Information Technology Investments and Productivity Changes in the Jordanian Banking Industry between 1993-2015

Hussam-Eldin Ali Daoud[1]

ABSTRACT

The objectives of this study are to measure the cost and profit efficiency of Jordanian banks, and to evaluate the effects of ITI in increasing productivity on the banking sector in Jordan during the period 1993–2015. Frontier approaches method and micro-data from a panel of 22 Jordanian banks have been used. The results are largely confirmed with the validity of the Frontier approaches. The profit frontier model suggests that banks with higher ITI can achieve more profits. The study shows that over time, the profit efficiency of Jordanian banks has worsened and they have been achieving a lower level of profit for any given level of output. The results also indicate that large banks are more cost efficient than smaller ones. Conversely, small banks are shown to be more profit-efficient than large ones. The study indicates that the average contribution of IT capital to TFP growth through cost and profit functions is as large as 0.5% and 1.1% per year, respectively. However, the level of ITI in Jordanian banks does have a significant impact on banks' costs, and that the technological change has occurred through technical progress. Therefore, Jordanian banks have, over time, been able to produce a given output at lower levels of cost. Jordanian banks should increase their financial allocations for IT investments and should use the latest electronic devices to facilitate the use of banking services.

Keywords: Information technology, productivity, profit and cost frontier, Jordanian banking sector.

INTRODUCTION

Historically, developing countries have strongly controlled the activities of their banks more than industrialised countries (Gruben & McComb, 1997). Despite this, the banking industry in many developing countries have experienced low levels of efficiency and, subsequently, poor performance. In order to address this inefficiency, many countries are eager to introduce Information Technology (IT) to be used by entities engaged in financial services. This has increased their banks' capacity to achieve more benefits, including gains in profitability. This requires an understanding of the role of Information Technology Investment (ITI) in increasing productivity. This study explores the link between ITI and total-factor productivity "TFP". Theoretical production analysis has always focused on production activity as an optimisation process (Fare & Grosskopf, 1994). Maximum production, minimum cost and maximum profit are presented as solutions to the optimisation process (Lovell, 1993). To determine whether a firm is efficient or inefficient, an empirical analysis compares the actual operations of the firm with best practice. In this study, frontier analysis is introduced as a tool to evaluate the efficiency of banks. By using profit frontier technique, the relationship between changes in TFP and the use of ITI can be estimated.

The specific objectives of this study are:

- To measure the cost and profit efficiency of Jordanian banks during 1993–2015, using frontier approaches.

[1] Economics, Business & Finance Department, Mutah University, Al-Karak, Jordan.

✉ dr.hussam73@gmail.com

- To measure the effects of ITI in increasing TFP in the banking sector in Jordan.

Therefore, this study seeks to answer the following questions:

1. Is there a relationship between cost (profit) frontier shifts and IT capital accumulation?

2. Is there a relationship between bank size and cost (profit) efficiency?

Over the past years, banks in Jordan (and all over the world) have invested significantly in IT and IT systems. It is widely believed that strategic IT investments will enable banks to cut costs and compete more effectively. It is also believed that ITI may significantly improve a bank's profit performance. However, currently there is no way to measure this performance or to determine precisely how much should be invested in IT. This study attempts to fill this gap by defining the core measure for FP, analysing ITI's effect of on it and determining an optimal level of ITI.

Understanding the role of IT and investment in IT and its relation to bank performance is crucial. As a result, this study has important policy implications for the financial sector of the Jordanian economy.

1.1. Research hypotheses

H_1:Cost (profit) frontier shifts are strongly correlated with IT capital accumulation.

H_2: Bank size is positively related to cost (profit) efficiency.

2.   2. Literature review

Several studies have emphasised the role of technological innovation as a primary source of structural changes, but empirical evidence of the effects of technical progress on TFP is still scarce. This study examines the effect of IT on Jordanian banking over the period 1993–2015.

Technological advances are followed by major total factor productivity pushes although the empirical evidence of these varies greatly across time periods, countries, and measurement strategies. Studies on TFP growth in the USA

conducted during the 1980s and the early 1990s generally found that the use of computers had a negligible impact on productivity (Roach, 1987; Berndt & Morrison, 1997). Later research found evidence of a significant contribution of IT capital to recent productivity growth in the USA (e.g. Jorgenson, 2000; Oliner & Sichel, 2000). On the other hand, more sceptical scholars argued that productivity gains were largely due to cyclical factors (Gordon, 1999).

Berger and Humphrey (1992) employed a parametric approach (i.e. TFA) and used data from the year 1980 to estimate cost efficiency. They measured technical change and productivity, and found little change in these measures during the 1980s. Bauer *et al.* (1993) measured efficiency levels for the period 1977–1988, using parametric approaches (i.e. stochastic frontier approach "SFA" and the thick frontier approach "TFA"; they found little improvement in efficiency scores during the study period. Wheelock and Wilson (1999) analysed the productivity of US banks during 1984–1993 using a non-parametric approach (DEA) and discovered a decline in technical efficiency. Berger and Mester (2003) investigated the effects of technological change over the deregulation period and beyond 1984–1997. Their results showed that cost productivity worsened by 4.2% annually between 1984–1991 and by 12.5% annually between 1991–1997. However, profit productivity improved by 4.3% annually between 1988–1991 and by 12.2% annually between 1991–1997.

Recent research has shifted to micro-data in the attempt to uncover the transformation that digital technologies induce in firm organisation and workplace activities. Parsons *et al.* (1993) estimated a cost function using data from a large Canadian bank over the period 1974–1987 and found a weak but significant correlation between productivity growth and the use of computers.

Brynjolfsson and Hitt (2003) estimated a production function for a panel of 600 large US firms, finding that the contribution of ITI to output growth significantly exceeded its factor share, which implies a positive effect of computers on productivity growth in the long run. OECD (2004)

gathered a set of empirical papers that offers a comprehensive overview of the impacts of IT on economic performance in advanced countries. The nine studies, based on micro-data, showed significant impacts of digital technologies on firm-level performance. In most cases, there was also evidence that ITI is associated with more rapid TFP growth, and that this effect differs across industries. Firms in the financial sector are among those that have benefited most from the new technologies.

In the context of the Jordanian banking sector, the literature regarding bank efficiency is scarce. Al-Jarrah and Molyneux (2003) used the SFA approach to examine efficiency levels in the Jordanian, Egyptian, Saudi Arabian and Bahraini banking systems during the years 1992–2000. To derive efficiency levels, he estimated three distinct economic efficiency concepts: cost, standard profit, and alternative profit efficiencies. The banks' output in this study includes loans, other earning assets, and off balance-sheet items, while inputs include interest on deposits, total personnel expenses, and expenses on land and buildings. The results indicated that cost efficiency averaged around 95% in 1992–2000 (89% for Jordan) and standard and alternative profit efficiencies averaged between 66% and 58% respectively, over the same period (66% and 50% for Jordan). The results also indicated that there were considerable differences in average bank efficiency levels across the four countries during the sample period, with Jordanian banks being the least cost- and profit-inefficient, and Bahrain banks being the most efficient. Al-Jarrah and Molyneux (2003) also reported that the Islamic banks are the most cost- and profit-efficient, with the larger banks relatively more so.

Isik *et al.* (2004) used DEA to investigate managerial, technical and scale efficiencies of banks operating in Jordan over 1996–2001. In estimating efficiency, the researchers constructed a year–specific production frontier and, to account for group effects, they normalised all inputs and outputs by the number of branch offices, calculating a separate frontier for each banking group. Additionally, they

used two approaches to measure banks' inputs and outputs (production and intermediation approaches). With the production approach, deposits are treated as bank outputs, whereas they are treated as bank inputs under the intermediation approach. Results for the production (intermediation) approach were 71% (89%) managerial efficiency, 89% (96%) pure technical efficiency and 79% (92%) scale efficiency. Although the two approaches produce different results, the component of managerial efficiency under both approaches suggests that a major source of inefficiency within the Jordanian banking industry is scale inefficiency. In common with Al–Jarrah and Molyneux(2003), this study reports that large banks are the most efficient.

Neither of these previous studies takes into account all banks operating in Jordan. More importantly, neither attempts to investigate the impact of IT on efficiency levels in Jordan.

3. Methodology

Aigner *et al.* (1977) and Meeusen and Van (1977) independently proposed the first stochastic frontier model. The stochastic frontier for cost minimisation can be given as:

$$C = C(y, p, u, v) \qquad \ldots \ldots (1)$$

or in logarithmic terms, and assuming that the efficiency and random error terms are multiplicatively separable from the remaining arguments of the cost function,

$$\ln(c_i) = C(\ln(y_{ki}, p_i)) + lnu_i + lnv_i \qquad (2)$$

Where C is costs of bank; C(,) is a suitable functional form, (y_{ki}) is the output vector, (p_i) is the price of inputs, (u_i) is the level of cost inefficiency, and (v_i) is a random error component that permits random variation of the frontier across banks, and captures the effects of measurement errors, other statistical noise and random shocks outside the bank's control. This error is assumed to be independently and identically distributed among normal random variables with zero mean and variance σ^2. u_i is a non-negative and one-

sided error component that follows a half-normal distribution, capturing the effects of inefficiency relative to the stochastic frontier. The SFA specifies a functional form for the cost and profit function and permits a composed the overall error term (εi). The inefficiency (ui) is measured by separating the inefficiency component from error term (εi) (Cummins *etal*., 1998) and the estimated inefficiency for any firm is taken as the conditional mean or mode of the distribution of the inefficiency term, given the residual, which is an estimate of the composed error (Berger & Humphrey, 1997; Bauer *et al*., 1998). The SFA can be employed within a single cross-section or in panel data.

It should be noted that productivity growth was decomposed into changes in best practice and changes in efficiency. This study is very close in spirit to that of Berger and Mester (2003). Best practice reflects the production choices of the best-performing firms in the industry. However, as technical progress shifts the efficient technological frontier, it also shifts the best practice frontier. This is the first link between IT capital deepening and TFP growth.

The second link between IT investment and TFP growth is the change in average industry efficiency. For each bank, an inefficiency score can be defined in terms of its distance, expressed in a proper metric, from the best practice frontier. Idiosyncratic shocks, poor management, and late adoption of new technologies combine to determine an ongoing average level of inefficiency within a given industry. A well-documented fact is that the pattern usage of new technologies over time typically follows an S-curve (Geroski, 2000). Firms lagging behind are likely to be less efficient because they use obsolete production plans. Once the diffusion of a new technology gains momentum, we should observe a closing of the efficiency gap. Firms that move over time from lower to higher efficiency levels add to industry TFP growth.

To account for the two channels linking IT and TFP growth, this study applied the stochastic frontier methodology developed by Coelli *et al*. (2005), which allows us to estimate simultaneously both a time-variant best practice and the pattern of industry inefficiency.

3.1. The empirical model

The concept of productivity efficiency flows directly from the microeconomic theory of the firm, and the production function represents the maximum rate of output that can be produced with given inputs and technology. This relationship can be expressed as $Y = f(X_m)$ where y represents output, Xm (m = 1, 2… M) is a vector of inputs and f (.) is a functional form.

Duality theory[1] establishes the relationships among production function, cost function, and profit function (Coelli *et al*., 2005). It is underlined by achieving minimum production cost (minimum input cost) and maximum profit function. When data on prices for inputs and outputs are available and a firm is operating in a competitive market and its aims are to achieve cost minimisation or/and profit maximisation, then it is possible for a firm to decide on the best mix of inputs or/and outputs meeting such aims. The cost function is the one that can be interpreted as being derived from minimising cost, subject to the constraint of a reasonable production technology. The cost function can be expressed as follows:

$$TC = f(P_m, Y_n) \qquad (3)$$

where TC variable is total costs, P_m (m = 1,2,…, m) represents a vector of input prices, and Y_n (n = 1,2,…,n) represents the given level of outputs.

A stochastic translog cost function was estimated with a time polynomial included as a production factor to allow for non-neutral technological progress.

A generalisation of the Cobb–Douglas functional

---

[1] Generally speaking, duality theory is a mathematical technique concerned with translating concepts, theorems, or mathematical structures into other concepts, theorems

or structures, in a one-to-one fashion (Sydsaeter & Hammond, 1995).

form is the so-called translog form, introduced by Christensen *et al.* (1973). The translog cost functional

form can be written as:

$$\ln(C_{it}) = b_0 + \overset{N}{\underset{n=1}{\textstyle\sum}} b_{yn} \ln Y_n + \overset{M}{\underset{m=1}{\textstyle\sum}} b_{pm} \ln P_m +$$

$$\tfrac{1}{2}\left(\overset{N}{\underset{n=1}{\textstyle\sum}} \overset{N}{\underset{i=1}{\textstyle\sum}} b_{yny_1} \ln Y_n \ln Y_i + \overset{M}{\underset{m=1}{\textstyle\sum}} \overset{M}{\underset{k=1}{\textstyle\sum}} b_{P_m P_k} \ln P_m \ln P_k \right)$$

$$+ \overset{N}{\underset{n=1}{\textstyle\sum}} \overset{M}{\underset{m=1}{\textstyle\sum}} b_{y_n P_m} \ln Y_n \ln W_m$$

$$+ \overset{N}{\underset{n=1}{\textstyle\sum}} b_{ty_n} \ln W_n T + \overset{M}{\underset{m=1}{\textstyle\sum}} b_{tp_m} \ln W_m T + b_6 I_{it} + T + b_7 H_{it} + n_{it}$$

Where; C_{it} : stand for costs of bank *i* in period t.Y_{ijt}: Vector of the outputs of bank *i*, which are the total loan and other earning assets.P_{ijt}: Vector of input prices, which are the prices of labour, physical, and financial capital inputs, computed as:

$$\text{Price of Labour:} P_1 = \frac{\text{Total Personal Expense}}{\text{Total Assets / Total Employment}}$$

$$\text{Price of Physical Capital:} P_k = \frac{\text{Non-interest - Personal Expense}}{\text{Fixed Assets}} \quad (4)$$

$$\text{Price of Financial Capital:} P_f = \frac{\text{Total Interest}}{\text{Total Deposits}}$$

I_{it}: IT investment.n_{it}: Measures inefficiency in terms of forfeited profits and error terms, which are usual white noise error terms. This term is modelled as follows: V_{it} is a random variable which is assumed to be $iidN(0,\sigma_v^2)$ and independent of the random variables Uit, which account for technical inefficiency and are assumed to be independently distributed as non-negative truncations of the N (μ_{it}, σ_u^2) distribution.σ_u^2

The best practice frontier, estimated through a cost function, focuses on the input side of bank production and may overlook important dimensions of banks' decision-making. Berger and Mester (1997) argued that the use of a profit frontier can be more appropriate than that of a cost frontier, because it accounts for both output and input

suboptimal bank decisions. However, in standard profit analysis, output prices are taken as exogenous, considering profit inefficiency as a sub-optimal choice with respect to input-output relative prices. This is not an accurate representation of the banking industry, because a large share of revenues originates from bilateral contracting in which banks have some bargaining power. Therefore, this study adopted the formulation of the profit function, introduced by Humphrey and Pulley (1997), in which output prices are flexible while output levels are taken as given. Errors in the choice of outputs do not affect the efficiency vector, while errors in setting output prices do. The estimated efficiency levels in this case measure how close a bank is to its maximum profit given an input-output quantity mix. The price to be paid for this gain is concerned with the assumption that profits are maximised conditionals on output levels, which is a very demanding hypothesis.

The profit function can be interpreted as the result of maximising profit subject to the constraint of reasonable production technology. The profit function can be expressed as follows:

$$\Pi = f(P_m, Y_n) \qquad \ldots\ldots(5)$$

Where II is the profit, P_n (n = 1,2,…,n) is a vector of output prices, and W_m is a vector of input prices. As with

the cost function, the profit function should satisfy many properties which are generalisations of cost properties.

The extension employed in this study is on the basis of two outputs and three inputs of banks; the translog profit frontier is specified as follows:

$$\ln(\Pi_{it}) = \beta_0 + \sum_{n=1}^{N} \beta_{yn} \ln Y_n + \sum_{m=1}^{M} \beta_{pm} \ln P_m +$$

$$\tfrac{1}{2} \left(\sum_{n=1}^{N} \sum_{i=1}^{M} \beta_{yny_1} \ln Y_n \ln Y_i + \sum_{m=1}^{M} \sum_{k=1}^{M} \beta_{P_m P_k} \ln P_m \ln P_k \right)$$

$$+ \sum_{n=1}^{N} \sum_{m=1}^{M} \beta_{y_n p_m} \ln Y_n \ln W_m$$

$$+ \sum_{n=1}^{N} \beta_{ty_n} \ln W_n T + \sum_{m=1}^{M} \beta_{tp_m} \ln W_m T + \beta_6 I_{it} + T + \beta_7 H_{it} + n_{it}$$
......(6)

Where: II_{it}: The ability to achieve revenue, then profit used by the owners, investors, lenders, and financial analysts to judge the success of management and efficiency in the use of available resources to achieve high performance level growth. This study uses Return on Assets (ROA), which measures the effectiveness of management in the use of available resources and the extent of their ability to achieve returns, and thus reflects the effect of operating, financing, investment, and technological activities. ROA is a useful measure of the performance of banks (Molyneux & Gardener, 1996; Polius & Samuel, 2000):

Y_{ijt}: Vector of the outputs of bank i; which are the total loan and other earning assets. n_{it}: Measures inefficiency in terms of forfeited profits and error terms, which are usual white noise error terms. This term is modelled as follows:

$$n_{it} = \delta_0 + \sum_{i=1}^{J} \delta Z_{itj} + \delta_t T + W_{it} \qquad .. \qquad (7)$$

Where $\square_\square$ is a constant term, z_{it} are individual time-varying covariates, t is a linear time trend to account for time patterns of inefficiency, and W_{it} is a white noise stochastic disturbance. This equation was estimated using maximum likelihood techniques that produce asymptotically consistent and efficient estimates.

Among the variables Zj, a measure of IT capital was included, because the difference in the adoption rate of new technologies across banks is likely to be reflected in the distribution of efficiency levels.

Let $\square_t$ be the estimated coefficient of IT capital obtained from previous equation. If its sign is negative (positive), a rise in IT capital reduces (increases) the extra cost or forfeited profits due to inefficiency. For each period t, the average contribution of IT was computed to industry inefficiency as follows:

$$Ineff - IT_t = \left(100 * \sum_i \delta_k IT_{it}\right) / N_t \quad .....(8)$$

Where Nt is the number of existing banks at period t. Ineff-ITt is a measure, expressed in percentage points, of the average cost reduction or of the profit increase due to the impact of IT on industry inefficiency. The first difference ΔIneff-ITt is the annual change in average inefficiency induced by IT capital accumulation. Averaging over time, the ΔInneff-ITts we obtain a measure of the average yearly TFP change due to the effect of IT capital accumulation on industry efficiency.

As a last step, the correlation between IT capital accumulation and shifts in the cost and profit frontiers for banks over time was investigated. The idea behind this exercise is that frontier shifts are driven by the

introduction of new best practices along with the increase of IT capital.

First, the time derivative of the frontier function for each bank in each year was computed, as follows:

$$\Pi' = \frac{\partial \pi}{\partial t} = \beta_{t1} + 2\beta_{t2} + \sum_{i=1}^{N} \beta_{yt_1} \ln Y_i + \sum_{j=1}^{M} \beta_{pt_j} \ln W_J \quad \text{.(9)}$$

Where Π stands for the cost or the profit function for each bank; i the time derivative is computed taking the projection on the frontier of its input-output mix. The frontier shifts represent the variation in total cost or profit for a given level of outputs and inputs owing to TFP changes.

As in the case of idiosyncratic inefficiency changes, frontier shifts reflect the effects of technical progress. More importantly, this shock is likely to hit each bank with different intensity and this is reflected on the frontier, which is estimated using information on all the production units in the sample.

To filter the effect of IT on frontier shifts, the panel of banks' frontier shifts for each year with a fixed effects regression of the kind was estimated:

$$\Pi' = \sum_{j=1}^{J} \theta_j \ln W_{jit} + \lambda_t + \eta_t + \varepsilon_{it} \quad \text{….. (10)}$$

Where W_j's are time-varying bank specific variables, the θ i's are bank fixed effects, the θ t's are time dummies, and ε_{it} is the white noise disturbance error. This procedure is very close to the approach proposed by Brynjolfsson and Hitt (2003). As in the case of the inefficiency estimates among the Wj variables, a measure of IT capital was included. In a similar way, an estimate of the average contribution of IT to the frontier shift in each period was obtained as follows:

$$FS - IT_t = \left(100 * \sum_i \theta_K IT_{it} \right) / N \quad \text{….. (11)}$$

Where θ k is the estimated coefficient of IT capital obtained from the equation and, as before, N is the number of banks indexed by I; the time mean of FS-ITt is

the measure of the average yearly TFP change due to the frontier shifts induced by IT capital accumulation.

3.2. The data

In the empirical analysis of this study, data referring to an unbalanced panel of 22 Jordanian banks over the period 1993–2015 was employed. Most data was furnished through primary annual and monthly statistical bulletins and reports issued by banks and by the Central Bank of Jordan, which include detailed information on financial decision variables. Data on ITI in computer maintenance cost software, internet cost, ATM cost, phone cost, equipment, and the number of employees working in the banks were collected yearly.

In the sample, there was a great variance across banks owing to size. In principle, banks of different sizes could have access to different production sets, and this could distort the estimates of the parameters of the frontier functions.

The appropriate representation of bank production operations and, in particular, the definition of bank output are loans, investments, and other earning loans. This type of output has generally been overlooked in previous research; it represents a major source of revenues for the banking industry.[2]

On the input side, three inputs were considered: labour, physical and financial capital services, ITI, and other financial decision variables. Table 1 presents the descriptive statistics of the dependent and explanatory variables used in empirical analyses. The reason that skewness is shown in addition to arithmetic's means is that skewness is employed instead of means as the group classification criterion in the following bank group analyses. Specifically, skewness is judged as a more appropriate criterion of bank groups by asset size than is means (Daoud, 2010), since there are three large-sized asset banks and nineteen small banks, while there are six large ITI banks and sixteen small banks.

---

2   Rogers (1998) and Clark and Siems (2002) are instances of the few exceptions. Both papers found that bank efficiency scores are affected by \ off-

balance-sheet activities, which are one of the sources of fees and commissions.

Table 1: Descriptive statistics of the dependent variables

	LNROA	COST	LNY1	LNY2	LNY3	LNPL	LNPK	LNPF	LNITI
Mean	-3.76327	3.1037	8.73	1.505714	8.055	-4.23979	-4.64701	-3.17031	14.28333
Median	-3.04621	3.0301	5.36	1.551450	4.9836	-4.19579	-4.5326	-2.99573	14.10685
Maximum	1.971883	5.4664	22.3	3.347642	21.295	-2.93709	-2.76717	-2.05573	17.35083
Minimum	-12.3393	0.1823	1.63	-100	0.7885	-5.94804	-7.11702	-5.60212	12.99624
Std. Dev.	2.079521	0.9146	6.46	0.760255	6.2527	0.592635	0.684545	0.555103	0.769831
Skewness	-2.91456	0.3186	1.12	-0436353	1.106	-0.18002	-0.73111	-1.08278	1.494792
Kurtosis	11.32169	3.1773	2.37	3.578025	2.4352	2.683674	4.049584	4.099384	5.659941
Jarque–Bera	1501.123	6.3602	78.6	15.65978	75.796	3.339981	47.11106	85.7711	232.8543
Probability	0.000	0.0416	0.000	0.000398	0.000	0.188249	0.0000	0.0000	0.0000
Sum	-1313.38	1083.2	3046	516.4600	2811.2	-1479.69	-1621.81	-1106.44	4984.882
Sum Sq. Dev.	1504.893	291.11	14517	197.6716	13605	122.2234	163.0734	107.2324	206.2386
Observations	349	349	349	343	349	349	349	349	349

The ability to measure revenue and profit can then be used by owners, investors, lenders, and financial analysts to judge the efficient use of resources to achieve high performance levels in order to continue and grow. In this study, ROA was used to measure the rate of return on assets, which reflects the effectiveness of operating activities and financing, investment, and technology. The rate of return on assets as a measure of the performance of banks is found in many studies, including those of Molyneux *et al.* (1996) and Polius and Samuel (2000).

On the right-hand side of the inefficiency and the frontier-shift regressions, several explanatory variables were included to control for environmental and individual bank characteristics. To investigate the impact of IT capital accumulation on productivity, the variable IT_CAP was introduced, representing the amount of IT capital stock per employee.

There is a widespread presumption that the impact of IT on productivity varies according to bank asset and ITI size. Bank activities are based on the acquisition and processing of soft information, which requires the "physical proximity" of the decision unit to customers (Berger *et al.*, 2005). Size is usually taken as a proxy for bank specialisation in this respect: large banks are taken

to have hard information and small banks are assumed to work mainly with soft information.

4.   Empirical results

4.1. Coefficients of the cost frontier

Table 2 shows that the coefficients of physical and financial inputs prices were positive and the coefficients of the price of physical capital and finance were equal to 0.1886, 0.04547, respectively, which means that, on average, a 1% increase in input price will increase cost by 0.1886%, 0.04547%, respectively. However, Table 1 shows that the coefficient of the labour input price was negative and equal to -0.217, which means that, on average, a 1% increase in labour price will decrease the cost by -0.217%.

The output (y_k) coefficient shows that, on average, a 1% increase in outputs y_2 (investments) and y_3 (other earning assets) will increase costs by 1.075% and 2.086% respectively. ITI is introduced in the model as an additional input, but the coefficient of ITI was 0.4974 and highly significant. This suggests that the level of ITI in Jordanian banks does have a significant impact on banks' costs.

With regard to the time trend (T), the coefficient of time was negative (-0.007) and highly significant at 1%.

This means that a technological change has occurred within the Jordanian banking sector and through technical progress; Jordanian banks have, over time, been able to produce a given output at lower levels of cost.

Table 2: Parameter estimations for the cost frontier

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	-6.149353	2.774083	-2.216716	0.0274
LNY1	-0.479518	0.370244	-1.295139	0.1962
LNY2	1.075279	0.365897	2.938743	0.0035
LNY3	2.086231	0.556875	3.746322	0.0002
LNPL	-0.217006	0.590123	-0.367730	0.7133
LNPK	0.188614	0.362850	0.519812	0.6036
LNPF	0.045473	0.652769	0.069661	0.9445
LNY2*LNY1	-0.027635	0.003052	-9.054834	0.0000
LNY2*LNY3	0.064579	0.050745	1.272621	0.2041
LNY3*LNY1	-0.049606	0.048535	-1.022071	0.3075
LNPL*LNPK	0.005480	0.066152	0.082845	0.9340
LNPL*LNPF	-0.146821	0.127010	-1.155979	0.2486
LNPK*LNPF	0.112233	0.090721	1.237122	0.2170
LNY1*LNPL	0.033242	0.059266	0.560890	0.5753
LNY1*LNPK	-0.095446	0.044563	-2.141815	0.0330
LNY1*LNPF	-0.172241	0.043732	-3.938548	0.0001
LNY2*LNPL	0.004369	0.061838	0.070661	0.9437
LNY2*LNPK	0.084833	0.044868	1.890707	0.0596
LNY2*LNPF	0.170007	0.048760	3.486635	0.0006
LNY3*LNPL	0.027590	0.092663	0.297746	0.7661
LNY3*LNPK	0.161656	0.060166	2.686851	0.0076
LNY3*LNPF	0.251985	0.102251	2.464363	0.0143
LNY1*T	0.000368	0.008367	0.043995	0.9649
LNY2*T	0.010845	0.008463	1.281489	0.2010
LNY3*T	0.001454	0.013229	0.109931	0.9125
LNPL*T	-0.039574	0.014967	-2.644105	0.0086
LNPK*T	0.022718	0.012364	1.837357	0.0671
LNPF*T	-0.022705	0.016880	-1.345129	0.1796
T	-0.111673	0.094146	-1.186165	0.2365
T^2	-0.007342	0.002068	-3.550710	0.0004
LNITI	0.497473	0.051905	9.584271	0.0000
Total assets (Z1)	(-0.134)*	0.031	-4.296	
ITI size (Z2)	(-0.421)	0.031	-3.293	
Age of bank (Z3)	(0.010)*	0.001	9.511	
R-squared	0.828070		Mean dep. Var	3.128299

Variable	Coefficient	Std. error	t-Statistic	Prob.
Adjusted R-squared	0.811432		S.D. dependent var	0.909155
S.E. of regression	0.394795		Akaike info criterion	1.065608
Sum squared residual	48.31757		Schwarz criterion	1.413961
Log likelihood	-150.6862		Hannan-Quinn criter.	1.204397
F-statistic	49.76876			
Prob(F-statistic)	0.000000			

4.2. Coefficients of the profit frontier

The results for the profit frontier model in Table 3 show expected signs for the coefficient of financial inputs prices. The signs for all input coefficients were negative (i.e. an increase in the price of financial should decrease profit), which means that an increase in the price of finance leads to a decrease in profits. For other input/output prices and outputs, the signs are consistent with the theoretical requirements of the profit function.

The coefficients for outputs y_1 (loans), y_2 (investments) and y_3 (other earning assets) in Table 3 suggest that, on average, a 1% increase in outputs y_1 and y_3 will increase profits by 0.159% and 0.464%, respectively. The profit frontier model has a positive and significant coefficient for ITI. This would suggest that banks with higher ITI can achieve more profits, because banks with high ITI are capable of producing more outputs, which in turn increases their profits. The results showed that the coefficient of the time trend (T) was negative. This suggests that over time the profit efficiency of Jordanian banks has worsened and they have been achieving lower level of profit for any given level of output.

There are two kinds of exogenous variables introduced in the estimation of the cost and profit frontier: control variables and environmental variables. Bank asset size is positively related to cost (profit) and efficiency relates to the size of bank (Z_1). The coefficient of Z_1 in Table 2 was negative -0.134 and significant at a level of 1%. This indicates that large Jordanian banks are more cost efficient than smaller banks. This can be attributed to several advantages larger banks enjoy over smaller ones, such as their ability to use more efficient technology at less cost. With regard to profit efficiency, Table 3 shows that the coefficient associated with Z_1 is positive and significant at a level of 1%. Although banks' IT size is positively related to cost (profit), efficiency relates to the IT size of bank (Z_2), and the coefficient of Z_2 in Table 2 was negative -0.421 and significant at a level of 1%. This indicates that high-ITI banks are more cost efficient than others. Larger Jordanian banks; therefore, enjoy an advantage over smaller ones. With regard to profit efficiency, Table 3 shows that the coefficient associated with Z_2 was positive and significant at a level of 1%. This indicates that large banks are less profit-efficient than smaller ones. This can be attributed to the different magnitude of shocks and the different speed at which banks respond to them.

These results illustrate that well-established banks are more cost- (profit) efficient than newly established ones, and that relates to the age of a bank (Z_3). Table 2 shows that the coefficient associated with Z_3 was positive 0.010 and highly significant. This suggests that new banks are more efficient than older ones. With regard to profit efficiency, Table 3 shows that the coefficient associated with Z_3 was positive and significant (0.03). The hypothesis that old banks are more profit-efficient than small ones is rejected. A possible explanation for this (as suggested by Isik & Hassan, 2003) is that old banks in developing countries suffer from bureaucratic ossification, whilst newly-established banks embrace new technology and procedures.

Table 3: Parameters estimation for the profit frontier

Variable	Coefficient	Std. Error	t-Statistic	Prob
C	-37.28676	2.926277	-12.74205	0.0000
LNY1	0.159029	0.441354	0.360321	0.7189
LNY2	-0.244499	0.412914	-0.592131	0.5542
LNY3	0.464307	0.646171	0.718551	0.4730
LNPL	-6.254717	0.591922	-10.56679	0.0000
LNPK	-2.084562	0.372468	-5.596620	0.0000
LNPF	-3.718252	0.648147	-5.736741	0.0000
LNY2*LNY1	0.030406	0.006282	4.839781	0.0000
LNY2*LNY3	-0.271681	0.059816	-4.541969	0.0000
LNY3*LNY1	0.209650	0.058271	3.597867	0.0004
LNPL*LNPK	-0.500392	0.083663	-5.981037	0.0000
LNPL*LNPF	-0.881407	0.123158	-7.156724	0.0000
LNPK*LNPF	0.077903	0.072731	1.071111	0.2850
LNY1*LNPL	0.058387	0.094490	0.617920	0.5371
LNY1*LNPK	-0.031063	0.046243	-0.671725	0.5023
LNY1*LNPF	0.011965	0.071684	0.166910	0.8675
LNY2*LNPL	-0.038980	0.101883	-0.382599	0.7023
LNY2*LNPK	0.063986	0.047847	1.337288	0.1821
LNY2*LNPF	0.107633	0.077030	1.397292	0.1633
LNY3*LNPL	0.427809	0.142464	3.002937	0.0029
LNY3*LNPK	-0.147411	0.061300	-2.404764	0.0168
LNY3*LNPF	-0.296946	0.117504	-2.527119	0.0120
LNY1*T	-0.075575	0.012358	-6.115594	0.0000
LNY2*T	0.067991	0.011425	5.951185	0.0000
LNY3*T	0.011489	0.016453	0.698289	0.4855
LNPL*T	-0.024814	0.022775	-1.089528	0.2768
LNPK*T	0.002394	0.012412	0.192885	0.8472
LNPF*T	-0.033093	0.018546	-1.784380	0.0753
T	-0.034188	0.115846	-0.295114	0.7681
T^2	-0.009827	0.003252	-3.022290	0.0027
LNITI	0.643117	0.084441	7.616202	0.0000
Total assets (Z1)	(1.13)*	0.12	9.14	
ITI Size (Z2)	(0.53)	0.38	-1.41	
Age of bank (Z3)	(0.01)**	0.01	2.16	
R-squared	0.696761		Mean dependent var	-2.496368
Adjusted R-squared	0.667415		S.D. dependent var	2.700097
S.E. of regression	0.800067		Sum squared resid	198.4331
F-statistic	23.74318		Durbin-Watson stat	2.081959
Prob(F-statistic)	0.000000			

4.3. Coefficients of control and environmental variables
4.3.1. Banks' asset size

An analysis of the efficiency scores based on bank size could give the regulatory authority useful information regarding the relationship between bank size and efficiency.

Table 4 shows that, in general, the largest banks have the highest scores. That is, the average cost efficiency score for banks with assets over 2500 MJD is about 0.90, while those with less than 500 MJD, it is about 0.82.

Table 4: Cost efficiency scores according to asset size (MJD)

Year	1.00–99.9 MJD[*]	100–199.9 MJD	200–299.9 MJD	300–499.9 MJD	500–999.9 MJD	1000–2499.9 MJD	2500–4999.9 MJD	Over 5000 MJD	Average per year
1993	0.84	0.86	0.83		0.84	0.99			0.87
1994	0.87	0.86	0.83	0.83	0.84	1.00			0.87
1995	0.88	0.86	0.84	0.86	0.82	0.93			0.87
1996	0.86	0.82	0.9	0.87	0.86	0.88	0.97		0.88
1997	0.83	0.83	0.93	0.85	0.85	0.88	0.99		0.88
1998	0.85	0.85	0.87	0.8	0.77	0.86	1.00		0.86
1999	0.84	0.93	0.84	0.78	0.73	0.85	1.00		0.85
2000	0.81	0.8	0.82	0.86	0.75	0.84	0.97		0.84
2001	0.82	0.84	0.85	0.84	0.79	0.86	0.99		0.85
2002	0.83	0.98	0.81	0.86	0.78	0.78	0.99		0.86
2003	0.68	0.88	0.75	0.82	0.73	0.72	0.99		0.79
2004	0.82	0.71	0.92	0.81	0.72	0.71	0.99		0.81
2005	0.88	0.84	0.76	0.76	0.79	0.78	0.82		0.80
2006		0.78	0.84	0.79	0.8	0.75	0.69	0.93	0.80
2007		0.80	0.83	0.79	0.81	0.75	0.80		0.81
2008		0.79	0.83	0.79	0.82	0.76	0.82		0.81
2009		0.79	0.82	0.78	0.82	0.75	0.71		0.80
2010		0.78	0.81	0.79	0.81	0.75	0.69		0.78
2011		0.78	0.81	0.78	0.80	0.75	0.70		0.77
2012		0.78	0.82	0.78	0.79	0.74	0.71		0.77
2013		0.78	0.83	0.79	0.79	0.76	0.70		0.775
2014		0.79	0.83	0.80	0.80	0.77	0.73		0.79
2015		0.78	0.81	0.79	0.81	0.75	0.69		0.77
Average	0.77	0.83	0.83	0.81	0.80	0.81	0.85	0.93	0.83

[*]MJD: Millions of Jordanian Dinars.

Table 5 shows contradictory results. Small banks are shown as more profit-efficient than large ones. This could be interpreted in light of the largest Jordanian banks, which accounted for about 40% of all Jordanian bank assets. The biggest one, the Arab Bank, which has more

than 100 branches outside Jordan, faces many problems, having granting loans to the American energy company Enron which went into bankruptcy in 2001. This negatively affected the profit of the bank. The large banks in Jordan have high levels of liquidity: the average

liquidity ratio (cash and deposits at banks to total assets) for large banks is about 60%, while for other banks it is about 44% (CBJ, 2010). Excess liquidity has a direct impact on the level of profits, as such assets usually bear zero or low interest rates (Armah & Park, 1998).

Table 5: Profit efficiency scores according to assets size (MJD)

Year	1.00–99.9 MJD[*]	100–199.9 MJD	200–299.9 MJD	300–499.9 MJD	500–999.9	1000–2499.9 MJD	2500–499.9 MJD	Over 5000 MJD	Average
1993	0.78	0.83	0.8		0.90	0.84			0.83
1994	0.77	0.83	0.8	0.80	0.90	0.87			0.85
1995	0.78	0.80	0.80	0.80	0.90	0.90			0.85
1996	0.84	0.84	0.80	0.70	0.90	0.85	0.94		0.84
1997	0.81	0.82	0.80	0.80	0.90	0.85	0.94		0.85
1998	0.84	0.87	0.80	0.70	0.80	0.77	0.88		0.82
1999	0.63	0.88	0.80	0.70	0.60	0.54	0.76		0.70
2000	0.83	0.83	0.70	0.90	0.70	0.69	0.50		0.74
2001	0.93	0.68	0.90	0.90	0.80	0.89	0.95		0.85
2002	0.93	0.92	0.90	0.90	0.90	0.69	0.89		0.87
2003	0.96	0.92	0.90	0.80	0.80	0.88	0.88		0.89
2004	0.89	0.79	0.90	0.90	0.90	0.66	0.81		0.84
2005	0.76	0.73	0.70	0.80	0.90	0.74	0.72		0.76
2006		0.61	0.50	0.50	0.70	0.63	0.49	0.54	0.57
2007		0.60	0.60	0.65	0.70	0.67	0.49		0.57
2008		0.60	0.60	0.64	0.70	0.68	0.49		0.56
2009		0.60	0.61	0.55	0.71	0.69	0.48		0.57
2010		0.61	0.50	0.50	0.70	0.63	0.51		0.57
2011		0.60	0.55	0.57	0.70	0.67	0.49		0.60
2012		0.60	0.56	0.56	0.71	0.64	0.49		0.59
2013		0.61	0.54	0.52	0.71	0.68	0.40		0.58
2014		0.61	0.57	0.53	0.71	0.63	0.45		0.58
2015		0.61	0.50	0.50	0.70	0.63	0.59		0.59
Average	0.77	0.73	0.70	0.69	0.78	0.73	0.65	0.54	0.72

[*]MJD: Millions of Jordanian Dinars.

4.3.2. Banks' ITI size

The parameters of the inefficiency equations,

estimated with the profit functions, are presented in Table 3. The effect of IT capital stock on inefficiency was negative and statistically significant. This result confirms

that banks with the most IT-capital are likely to be closest to the efficient cost and profit frontiers. Specifically, for the small bank, an increase of one standard deviation in the level of IT capital per employee will generate a 3.7% cut in costs and a 7.5% profit boost due to decreased inefficiency.

The average contribution of IT capital to TFP growth via the catching-up effect estimated from the cost function is as large as 0.5% per year. The same contribution estimated through the profit function is higher and amounts to 1.1%. One possible explanation for this difference is that banks that invest in new technologies improve the quality of the services they supply. This is reflected in higher prices and short-run profits, as noted by Berger and Mester (2003). If the production of higher quality services also requires higher costs, it is plausible the productivity gains measured in terms of short-run

profit efficiency are higher than those measured in terms of cost efficiency.

Table 6 shows a negative and statistically significant relationship between IT-capital and cost efficiency, which indicates that high levels of IT in Jordanian banks decrease the costs. The relationship between the IT variable and the rate of return (performance of banks), is relatively strong and statistically significant, which may indicate that the ITI in banks is efficient.

In banks as a whole, most variables are positively correlated with the degree of efficiency. Software, internet, ATM and training based on IT classification of large- and small-asset banks are negatively correlated with the degree of efficiency. Software, internet, ATM, and training do have positive effects on efficiency measured through the cost and profit function.

Table 6: Cost function shifts

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.889486	0.989588	0.898845	0.3694
ITCAPITAL	-0.907746	0.156708	-5.792575	0.0000
MAINTENANCE	0.066108	0.073371	0.901012	0.3682
SOFTWARE	0.441143	0.051182	8.619059	0.0000
INTERNET	0.310516	0.082953	3.743274	0.0002
ATM	0.252269	0.066639	3.785578	0.0002
TRAINING	0.089635	0.050719	1.767304	0.0781
AGE	0.015866	0.001576	10.06717	0.0000
ASSETSIZE	1.246210	0.097531	12.77751	0.0000
T	0.346666	0.053849	6.437725	0.0000
R-squared	0.685198	Mean dependent var		3.084233
Adjusted R-squared	0.676890	S.D. dependent var		0.937650
S.E. of regression	0.532987	Akaike info criterion		1.607436
Sum squared resid	96.86949	Schwarz criterion		1.717429
Log likelihood	-272.1049	Hannan–Quinn criter.		1.651212
F-statistic	82.46905	Durbin–Watson stat		0.459530
Prob(F-statistic)	0.000000			

In small-asset and low-IT banks, all variables are negatively correlated with the degree of efficiency. Maintenance, software, internet, ATM, and training have negative effects on inefficiency when measured through the profit function. However, IT-capital has a negative effect on efficiency when measured through the cost function. Large asset banks display greater inefficiency through both cost and profit functions. The interpretation is that, in the majority of cases, most basic activities take time or are not fully adjusted, leading to some excess capacity.

Table 7: Profit function shifts

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.407636	0.089610	-4.549013	0.0000
IT CAPITAL	0.124607	0.014189	8.781843	0.0000
MAINTENANCE	-0.051652	0.006644	-7.773883	0.0000
SOFTWARE	-0.027923	0.004632	-6.028230	0.0000
INTERNET	-0.019866	0.007510	-2.645359	0.0085
ATM	-0.024475	0.006030	-4.058697	0.0001
TRAINING	-0.015661	0.004593	-3.409939	0.0007
AGE	-0.000127	0.000143	-0.891273	0.3734
ASSET SIZE	-0.001931	0.008833	-0.218564	0.8271
T	-0.063766	0.004866	-13.10377	0.0000
R-squared	0.492839	Mean dependent var		-0.440912
Adjusted R-squared	0.479493	S.D. dependent var		0.066906
S.E. of regression	0.048270	Akaike info criterion		-3.196021
Sum squared resid	0.796853	Schwarz criterion		-3.086258
Log likelihood	572.4997	Hannan-Quinn criter.		-3.152341
F-statistic	36.92693	Durbin-Watson stat		0.549854
Prob(F-statistic)	0.000000			

4.4. Technological change

As mentioned, included the time trend (T) in the model was included to account for technological change in the Jordanian banking industry over 1993–2015. Baltagi and Griffin (1988), Kumbhaker and Lovell (2000), Altunbas & Chakravarty. (2001) and Coelli *et al.* (2005) showed that the technological change can be estimated by calculating the variation in total cost due to a given change in technology.[3] This can be measured by the partial derivative of the estimated SFA cost frontier.

The measures of technical progress indicate the possible contribution of technical advances in reducing average banking costs across time for Jordanian banks 1993–2015. This shows that technological change has

---

[3] DeYoung (1997) stated that technological change can shift the cost frontier in a number of ways: first, adopting the new low-cost technologies such as ATMs to substitute existing high-cost technology; second, using new computer systems that allow the banks to reduce costs by the substitution of physical capital by labour; and third, deregulation can provide opportunities to recognise inputs in a lower-cost fashion.

made a positive contribution, reducing the real annual cost of production. Results in Table 8 suggest that the annual rate of reduction in total cost attributed to technological change was around 2% in 1993, decreasing to 0.9% in 1997. After 1997, the effect of technical change increased slightly from 1.1% in 1998 to 1.7% in year 2004. However, it decreased slightly from 1.2% in 2005 to 0.5% in 2015. These findings seem plausible because banks in Jordan invested heavily in technology, especially in 1997, when they started computerising all their operations, introduced ATMs, and applied online systems of communication.

By adopting the terminology of Baltagi and Griffin (1988), Altunbas *et al.* (1999) and Kasman and Kirbas (2006), the technological change can be decomposed as follows:

1. Pure technical change ($\tau_1 + \tau_{11}T$), the part related to time

2. Scale augmenting technical change ($\sum_{k=1}^{3} \kappa_k \ln y_k$), the part related to outputs

3. Non-neutral technical change ($\sum_{n=1}^{2} \theta_n \ln(w_n / w_s)$), the part related to prices

Table 8: Technological change in the banking industry, 1993–2015

Year	Technological change	Year	Technological change
1993	**-0.020**	2005	**-0.012**
1994	-0.018	2006	-0.005
1995	-0.014	2007	-0.006
1996	-0.011	2008	-0.005
1997	**-0.009**	2009	-0.008
1998	**-0.011**	2010	**-0.008**
1999	-0.012	2011	-0.009
2000	-0.012	2012	-0.008
2001	-0.015	2013	-0.008
2002	-0.015	2014	-0.008
2003	-0.015	2015	**-0.008**
2004	**-0.017**		
Average			-0.011

*Values in bold statistically significantly different from 0 at 5% level

Pure technological change accounts for the reduction in total costs over time due to technological changes. Scale augmenting technical change accounts for the reduction in cost due to efficient scale of production. Finally, non-neutral technical change reflects the reduction in total costs due to a variation in input prices. Table 9 suggests that the main source for technological change for Jordanian banks over 1993–2015 is due to pure technical change.

Table 9: Decomposition of technological changes

Year	Pure technological change	Scale augmentation change	Non-neutral technological change	Total technological change
1993	**-0.018**	**-0.003**	0.002	-0.020
1994	**-0.018**	-0.003	0.003	-0.018
1995	**-0.017**	0.000	0.003	-0.014
1996	**-0.016**	0.002	0.003	-0.011
1997	**-0.015**	**0.001**	0.005	-0.009
1998	**-0.014**	0.000	0.003	-0.011
1999	**-0.014**	0.000	0.001	-0.012
2000	**-0.013**	-0.001	0.002	-0.012
2001	**-0.012**	-0.001	-0.002	-0.015
2002	**-0.011**	0.000	-0.004	-0.015
2003	**-0.010**	0.001	-0.005	-0.015
2004	**-0.010**	**-0.002**	-0.005	-0.017
2005	**-0.009**	**0.001**	-0.004	-0.012
2006	**-0.008**	0.004	0.000	-0.005
2007	**-0.008**	0.001	0.001	-0.005
2008	**-0.008**	0.001	0.000	-0.005
2009	**-0.007**	0.001	0.001	-0.005
2010	**-0.007**	**0.001**	-0.001	-0.004
2011	**-0.007**	**0.001**	0.001	-0.005
2012	**-0.007**	**0.001**	0.001	-0.005
2013	**-0.008**	**0.001**	0.001	-0.005
2014	**-0.007**	**0.001**	-0.001	-0.005
2015	**-0.007**	**0.001**	-0.001	-0.005
Average	-0.011	0.0003	0.0002	-0.01

5. Conclusions and policy implications

Profit functions have been estimated allowing for individual banks' displacement from the efficiency frontier and non-neutral technological change. Data on IT capital stock for individual banks enabled the researchers to distinguish between movements along time. Profit frontier shifts were found to be strongly correlated with IT capital accumulation (the null hypothesis H_1 & H_2 were not rejected). Banks adopting IT capital-intensive techniques are closer in average to best practice in the banking industry, implying *ceteris paribus* a higher level of efficiency. This last result was interpreted as evidence of a catching-up effect consistent with the usual pattern of diffusion of new technologies. Compounding the estimates from the inefficiency regressions with those coming to the analysis of frontiers, the TFP growth associated with IT investment is 1.3% if estimated from the cost function and 1.8% if estimated from the profit function. These figures appear quite large if compared with the estimated TFP growth for the banking industry

of other studies. Further comparisons should be made with homogenous figures restricted to IT contribution, referring to the financial sector as well to other industries, which are not available. Nonetheless, the results reported here are in line with those obtained by other studies based on micro-data: they support the hypothesis that ITI contributes to output growth not only through capital deepening, but also because of the changes it induces in workplace organization. Skepticism about the existence and magnitude of productivity gains brought about by

digital technologies in the financial sector are unwarranted.

The study findings have a number of policy implications. First, Jordanian banks should increase their financial allocations for IT. Second, bank decision-making can be enhanced by modernising and developing information systems, Third, Jordanian banks should use the latest electronic devices to facilitate the use of banking services..

REFERENCES

Aigner, Dennis; CA Knox Lovell & Peter Schmidt. (1977). Formulation and Estimation of Stochastic Frontier Production Functions, *Journal of Econometrics*, 6: 21–37.

Al-Jarrah, I., & Molyneux, P. (2003). Efficiency in Arabian Banking. Paper presented at *The International Conference on Financial Development in Arab Countries*, Abu Dhabi, UAE.

Altunbaş, Yener & Shanti P. Chakravarty (2001). Frontier Cost Functions and Bank Efficiency, *Economics Letters*, 72: 233–40.

Altunbas, Yener; John Goddard, & Phil Molyneux (1999). Technical Change in Banking. *Economics Letters*, 64: 215–21.

Armah, Bernard Kaku Ndarku & Timothy Park, A. (1998). Agricultural Bank Efficiency and the Role of Managerial Risk Preferences, *American Agricultural Association Annual Meeting*, Salt Lake City, Utah.

Baltagi, Badi H., & James Griffin (1988). A General Index of Technical Change, *Journal of Political Economy*, 96: 20–41.

Sanchez, Benito; Kabir Hassan, & James Bartkus (2013). Efficiency Determinants and Dynamic Efficiency Changes in Latin American Banking Industries. *The Business and Economics Research Journal*, 6, (1): 27-52.

Berger, Allen N., & David, Humphrey, B. (1992). Measurement and Efficiency Issues in Commercial

Banking. A chapter in *Output Measurement in the Services Sector*, ed Z Griliches, University of Chicago Press, IL, 245–300.

Berger, Allen N., & David B. Humphrey (1997). Efficiency of Financial Institutions: International Survey and Directions for Future Research. *European Journal of Operational Research*, 98: 175–212.

Berger, Allen N., and Loretta J. Mester (1997). Inside the Black Box: What Explains Differences in the Efficiencies of Financial Institutions?. *Journal of Banking and Finance*, 21: 895–947.

Berger, Allen N., George RG Clarke, Robert Cull, Leora Klapper, and Gregory F. Udell. (2005).Corporate Governance and Bank Performance: A Joint Analysis of the Static, Selection, and Dynamic Effects of Domestic, Foreign, and State Ownership. *Journal of Banking and Finance*, 29: 2179–221.

Berger, Allen N., and Loretta J. Mester (2003). Explaining the Dramatic Changes in Performance of US Banks: Technological Change, Deregulation, and Dynamic Changes in Competition. *Journal of Financial Intermediation*, 12: 57–95.

Berger, Allen N., and Loretta J. Mester (1997). Assessing the Productivity of Information Technology Equipment in US Manufacturing Industries, *Review of Economics and Statistics*, 79: 110–25.

Brynjolfsson, Erik & Lorin M. Hitt (2003). Computing Productivity: Firm-Level Evidence. *Review of Economics and Statistics*, 85: 793–808.

Christensen, Laurits R.; Dale W. Jorgenson, & Lawrence J. (1973). Transcendental Logarithmic Production

Frontiers, *Review of Economics and Statistics*, 55: 28–45.

Clark, Jeffrey A., & Thomas F. Siems (2002). X-Efficiency in Banking: Looking Beyond the Balance Sheet, *Journal of Money, Credit and Banking*, 34: 987–1013.

Coelli, Timothy J.; Dodla Sai Prasada Rao; Christopher J. O'Donnell, & George Edward Battese (2005). *An Introduction to Efficiency and Productivity Analysis,* Ed. 2, Springer, New York.

Cummins, D.; M. Weiss, & Hongmin Zi (1998). *Organisational Form and Efficiency: An Analysis of Stock and Mutual Property-Liability Insurers*. Working paper, Wharton Financial Institutions Center, University of Pennsylvania, PA.

Daoud, H. (2010). *Macroeconomics*. Ed.1, Dar Almasera.

De Young, Robert (1997). Measuring Bank Cost Efficiency: Don't Count on Accounting Ratios. *Financial Practice & Education,* 7: 20–31.

Fare, R.; Grosskope, S., & and Lovell, C. (1994). *Production Frontier*. Cambridge: Cambridge University.

Florens, Jean-Pierre; Léopold Simar, & Ingrid Van Keilegom (2014). Frontier Estimation in Nonparametric Location-Scale Models, *Journal of Econometrics*, 178: 456–470.

Geroski, Paul A. (2000). Models of Technology Diffusion. *Research Policy*, 29: 6 03–25.

Gordon, Robert J. (1999). *Has the New Economy Rendered the Productivity Slowdown Obsolete?* Working Paper, North western University, IL.

Gruben, William C., & Robert P. McComb (1997). Liberalisation, Privatisation and Crash: Mexico's Banking System in the 1990s, *Economic Review* , 1 : 21–31.

Humphrey, David B., & Lawrence B. Pulley (1997). Banks' Responses to Deregulation: Profits, Technology, and Efficiency, *Journal of Money, Credit and Banking*, 29: 73–93.

Daoud, Hussam-eldin; Torki M. Al-Fawwaz, & Yaser Arabyat (2016). The Econometrics Effect of Information Technology Investment on Financial Performance in the Jordanian Banking Sector over the Period 1993-2014. *Research Journal of Finance and Accounting*, 7 (8): 172-182.

Isik, Ihsan; Lokman Gunduz, & Mohammed Omran (2004). *Managerial and Scale Efficiency in the MENA Banking: A Panel Study of the Jordanian Banking Sector*. Working Paper, Arab Monetary Fund, Abu Dhabi, UAE.

Jorgenson, Dale W.; Kevin J. Stiroh; Robert J. Gordon, & Daniel E. Sichel (2000). Raising the Speed Limit: US Economic Growth in the Information Age. *Brooking Papers on Economic Activity*, 1: 125–211.

Kasman, Adnan & Saadet Kirbas-Kasman (2006). Technical Change in Banking: Evidence from Transition Countries, *International Journal of Economics and Business,* 13: 129–44.

Kumbhakar, Subal & CA Knox Lovell (2000). *Stochastic Frontier Analysis*, Cambridge: Cambridge University Press, Cambridge.

Simar, Léopold & Paul W. Wilson (2015). Statistical Approaches for Non-Parametric Frontier Models: A Guided Tour. *International Statistical Review*, 83 (1): 77–110.

Meeusen, Wim & Julien van Den Broeck (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composite Error, *International Economic Review*, 18: 435–44.

Molyneux, Philip; Yener Altunbaş & and Edward PM Gardener (1996). *Efficiency in European Banking*, John Wiley, Chichester.

Oliner, Stephen D. & Daniel E. Sichel (2000). The Resurgence of Growth in the Late 1990s: Is Information Technology the Story? *Journal of Economic Perspectives,* 14: 3–22.

Polius, Tracy & Wendell Samuel (2000). Banking Efficiency in the Eastern Caribbean Currency Union: An Examination of the Structure-Conduct-Performance Parading and the Efficiency Hypothesis, *Money Affairs*, 15: 75–92.

Roach, Stephen Samuel (1987). *America's Technology Dilemma: A Profile of The Information Economy*. Morgan Stanley, NY.

Rogers, Kevin (1998). Product Mix, Bank Powers, and Complementarities at US Commercial Banks. *Journal of*

Economics and Business, 50: 205–18.

Sydsæter, Knut & Peter Hammond (1995). *Mathematics for Economic Analysis*. Prentice Hall, NJ.

Wheelock, David C., & Paul W. Wilson (1999).Technical

Progress, Inefficiency, and Productivity Change in US Banking, 1984–1993. *Journal of Money, Credit and Banking*, 31: 212–34.

الاستثمار في تكنولوجيا المعلومات والتغيرات التكنولوجية
في القطاع المصرفي الأردني للفترة 1993-2015

حسام الدين علي داود[1]

ملخص

تهدف هذه الدراسة الى قياس كفاءة وربحية البنوك الأردنية لتقيم آثار الاستثمار في تكنولوجيا المعلومات على الإنتاجية في قطاع البنوك في الأردن خلال الفترة 1993 – 2015، واعتمدت الدراسة على منهج التحليل الحدودي frontier approach، والبيانات الجزئية لمجموعة مكونة من 22 مصرفا أردنيا. وأظهرت النتائج صلاحية المنهج الحدودي. ويشير النموذج الحدودي للربح إلى أن البنوك ذات الاستثمار المرتفع في تكنولوجيا المعلومات يمكن أن تحقق المزيد من الأرباح. وأظهرت النتائج أن كفاءة الربح في البنوك الأردنية قد انخفضت مع مرور الوقت وأنها حققت مستويات أدنى من الربح لأي مستوى معين من الإنتاج. وتشير النتائج إلى أن المصارف الكبيرة وذات الاستثمار المرتفع في مجال تكنولوجيا المعلومات أكثر كفاءة من حيث التكلفة من المصارف الأصغر حجما. بينما تظهر البنوك الصغيرة بأنها أكثر كفاءة من حيث الربح من البنوك الكبيرة. كما أظهرت الدراسة أن متوسط مساهمة استثمارات تكنولوجيا المعلومات في إجمالي نمو إنتاجية عناصر الانتاج من خلال دالة التكلفة ودالة الربح أكثر من 0.5 % و1.1% سنويا على التوالي. وتؤكد الدراسة أن السبب الرئيسي للتغير التكنولوجي للبنوك خلال الفترة 1993-2015 يعزى الى التغير التقني. وعليه تؤيد نتائج الدراسة أن مستوى الاستثمارات في تكنولوجيا المعلومات في المصارف الأردنية له تأثير كبير على تكاليف البنوك، واحداث التغير التكنولوجي داخل القطاع المصرفي الأردني من خلال التقدم التقني، مما مكّن البنوك الأردنية، بمرور الوقت، من إنتاج منتجاتها بالمستويات الدنيا من التكلفة. توصي الدراسة بزيادة المخصصات المالية للبنوك الأردنية في الاستثمار بتكنولوجيا المعلومات، ويجب على البنوك الأردنية استخدام أحدث الأجهزة الإلكترونية لتسهيل استخدام الخدمات المصرفية.

الكلمات الدالة: تكنولوجيا المعلومات، إنتاجية، حدود الأرباح والتكاليف، قطاع البنوك الأردني.