank | 0.91 | 0.92 |
| Animal Resource Bank | 0.33 | 0.49 |
| Mean | 0.23 | 0.29 |
| Standard Deviation | 0.26 | 0.26 |
| | Joint venture Banks | |
| Fisal Islamic Bank | 0.49 | 0.60 |
| Sudanese Islamic Bank | 0.88 | 0.91 |
| Alshmal Islamic Bank | 0.61 | 0.70 |
| Al Baraka Bank | 0.67 | 0.76 |
| Sudanese-French Bank | 0.76 | 0.87 |
| Export Development Bank | 0.92 | 0.89 |
| Saudi-Sudanese Bank | 0.91 | 0.93 |
| Tadamon Islamic Bank | 0.74 | 0.85 |
| Mean | 0.72 | 0.79 |
| Standard Deviation | 0.15 | 0.12 |

Source: Own calculations based on sample data.

The results under the production approach reveal that the average cost efficiency scores for the government and joint venture banks are 0.29 and 0.79, respectively. Once more, WNB ranked as the most efficient government bank with a cost efficiency score of 0.92, while ABS ranked as the most inefficient government bank with a cost efficiency score of 0.13. With regard to joint venture banks, we observe that SSB ranked as the most cost efficient bank with cost efficiency score of 0.93, and FIB ranked as the most inefficient bank with a cost efficiency score of 0.60. These results suggest that joint venture banks were more efficient under both approaches compared to government banks. Based on the standard deviations reported in table (5), we tested whether the two approaches give different means of cost efficiency for each set of banks. The t-values for the cost efficiency results for government and joint venture banks are the same and equal to 3.54, indicating that the two average scores for each group are significantly different at the 1% significance level.

## CONCLUSION

Motivated by the catalytic role that the banking sector could play in the economy, this paper assessed the efficiency of sixteen Sudanese banks over the period 1996-2004 using the parametric Stochastic Frontier Approach (SFA) under the production and intermediation approaches. The results under both approaches indicate that Sudanese banks are inefficient. Nonetheless, specialized banks are relatively less inefficient than commercial banks while joint venture banks are less inefficient than government banks. Most important, although the majority of Sudanese banks operate under increasing returns to scale, the very low estimates of overall average cost efficiency scores means that they have not exploited the advantages of such scale. In short, these banks suffer from diseconomies of scale. With an average efficiency score lower than the world's average, coupled with measures to open up the sector for foreign banks, Sudanese banks could survive fierce competition only through improving efficiency toward the world best practice frontiers. Efficiency could be improved through a number of measures, including the improvement in productivity through human capital development, investment in research and development, application of the research findings and recommendations, specialization of managers in specific tasks, spreading marketing and promotional costs over a wider range of products, the introduction of new technologies and internet banking services (involving automation and computerization) and, most important, through a credible management chosen on the basis of qualification, competence and expertise. Over time, these measures could give rise to substantial gains in terms of economies of scale and efficiency (or lower average cost), and to considerable improvement in the ability to compete and make profits.

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## Appendix

### Table (A.1): Percentages of Bank's Outputs and Inputs

| Bank | Code | INVS | CONTA | WAGE | DEPS | FXSS |
|---|---|---|---|---|---|---|
| Fisal Islamic Bank | FIB | 3 | 3 | 2 | 4 | 7 |
| Bank of Khartoum | BOK | 11 | 11 | 14 | 13 | 16 |
| Omdurman National Bank | ONB | 34 | 34 | 10 | 26 | 17 |
| Sudanese Islamic Bank | SIB | 4 | 3 | 6 | 4 | 6 |
| Saving and Social Development Bank | SSDB | 2 | 1 | 3 | 2 | 4 |
| Islamic Cooperative Development Bank | ICDB | 6 | 4 | 6 | 4 | 4 |
| Elnilein Industrial Development Bank | EIDB | 12 | 7 | 12 | 9 | 8 |
| Al Shamal Islamic Bank | AIB | 3 | 3 | 3 | 4 | 5 |
| Al Baraka Bank | ABB | 4 | 1 | 2 | 3 | 3 |
| Agricultural Bank of Sudan | ABS | 2 | 3 | 15 | 1 | 2 |
| Sudanese French Bank | SFB | 3 | 11 | 7 | 13 | 9 |
| Export Development Bank | EDB | 2 | 1.8 | 3 | 1 | 2 |
| Workers National Bank | WNB | 1 | 0.2 | 1 | 1 | 1 |
| Saudi Sudanese Bank | SSB | 3 | 4 | 7 | 4 | 3 |
| Animal Resources Bank | ARB | 4 | 8 | 4 | 5 | 7 |
| Tadamoun Islamic Bank | TIB | 6 | 5 | 5 | 6 | 6 |
| **Total** | | **100** | **100** | **100** | **100** | **100** |

Source: Own Calculations.

### Table (A.2): The Type of Economies of Scale of Individual banks in Sudan, 1996-2004

| Bank | Intermediation Approach | Production Approach |
|---|---|---|
| Fisal Islamic Bank | IRS | IRS |
| Bank of Khartoum | DRS | DRS |
| Omdurman National Bank | CRS | CRS |
| Sudanese Islamic Bank | IRS | IRS |
| Saving and Social Development Bank | IRS | IRS |
| Islamic Cooperative Development Bank | CRS | DRS |
| Elnilein Industerial Development Bank | DRS | DRS |
| Alshmal Islamic Bank | DRS | CRS |
| Al Baraka Bank | IRS | IRS |
| Agricultural Bank of Sudan | CRS | DRS |
| Sudanese-French Bank | CRS | CRS |

| | | |
|---|---|---|
| Export Development Bank | IRS | IRS |
| Workers National Bank | IRS | IRS |
| Saudi-Sudanese Bank | CRS | CRS |
| Animal Resource Bank | CRS | CRS |
| Tadamon Islamic Bank | IRS | DRS |

Source: Own calculations based on sample data.

**Table (A.3): Variable codes and Source of data**

| Variable Category | Variable | Variable Definition | Unit of Measurement | Source of Data |
|---|---|---|---|---|
| Output | INVT | Total Investment | Millions of SDD | Banks annual reports |
| | CONTA | Contra Account | | |
| Input | DEPS | Total deposits | | |
| | WAGE | Total wages | | |
| | FXSS | Fixed assets | | |
| Input Price | UCL | Unit cost of labor | Thousands of SDD | Computed |
| | UCF | Unit cost of funds | Percentages | |
| | UCK | Unit cost of capital | | |

Source: Own Construction.